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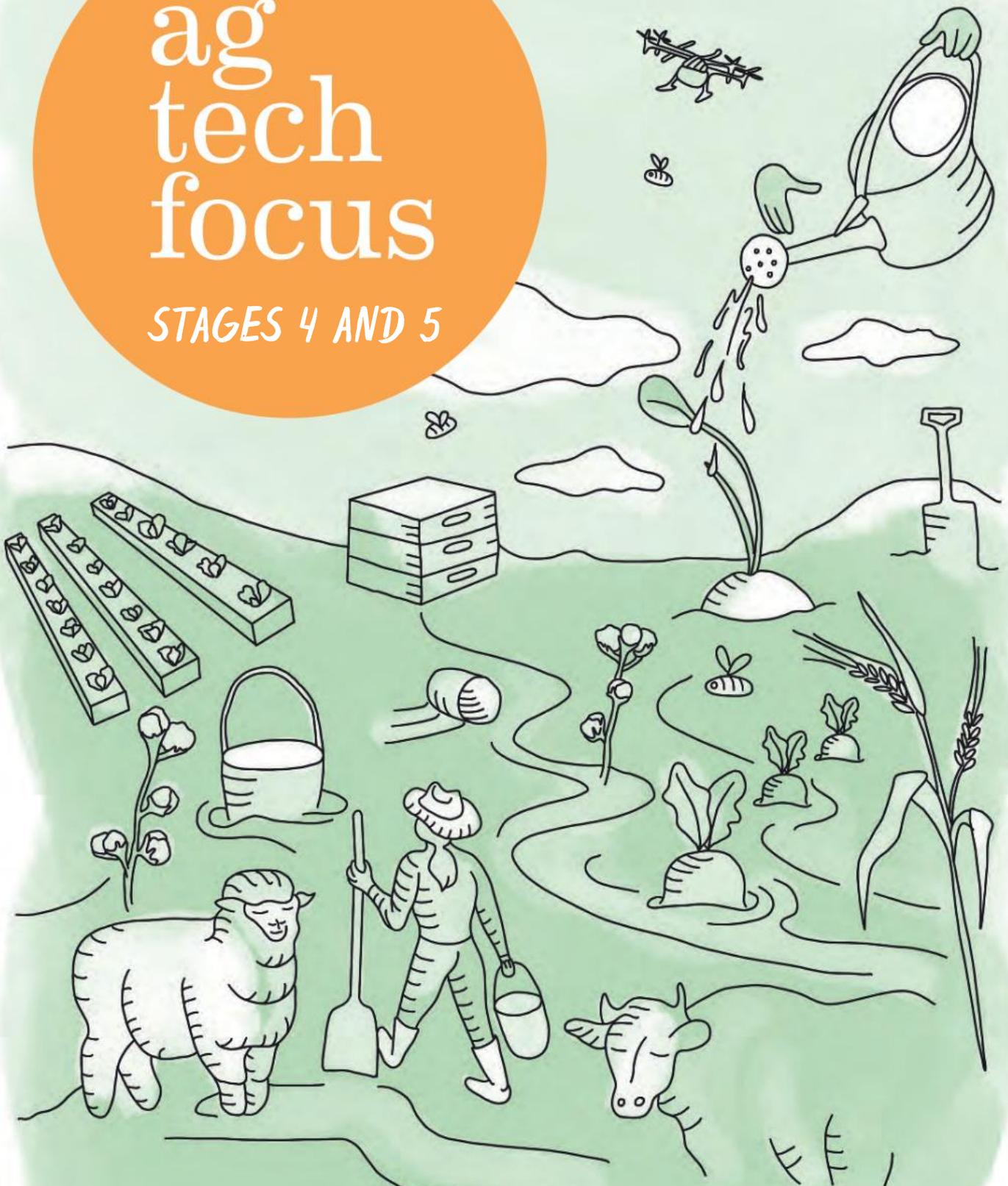
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# ag tech focus

STAGES 4 AND 5



MELLISSA MARSHALL, ERIN BLAKE, NICOLET WESTERHOF,  
SAMANTHA JARRETT, SOFIA HAMEED, STELLINA TRESTRAIL

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# introduction

*Ag Tech Focus* is the brand new textbook for Agriculture students across Years 7–10. The text covers all knowledge and skills required for the NESA Stages 4 and 5 Agricultural Technology syllabus. In addition, the text can be used to teach the NESA Stage 4 Technology Mandatory course, as well as other agriculture syllabi around Australia and New Zealand.

This textbook addresses the key contemporary issues affecting Australian agriculture across a range of enterprises, including those that can be taught in rural locations, and those more suited to an urban classroom location.

The text takes a practical approach, with a variety of structured experiments and practical activities to

explore different concepts and processes. The Let's Review sections provide basic and extension activities to allow tracking of your understanding throughout a chapter. Case studies highlight important or interesting Agriculture issues and bring your learning into a real-world perspective.

The text is fully supported with NelsonNet resources, including worksheets, practical activities, data scenarios, chapter review quizzes, weblinks and video links to enhance your learning.

*Ag Tech Focus* is a fun and practical look at modern Australian agriculture, and will support students studying Agriculture across Australia and New Zealand.

## meet the authors

**MELLISSA MARSHALL** is the lead author of *Ag Tech Focus*. She teaches Agriculture and Science at Moruya High School on the South Coast of New South Wales. Before teaching, Mellissa worked as a vet and brings a unique perspective to the text.

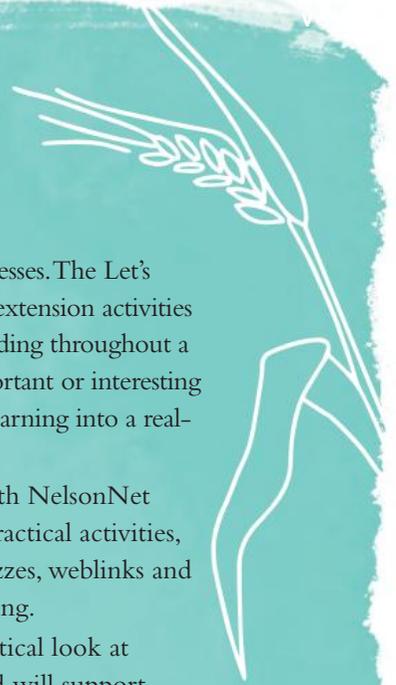
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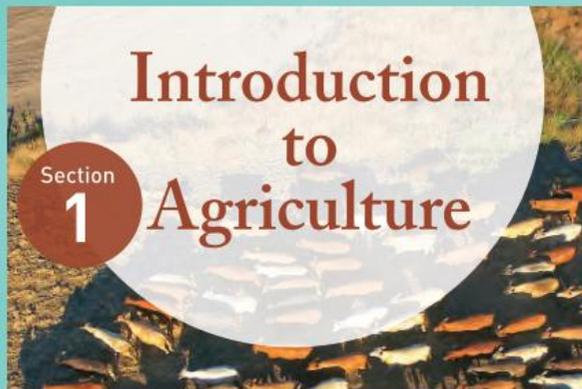
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# acknowledgements

The authors and publisher would like to thank our excellent review team who helped develop this textbook: Grant Jackson, Karen Johnston, Leonie Mutch, Ellie Quinn and Laura Tolley.

## how to use this text



### Section 1

The first section of *Ag Tech Focus* introduces you to concepts and processes about Agriculture, such as climate, soil, business and research. These concepts can be studied independently or alongside the specific enterprise chapters.

How does multiculturalism influence Australian agricultural production?  
How can Australian farmers market their products?

### Stimulus questions

Stimulus questions on the chapter opener pages address what will be learnt in the chapter. These questions are designed to encourage thought before starting a chapter or enterprise. They structure the learning across a chapter, can be adapted for project-based learning and will be re-addressed in the chapter summary.

**COMPARING SEED PROPAGATION METHODS**

**PURPOSE**  
To compare growing seedlings with or without a polytunnel

**HYPOTHESIS**  
Do you think seedlings will grow fastest with or without a polytunnel?

**RISK ASSESSMENT**  
! Conduct a risk assessment using the template on NelsonNet.

**MATERIALS**

- Polytunnel or polytunnel kit
- Six seedling trays (three for each treatment group)
- Seed-raising mix
- Radish or silverbeet seeds
- Icy pole sticks
- Permanent marker
- Suitable area outside to place trays

**LET'S EXPERIMENT**  
assessment template  
waka  
Polytunnel kit

### Experiments

Structured experiments fulfil syllabus requirements to conduct a controlled experiment. Experiments are fully explained and follow the structure of scientific experiments – purpose, materials, method, results, discussion. All experiments should be conducted under teacher supervision.

**COMPARING TYPES OF SEED**

**PURPOSE**  
To identify the difference between a corn seed (monocot) and a bean seed (dicot)

**MATERIALS**

- Bean seeds
- Corn seeds
- Petri dish
- Water
- Scalpel
- Pen and paper

**RISK ASSESSMENT**  
! Scalpels should be handled with care.

**METHOD**

**LET'S ENGAGE**  
germination of a seed to produce seedling

### Let's engage

Let's Engage activities throughout the text provide structured guidance on completing practical activities. These follow a similar structure, detailing purpose, materials, method and discussion, to help support you when doing practical activities.

**AG IN FOCUS**

**MEASURING FARM PERFORMANCE WITH GROSS MARGINS**

**Identify**  
A wheat farmer would like to measure the effectiveness of different crop rotations on the yield of successive wheat crops.

**Understand**  
The income and variable costs are listed below:

Crop rotation	Cereal	Canola	Pulse
Gross income	\$848	\$1007	\$1100

## Ag in focus

Ag in Focus sections are case studies that bring your learning into a real-world perspective. Ag in Focus sections feature specific contemporary agriculture problems and interesting topics or concepts to further research. All follow design-based pedagogy, asking you to identify, understand, discuss and develop.

**LET'S DISCUSS**

1 How can canola farmers mitigate the effects of climate change both in the short and long term?

## Let's discuss

Let's Discuss activities are intended to encourage class debate, discussion and collaboration.

**LET'S REVIEW**

**LOOKING BACK**

- Which growth stages of the canola plant are pests most likely to cause damage?
- Identify the growth stage of canola where biopesticides can be used.
- Outline two weather conditions that encourage pest populations to increase.
- Describe three environmental conditions that encourage the development of diseases.
- Identify five disease-management strategies.

**FOR YOU TO DO**

## Let's review

Let's Review sections provide opportunity for review questions and extension activities.

**Let's summarise**

How can canola be grown profitably and in an environmentally friendly way?

Management decisions ensure a farmer can grow canola profitably and without harming the environment. Crop rotations with pasture or wheat can be used with canola, which helps the soil retain moisture and prevents weeds. This results in greater yields for the farmer, as well as ensures the soil does not degrade.

Create a table identifying other management decisions that can be made, which will benefit both profit and the environment.

Management decision	Benefit to profit or production	Benefit to the environment

Why do farmers choose to grow canola?

## Chapter summary

Chapter summaries provide an opportunity for you to synthesise the information learnt across a chapter. Stimulus questions are answered, and synthesis activities are suggested to help you process all you have learnt.



Data scenario



Worksheets



Practice quiz



Scaffold



Template

## NelsonNet

Further resources are included on NelsonNet. These include worksheets, data scenarios, chapter review quizzes and templates. Throughout the text, icons in the margins indicate where there is opportunity to use NelsonNet material in addition to the activities in the text.



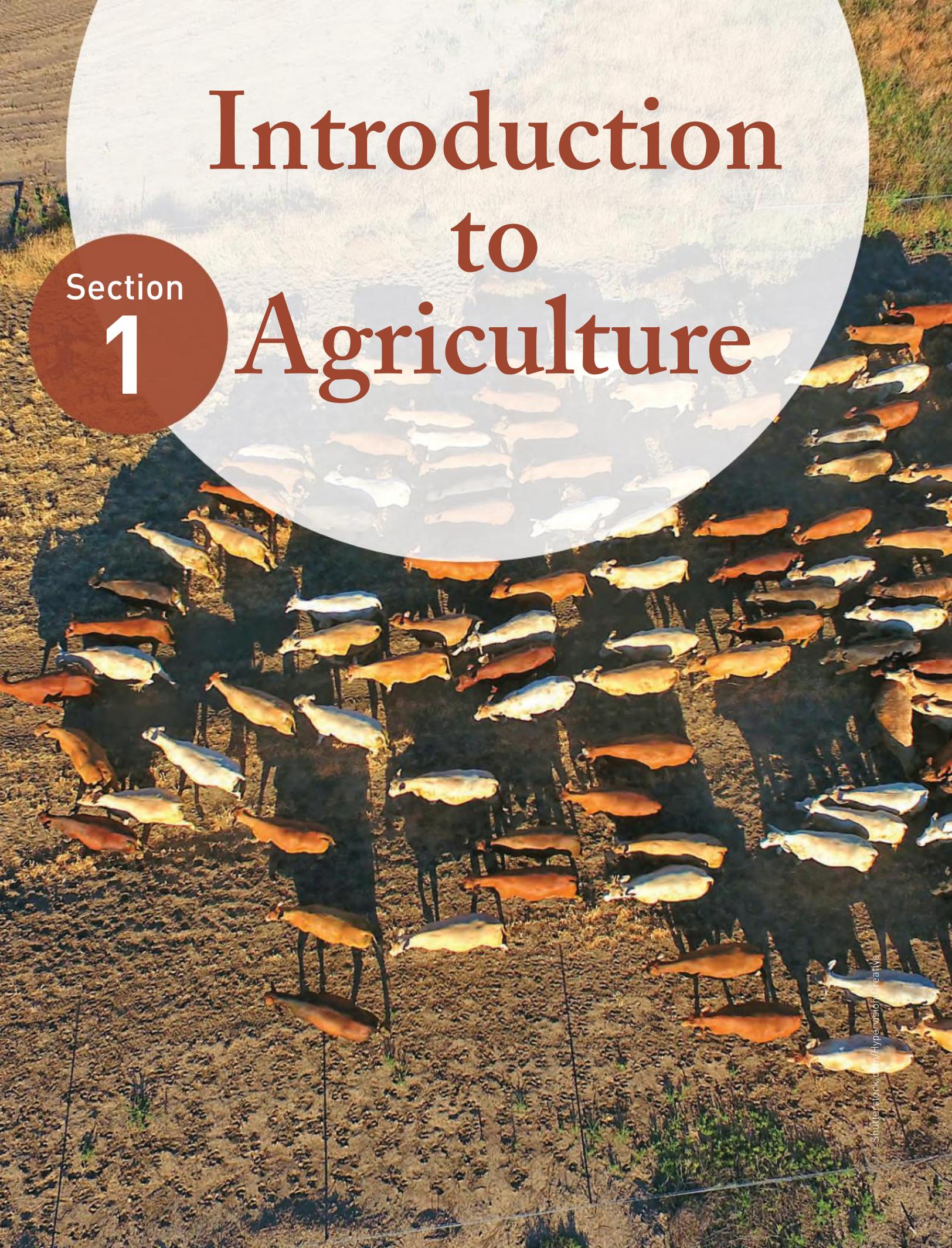
Weblink



Video

## Weblinks

There are lots of opportunities across the text to investigate further online, with weblinks and videos. Icons in the margins indicate where these could be used. All weblinks and video links can be accessed on NelsonNet or through your eBook version by clicking on the icon.



# Introduction to Agriculture

Section

1



## CHAPTER 1

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# An introduction to agriculture

## CHAPTER SUMMARY

This chapter serves as an introduction to modern agriculture in Australia and around the world. It explores the history of agriculture, and the many influences that have shaped modern Australian farming. The unique Australian environment, with its harsh climate and geographic isolation, has presented challenges and opportunities to traditional owners for tens of thousands of years and agricultural landowners for over two centuries. By the end of this chapter, you will have gained an insight into some of these factors and will understand how farming systems function in the natural world.

**What is agriculture, and how does it affect our natural environment?**

**How has Australian agriculture changed over time?**

**What does agriculture look like in other parts of the world?**

# 1.1 A history of modern agriculture

## The dawn of agriculture and civilisations

Agriculture is the science, art and practice of growing and harvesting living things for food, fibre and other useful products. According to archaeological evidence, humans began practising primitive farming techniques around 9000–12000 years ago. This probably occurred by chance when **nomadic** hunter-gatherer tribes returned to previous camping spots and discovered plants that had sprouted and grown from discarded seeds.

**nomadic** the tendency to wander from place to place

**cultivate** to work the soil and prepare it for planting

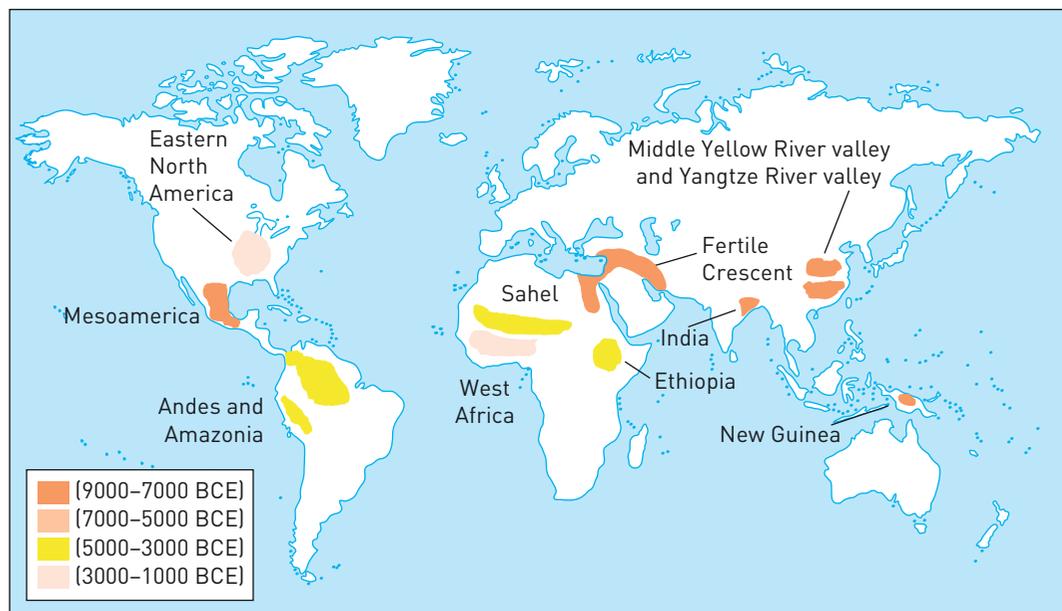
**domestication** the process of selecting and changing organisms to best suit the needs of humans and bring them under human control

**selective breeding** a system where plants or animals with desirable traits are chosen to produce offspring with these characteristics, resulting in new breeds or varieties over time

Humans learnt to **cultivate** soil and plant seeds they had stored from the previous season. Over time, as the farmers selected seeds to keep and grow, the characteristics of the plants changed to resemble the crops we cultivate today. These first crops have become staples in our diet, and further selective breeding has resulted in new and diverse varieties.

The **domestication** of sheep and goats allowed early farmers plentiful access to meat, fur, hides and milk. Some animals were domesticated for companionship (dogs), pest control (cats) and as a source of labour and transport (cattle and horses). Domesticated animal species are quite different from their wild relatives due to **selective breeding** for docile, productive traits.

Agriculture began independently in several regions including the Middle East, China, Africa and South America. The Fertile Crescent in the Middle East is known as the birthplace of agriculture, with cultivation of plants and taming of animals developing in the areas surrounding the Tigris, Euphrates and Nile rivers.



**Figure 1.1** The emergence of agriculture around the world

Farming allowed communities to settle in one location and populations to increase. The dawn of civilisation – people living in villages, towns and cities and performing individual, specialised tasks – was only possible because agriculture freed people from constantly moving and foraging for food.

During the thousands of years that followed, farming techniques improved, stronger tools were forged, and new ways of farming – including the use of fossil fuel-powered machinery – transformed societies and agriculture.



## LET'S DISCUSS

- 1 How different would our lives be without agriculture? What would a normal day look like?
- 2 What activities do we get to participate in because of the free time agriculture gives us?

## Indigenous farming: caring for Country

Australia's agricultural history is unique. For 40 000–80 000 years, Aboriginal and Torres Strait Islander peoples learnt to control and manage Australia's harsh climate and poor soils. Guided by the Dreaming – a set of spiritual and cultural laws, beliefs and creation stories – Aboriginal and Torres Strait Islander peoples continue to act as custodians of the land, based on a sense of belonging rather than ownership of country.

'Country' is a term linking culture, landscape and all living things, including humans. Laws, customs and knowledge about Country are passed down orally and owned by communities rather than individuals. This knowledge is considered the **intellectual property** of Aboriginal and Torres Strait Islander Australians. Aboriginal ownership of this intellectual property can be difficult to legally enforce because most laws consider property, including knowledge, to be recorded in writing and owned by individuals. This has been the cause of the loss, and sometimes piracy, of Aboriginal and Torres Strait Islander cultures, knowledge and customary rights.

**intellectual property** relates to creations and knowledge, including the thoughts and ideas behind inventions and ways of doing things

### AG IN FOCUS

#### ABORIGINAL INTELLECTUAL PROPERTY: THE KAKADU PLUM

##### Identify

Kakadu plums have been used by the Aboriginal peoples of the Northern Territory for thousands of years. The plums are one of over 24 000 bush foods found in Australia, the combined commercial value of which is estimated at over \$200 million annually. Biopirates are patenting Aboriginal knowledge relating to the Kakadu plum and other bush foods, affecting local peoples' rights to harvest and sell these valuable crops.



© 2018 Leanne Atherton, used under license from Austockphoto

**Figure 1.2** Kakadu plums are an important bush food and medicine.

## Understand

Biopiracy is the act of locking up or claiming intellectual property relating to knowledge about the natural world while failing to pay or acknowledge the traditional owners of that knowledge or resource. Approximately 150 patents exist for Australian bush foods, many of which are held by large multinational companies with no ties to local Aboriginal peoples. A patent is a special kind of licence that gives a company the legal right to make, use and sell an invention and stops others from being able to do the same.

Kakadu plums contain the highest level of vitamin C of any known food, have potent antimicrobial and antioxidant properties and are being investigated as a potential treatment for multiple sclerosis, Alzheimer's and Crohn's diseases. The fruit is a bush medicine and food crop of Aboriginal nations in the Northern Territory and is harvested from the wild and sold commercially.

Demand for the fruit now exceeds what can be harvested from the bush, and local Aboriginal groups, including members of the Larrakai nation, are considering planting orchards of Kakadu plums. Several companies, including some from overseas, own patents on processing and using Kakadu plums. Local Aboriginal groups argue that the plum has been used for thousands of years and knowledge about its location, uses and how to harvest it belongs to them.

## Discussion

- 1 Define the terms 'biopiracy' and 'patent'.
- 2 Outline the benefits and properties of Kakadu plums that make them valuable to consumers and companies.
- 3 Assess the importance of the Kakadu plum to local Aboriginal peoples.
- 4 Evaluate the impact of the loss of intellectual property rights relating to the Kakadu plum on local Aboriginal peoples. Consider cultural, environmental, health, social and economic impacts.



Weblink

Learn more about the Kakadu plum and the issue of Aboriginal cultural knowledge.



Worksheets

Explore Aboriginal farming practices in more detail by completing the worksheet.

## Aboriginal land management

Australia is home to around 500 nations or cultural groups, each with their own land management practices. Some of the more common practices include:

- firestick farming: land was burnt with cool fires at particular times of the year in patterns to create grasslands and open forest. This encouraged grazing animals, such as kangaroos and wallabies, to live there where they could then be hunted. It also encouraged edible plants such as cycads to grow, allowing them to be harvested.

- cultivation of plants: early European explorers describe riding through acres of native grasses that had been cut and laid in **windrows** to dry. Fields of yam daisies appeared as seas of yellow flowers. Daisy tubers were harvested with digging sticks, and the tops replanted for next year's harvest.
- aquaculture: fish traps in Brewarrina and other locations were carefully engineered to allow the passage of breeding stock upstream while trapping and holding huge harvests of fish when needed.

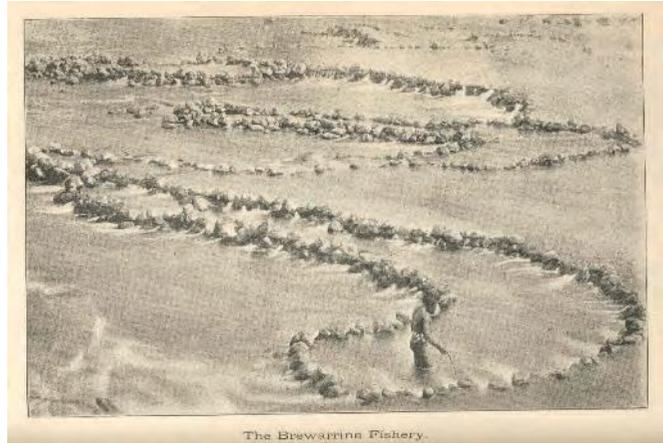


Figure 1.3 Brewarrina fish traps

Thompson, Lindsay G. (1893) History of the Fisheries of New South Wales : with a Sketch of the Laws by Which They Have Been Regulated, Sydney, NSW, Australia: Charles Potter, Government Printer. Freshwater and Marine Image Bank

**windrow** a long line of material raked by hand, machinery or the wind

## DID YOU KNOW?

Australian native plants have adapted to fire; the banksia can hold its seeds for years until a fire passes through, triggering their release.

## AG IN FOCUS

### THE RETURN OF THE FIRESTICK

#### Identify

Aboriginal fire management is being used to prevent destructive bushfires in the Gippsland region of Victoria.



Figure 1.4 Firestick farming

Dale Musgrave firestick farming in Cape York from Fire and the Story of Burning Country by Peter McConchie

>

## Understand

The Black Saturday bushfires of 2009 devastated large areas of Victoria and caused the deaths of 173 people. The Wurundjeri, Dja Dja Wurrung, Wadawurrung and Gunaikurnai people, in association with Parks Victoria and landowners, are reintroducing Aboriginal firestick farming practices to some of these areas. Knowledge about when and how to undertake cool burns of bushland is being shared by traditional owners to prevent intense, destructive bushfires in the future. Gippsland's first traditional burns in 160 years have been conducted under this program.

Cool burns allow for reduction in fuel loads while protecting plants, animals and micro-organisms. Unlike bushfires or normal hazard-reduction burns, traditional burns protect vegetation, logs and other habitats, allowing ecosystems to recover and flourish once the fire has passed.

Similar projects are being undertaken in other areas of Australia. Fire-starters are dropped from a helicopter onto strategically selected areas of the vast Pilbara region in Western Australia by the Kanyirninpa Jukurrpa rangers. The Central Land Council also uses these fire-starters, or aerial incendiary devices, to conduct cool burns on vast areas of the arid inland.

## Discussion

- 1 What factors have contributed to the loss of Aboriginal fire management in the Australian bush?
- 2 How do traditional burns differ from bushfires?
- 3 Explore traditional fire management practices used by the Central Lands Council and the Return of the Firestick project.



Web link

Central Lands Council



Video

Watch the video *Return of the Firestick – Caring for Country with Indigenous Fire*

## First Fleet farmers

Farm animals and seeds were transported from England on the First Fleet. Farm Cove was chosen as the first farm, but the fragile, rocky soil and the lack of agricultural knowledge and skill of the convicts and soldiers soon led to failure. The crops, livestock and tools they had brought with them proved unsuitable in the new climate and landscape.

James Ruse managed to grow the first successful wheat crop at Experiment Farm, Paramatta, in 1789. More farms were established in the fertile areas surrounding Sydney, with land grants available for new farmers.

## The early industries

### The wool industry

Fat-tailed sheep arrived with the First Fleet and were intended for meat production. The first Spanish-bred sheep were imported to Australia in 1797. John and Elizabeth Macarthur pioneered Australia's merino wool industry, selectively breeding imported Spanish merinos to produce an even finer wool than the famous Spanish breed. While John Macarthur promoted Australian wool in Britain and organised trading contacts, Elizabeth oversaw the sheep breeding program and farm management.

In 1813, **squatters** moved over the Great Dividing Range and took advantage of the vast grasslands they found there for grazing sheep. The plains of Australia behaved very differently from the land these settlers had left behind in Great Britain. Native grasslands fattened livestock in their first year of grazing, but the hard-hooved sheep and cattle compacted the fragile soil. Native grass species were not suited to continuous heavy grazing and many of the more **palatable**,

**squatter** farmer who occupies land without legal ownership

**palatable** tasty – palatable foods are readily eaten

nutritious species were decimated. Cleared of trees and scrub, fragile soils rapidly eroded, clogging up creeks and rivers with silt.

## The wheat industry

Australia's first successful wheat crop was grown in 1789 by James Ruse, an ex-convict and one of the few early colonists with any farming experience. As the colony expanded inland, the area sown to wheat also increased. The lack of transportation, difficulties in using available tools to cultivate the land and poor soil nutrient levels hampered the development of the wheat industry.

A series of technological innovations improved conditions for the wheat industry, which peaked in the 1930s.



Figure 1.5 Settlers cleared the land for agriculture.

Caire, Nicholas, National Library of Australia, an3105280-s25

Table 1.1 Technological innovations in the Australian wheat industry

Innovation	Year	Effect on the wheat industry
Railways	Mid 1800s	Inland crops could more easily be transported to market.
Mallee scrub roller	1860–70 (exact date unknown)	Small trees and scrub could be rolled over and then burnt before cultivation. Allowed large areas of Victoria and South Australia to be opened up to cropping.
Stump-jump plough	1876	Allowed farmers to jump the stumps left by the mallee scrub roller, making cultivation easier.
Superphosphate fertiliser	1887 onwards	Dramatically increased the yields of wheat grown on phosphorus-deficient soil.
Combine harvesters	1934	Combined and automated three harvesting tasks: reaping (cutting and gathering), threshing (loosening grains) and winnowing (removing the chaff and straw).
Federation wheat	1903 (first distributed)	Resistant to rust disease that had wiped out many earlier harvests.

These advances made cropping more profitable but also allowed farmers to clear and cultivate marginal, easily degraded land. Conventional **tillage** led to a breakdown of soil structure, resulting in soils prone to erosion and compaction. The removal of trees and deep-rooted native plants to make way for shallow-rooted wheat and other cereal grains allowed the water table to rise in some areas, bringing plant-killing salt with it. The replacement of diverse native species with **monocultures** eliminated habitats for native animals and beneficial insects.

## The cattle industry

The gold rush, which began in 1851, led to an increase in demand for beef in the inland areas of Australia. Sir Sidney Kidman took advantage of this new market by expanding the cattle industry and becoming, for a time, the largest landowner in the world.

Cattle droving, where stock was moved through the land to find feed or reach market, became a prominent feature of the Australian bush. Only the toughest cattle survived, leading to hardy, productive animals suited to the Australian climate and terrain.

**tillage** the turning over and preparation of soil for planting crops

**monoculture** a crop or planting consisting of a single species or variety



Construct a timeline showcasing the development of Australian agriculture with the *Australian agricultural timeline* worksheet on NelsonNet.



Worksheets

Find out more about the significance of drovers to Australian agriculture with the NelsonNet worksheet.



Alamy Stock Photo/Bill Bachman

**Figure 1.6** Droving Hereford cattle

## Multiculturalism and farming

Australia is a multicultural nation and our agricultural landscape and industries have been shaped by immigration. Chinese immigrants who arrived in Australia for the gold rush also turned their attention to market gardening, fishing and horticulture. Between the 1880s and 1930s, New South Wales' vegetable production and trade was dominated by Chinese market gardeners.

German immigrants settled areas of South Australia, including the Barossa Valley, where they established dairies, wheat production, vineyards and wine-making enterprises.

The Queensland sugarcane industry was built on the backs of South Sea Islander workers. Known as Kanakas or sugar slaves, these men, women and children cleared land and planted sugar cane along the Queensland coast. While some may have travelled here voluntarily, many were kidnapped or sold. They were required to work within 30 miles of the coast and were paid one-fifth the wages of white workers.



Alamy Stock Photo/Lakeview Images

**Figure 1.7** A boat delivering South Sea Islander slaves to work on sugar plantations in Queensland

Italian and Greek immigrants introduced Australians to zucchini, capsicum, eggplant, globe artichokes and the coffee shop. Italian agricultural knowledge and skills transformed the Murrumbidgee irrigation region into a thriving food bowl.

The Australian agriculture sector still relies on immigrant workers to help address labour shortages. The Pacific Seasonal Worker program offers employment and accommodation to workers from East Timor and nine Pacific island countries. In exchange for Australian wages, which are generally higher than wages in their home countries, these workers fill short-term seasonal jobs, often in remote locations.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the following terms: cultivate, domestication, the Dreaming, firestick farming, and squatters.
- 2 Outline some of the reasons for domesticating animals.
- 3 Where and when did agriculture begin?
- 4 What effect did firestick farming have on the Australian landscape?

### FOR YOU TO DO

- 1 Write a diary entry for a nomadic hunter-gatherer. Include the daily activities, food that may have been consumed and the dangers that may have been faced in that period.
- 2 Explore what bushfoods and land management practices were used in your local area.
- 3 Investigate the cultural heritage of people in your town or city. What influence have these different cultural groups had on Australian agriculture and diets?
- 4 Construct a timeline of Australian agricultural history since 1788 using the information in this chapter.

### TAKING IT FURTHER

- 1 Research one recent agricultural technology and analyse its impact on farming.
- 2 Investigate the Soldier Settlement Schemes granting agricultural land to returned servicemen after World War I and World War II.
- 3 Watch Bruce Pascoe talk about Aboriginal agriculture. How did he research Aboriginal agriculture and what evidence did he find?



Weblink

Soldier settlement schemes



Video

Bruce Pascoe

## 1.2 Agriculture in Australia

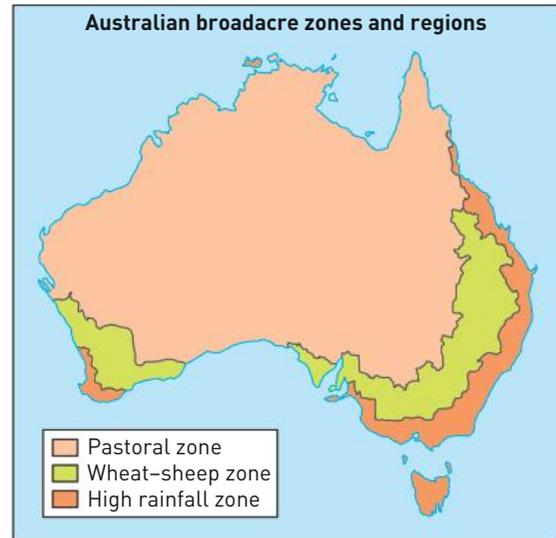
### The Australian continent

Australia is an ancient continent with fragile nutrient-deficient soils. It is also remarkably flat and dry. The terrain and climate vary considerably.



Australia is the second-driest continent on Earth. Antarctica is the driest, with an average rainfall of 166 mm a year.

The eastern and south-western coastal strips, along with Tasmania, receive the highest and most predictable rainfall, forming the high rainfall zone. The Great Dividing Range follows the east coast and is crucial to the climate of this region. Easterly winds from across the sea are forced up this mountainous range, forming rain. On the western side, the terrain slowly descends to form the Tablelands, containing some of our best agricultural soils. This area to the west of the mountains forms part of the wheat-sheep zone: cropping of cereals, oilseeds and cotton, as well as sheep and cattle grazing happen here and in the southern parts of Western Australia where rainfall is sufficient.



**Figure 1.8** Australia's three main agricultural zones

The Murray–Darling Basin and surrounding lowlands was once the site of an ancient saltwater sea. It drains one seventh of Australia's landmass, and has been transformed into a food bowl due to extensive irrigation systems.

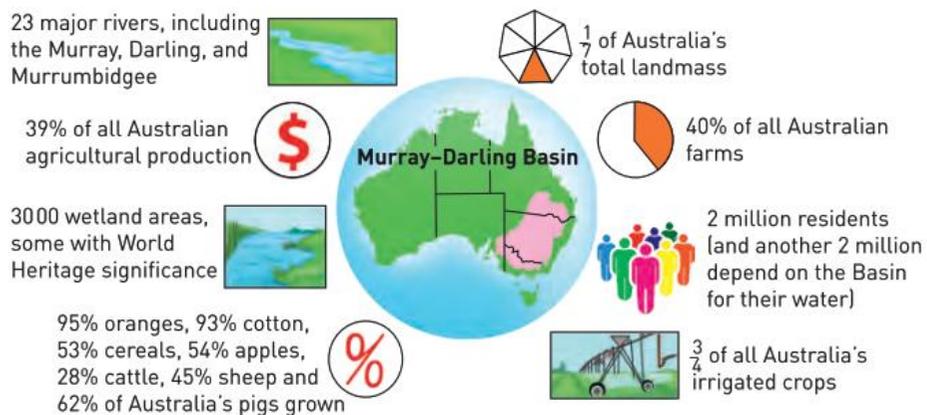
Further inland, annual rainfall reduces and soils become less fertile. The pastoral zone is suited to grazing beef cattle and sheep on native pastures. In parts of South Australia, the Northern Territory and Western Australia, huge cattle stations run beef cattle on some of the most marginal farm land in the country.

## AG IN FOCUS

### THE MURRAY-DARLING BASIN

#### Identify

The Murray–Darling Basin is arguably the most important agricultural region in Australia. The Basin stretches from Queensland through New South Wales, Victoria, South Australia and the Australian Capital Territory. The Murray, Darling and Murrumbidgee rivers offer a lifeline to farms, towns and a multitude of unique and fragile ecosystems.



**Figure 1.9** The importance of the Murray–Darling Basin

## Understand

Murray–Darling irrigation systems involve an extensive series of dams, locks and weirs, as well as a network of irrigation channels. Water moves through entirely due to the force of gravity. The Murray–Darling Basin Authority (MDBA) plans and controls the water resources to ensure they are used sustainably and fairly. This is a difficult job because the water must be shared between several states and allocated to agriculture, townships and the environment.

Since the beginning of irrigation, river flows in some areas of the Basin have reduced by up to 90%. Wetlands that were naturally flooded by snow melts in winter and spring now have reversed regimes because farms need water for irrigation over the warmer months. As a result, the lifecycle of many plants and animals along the rivers have been disrupted. Reduced flows also fail to flush salt from river systems. The MDBA allocates water for the environment to promote river health and improve water quality. Water levels may be increased to trigger the breeding of a particular fish, or to flush salt from the mouth of the Murray River.

Irrigated farms in the Basin possess water licences and are allocated water each year, based on how much water is in the system and the climatic conditions. Sometimes farmers receive no allocation, meaning that even though they possess a water licence, they cannot irrigate their crops. They can attempt to buy water from other licence owners, but this is generally very expensive.

Recreational users of the river system must also be accommodated. Water-skiing, fishing and other aquatic activities are economically important for many river towns. When water levels drop, for example to control aquatic weeds in Lake Mulwala, towns can lose tourism income. Towns and communities along the river also need water for domestic and business use.

Aboriginal people have been living in the Basin for at least 30 000 years, using the river and surrounding country for medicine, food, water, shelter and transport. Evidence of habitation, hunting and fishing (including the Brewarrina fish traps) is present all along the river systems. The Basin has cultural and spiritual significance to the Aboriginal people of this part of country.

With so many competing interests, the Murray–Darling Basin’s water is a controversial issue that affects all Australians.

## Discussion

- 1 How important is the Murray–Darling Basin to Australian agriculture?
- 2 Make a list of all the competing interests that rely on water from the Basin. Some have been discussed in this case study, but there are more. Decide on a priority list for water allocation and justify your decisions.
- 3 Download the Run the River app from the Murray–Darling Basin Authority and attempt to manage water allocations yourself.



Weblink

Run the River

## Climate

### Climate regions and seasons

Australia’s climate is highly variable with low, unreliable rainfall. Large sections of Australia do not have the four distinct seasons of summer, autumn, winter and spring. Indigenous calendars have up to 12 seasons in some regions, based on local climate conditions.

The CSIRO’s agro–ecological system classifies Australian regions based on their agricultural use and environmental features including climate.

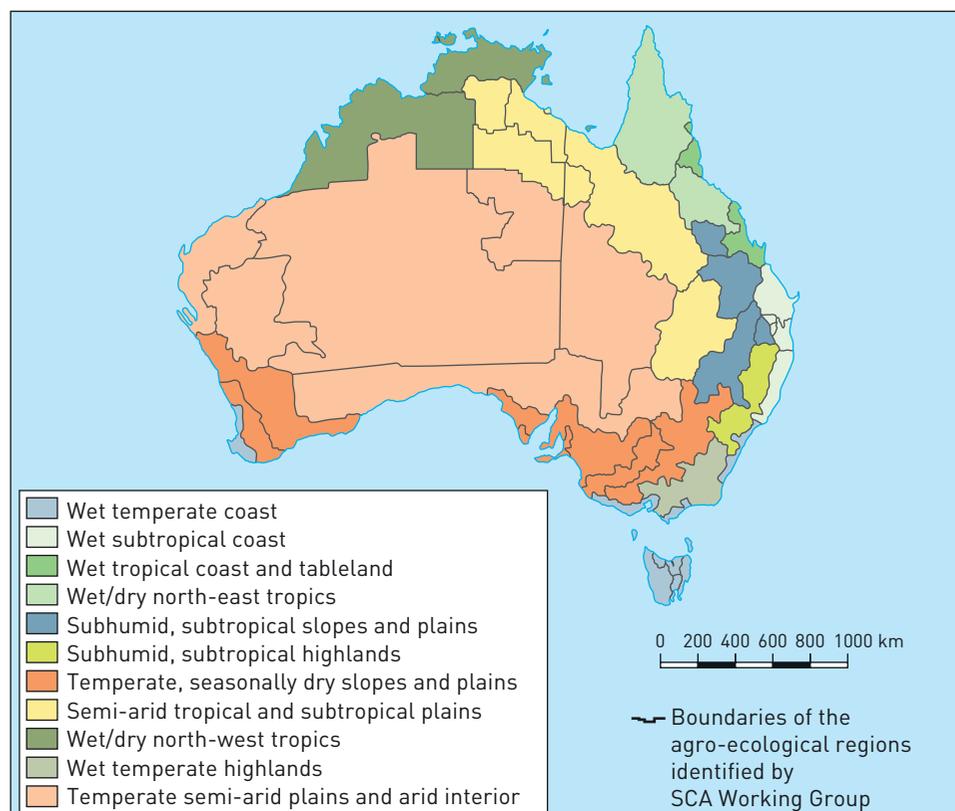


Weblink

Explore Indigenous calendars

**Table 1.2** Agro-ecological regions of Australia

Agro-ecological region	Climate	Agricultural uses
Wet temperate coast	Cool to warm, winter-dominant or uniform rainfall	Dairy, cropping, beef, horticulture, forestry
Wet subtropical coast	Warm temperatures, summer-dominant or uniform rainfall	Dairy, beef, sugar cane and other crops, horticulture, forestry
Wet tropical coast and tableland	High temperatures and high non-seasonal rainfalls	Sugar cane, beef cattle
Wet/dry north-east tropics	High temperatures, wet (summer) and dry (winter) seasons	Beef cattle, sugar cane, rice, horticulture
Subhumid, subtropical slopes and plains	Hot summers and mild winters, summer-dominant rainfall	Wheat/sheep Irrigated cotton Oilseed and summer crops
Subhumid, subtropical highlands	Warm summers and cool winters, summer-dominant or uniform rainfall	Sheep and cattle Irrigated horticulture and cropping
Temperate, seasonally dry slopes and plains	Hot summers, cool winters, winter-dominant rainfall	Wheat/sheep in southern region Irrigated horticulture and cropping along river systems
Semi-arid tropical and subtropical plains	Hot, very dry in the centre	Sheep and cattle
Wet/dry north-west tropics	Hot summers and warm winters, summer-dominant rainfall	Beef cattle Limited dryland cropping and some irrigated horticulture
Wet temperate highlands	Cool temperatures, winter-dominant or uniform rainfall	Sheep, beef, dairy, forestry
Temperate semi-arid plains and interior	Warm to hot, dry	Some cattle grazing

**Figure 1.10** Australian agro-ecological regions

## Climate drivers

A number of large-scale, often global, factors influence our climate: these are called climate drivers, the most well-known of which is the El Niño Southern Oscillation Index. During El Niño, warm, moist air is driven away from Australia towards South America, resulting in drier winters and springs. The moist air is driven back towards Australia during La Niña, resulting in wetter winters and springs. El Niño can intensify and prolong droughts.

The Southern Annular Mode is a ring of westerly winds that circle Antarctica in the Southern Ocean. During a positive Southern Annular Mode, these winds contract south towards Antarctica and away from New Zealand and Australia bringing stable, drier conditions. A negative phase, where westerly winds extend north towards the equator, leads to more rainfall in New Zealand and southern Australia.

## Climate change

Australian agriculture faces several challenges due to climate change, some of which are already having an impact on production. In some areas of Australia, rainfall zones have moved up to 400 km, resulting in crops that may have been grown for generations no longer being suitable for those regions.

In the future we are likely to see the following climatic changes:

- an increase in terrestrial (land) and sea temperatures
- lower rainfall in the southern half of the continent
- more severe droughts and floods
- an increase in the intensity of rain and tropical cyclones in the north.

Australia's nut and fruit industries are particularly vulnerable to climate change because the trees need a certain number of cool days and nights to produce flowers and fruit. Warmer nights also reduce the growth of pastures and therefore the amount of feed available for livestock. This will be particularly challenging for the dairy industry because milk production requires a very high plane of nutrition.

## Uniquely Australian animals

Australia's harsh and varied environment, coupled with its isolation from other land masses, has allowed the evolution of unique plant and animal species. Several introduced species of plants and animals have also been bred to suit the Australian environment.

### Droughtmaster cattle and Australian Milking Zebu

The Droughtmaster cattle breed was developed by crossing European Shorthorn cows with Indian Brahman bulls. Thanks to their Indian heritage, they thrive in the extreme heat of Queensland's tropical environments and are resistant to cattle ticks and eye cancers. Australian Milking Zebu were also bred from a cross between Indian and European breeds. Developed by the CSIRO, these cows inherited good milk production from Jersey cattle, and heat and tick resistance from Indian Zebus.

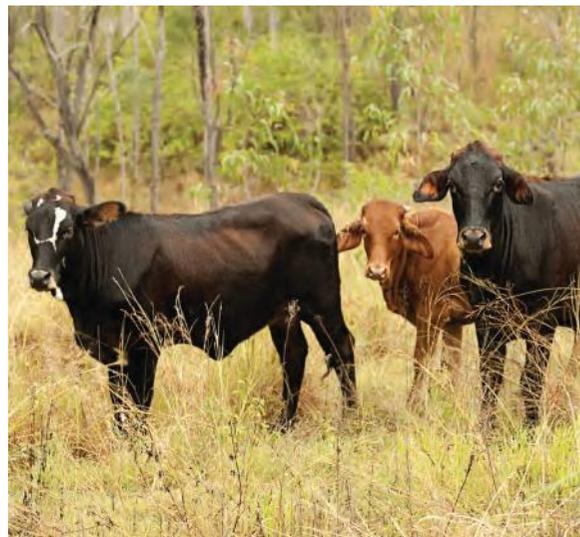


Figure 1.11 Droughtmaster cattle



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Learn about the current seasonal outlook and the influence of climate drivers.

## Merino sheep

Originally from Spain, the merino sheep has become an Australian icon. The small-framed sheep brought out in the early colonial days were selectively bred by George and Frederick Peppin to produce a large-framed animal with long, fine wool. Samuel McCaughey introduced a wrinkly-skinned sheep from the United States around the turn of the 19th century that further transformed the merino. While the extra skin wrinkles meant extra wool, it also increased the likelihood of the sheep becoming flyblown, made them difficult to shear and less heat tolerant. Wrinkles have now been bred out of most merinos.



WebLink

Investigate plain-bodied SRS merinos

Tyrell Collection, Museum of Applied Arts and Sciences, Sydney



Figure 1.12 Heavily wrinkled merino sheep



© Glenwood Merinos

Figure 1.13 Modern plain-bodied SRS merinos

## Kangaroos

Kangaroo meat has gained popularity in recent times but these native animals are not farmed. Stressful events, such as confinement in cages and transportation, cause a syndrome called capture myopathy where the kangaroo's muscles suffer significant and often fatal damage. This is not only an animal welfare issue, but also renders the meat unfit for consumption. Kangaroos are shot in the wild by skilled licensed operators.

## Uniquely Australian plants

### Federation wheat

Black stem rust devastated many early crops and pushed wheat farming further and further into unsuitable dry regions. William Farrer undertook numerous wheat breeding experiments to find a solution. Using his wife's hairpins, he artificially pollinated wheat to produce new **hybrid** varieties. Federation wheat was a cross between an early maturing Indian variety and a high yielding European variety. Because Federation wheat matured early, it could be harvested before humid weather set in and rust became a problem.

**hybrid** an organism bred from crossing two different varieties, breeds or species



Video

Learn more about how Topaz rice was developed

### Topaz rice

Most long grain rice varieties are suited to tropical or subtropical conditions. Topaz rice, developed by the New South Wales Department of Primary Industries in conjunction with industry bodies, has been selected for its ability to grow in the colder climate of the NSW Riverina region. Topaz

is a dwarf variety, meaning it is less likely to fall over or ‘lodge’ before harvesting. Yields of Topaz rice are higher than other fragrant rices grown in the Riverina because Topaz has been specifically developed for cooler climates and less of the grain is lost due to lodging.

## Saltbush

There are several varieties of saltbush, all of which are deep-rooted, drought-tolerant, **perennial** species. The leaves of saltbush taste salty because the plant plays a role in trapping soil salts in **salinity**-prone areas. Deep roots extend down into the water table, sucking up groundwater and reducing the amount of salt that leaches into the upper layers of soil. Not only is saltbush effective in helping to protect soils from salt, it is also an excellent animal feed. Saltbush is now being planted for grazing, made into hay and even pressed into pellets.



www.stockoz.com.au

**perennial** a plant that lives for more than two years

**salinity** the accumulation of salt in soil or water

**Figure 1.14** Saltbush can be grazed by animals such as sheep.

## AG IN FOCUS

### ARCADIA SALTBUSS LAMB

#### Identify

Graham and Amanda Strong run Arcadia Saltbush Lamb near Narrandera, NSW. This property uses old man saltbush and other native plant species as animal feed.

#### Understand

Arcadia was traditionally used for cropping but now the Strongs run merino sheep for fine wool and meat. Rows of old man saltbush have been planted as fodder crops, and during dry periods are used as a feedlot for the sheep. Penning the sheep in smaller saltbush paddocks gives the native pastures a rest and gives the lamb meat a distinctive salty seasoned taste.

Saltbush can become tall and woody and needs to be slashed regularly. It has adequate protein but lacks some minerals and does not have enough energy to fatten sheep. Ideally, it should be used alongside pasture or grain.

The Strongs have also adapted their seeder to plant native seeds, sowing shelter belts of trees, shrubs and grasses throughout the property. The seeds were collected from the local area, often on road verges, and were selected for their hardiness and productivity.

#### Discussion

- 1 Outline the benefits of using saltbush as a fodder crop.
- 2 Can sheep survive on saltbush alone? How should their nutrition be managed?
- 3 Research the advantages of planting shelter belts of native trees and shrubs on farmlands.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify the three main agricultural zones and briefly describe them.
- 2 What effect does the Great Dividing Range have on rainfall patterns?
- 3 What are 'climate drivers' and how does the Southern Oscillation Index affect Australia's rainfall?
- 4 Describe three agro-ecological regions and identify the agricultural industries that are found there.
- 5 Why were Droughtmasters and Australian Milking Zebus developed?
- 6 Explain why kangaroos are not currently farmed.

### FOR YOU TO DO

- 1 Using the agro-ecological region information, plot the main agricultural industries on a map of Australia.
- 2 Investigate climate drivers at Climate Kelpie and copy and complete the table.



Web link

Climate Kelpie

Climate driver	Description	Effect on Australian climate	Effect on agricultural production

- 3 Explore the CSIRO's Indigenous calendars. Compare one calendar to the traditional four-season calendar used by most of Australia.

### TAKING IT FURTHER

- 1 Research one agriculturally significant plant or animal that is either native to Australia or has been bred to thrive in Australian conditions.
- 2 Use the Bureau of Meteorology's Climate Data Online to compare the climate of your home region and one other region in Australia.



Web link

CSIRO Indigenous calendars



Web link

Bureau of Meteorology  
Climate Data

## 1.3 Agriculture around the world

### Farming in New Zealand

New Zealand has rich deep soils and a mild climate suited to farming a variety of crops and livestock. New Zealand has been farmed for hundreds of years, with the Maori's Polynesian ancestors introducing sweet potato, taro, bottle gourds and yams long before European settlement. In fact, by the time Europeans arrived in New Zealand, Maori agriculture was well established and the settlers relied on Maori landowners for food and supplies.

The introduction of merino sheep from Australia in the 1840s was a turning point for New Zealand agriculture: within 20 years there were three million sheep, mainly on the South Island. Romney sheep now dominate on the North Island and are the main source of wool and frozen lamb for export.



Gina Guarnieri

**Figure 1.15** Romney sheep are the most common breed on the North Island of New Zealand.

and Australia. Like Australia, New Zealand benefits from being ‘out of season’ compared with the major export markets in the northern hemisphere. Summer fruits can be sold in the northern hemisphere winter, avoiding competition from local producers, and vice versa.

Land clearing and grazing of sheep and cattle have damaged New Zealand’s soils. Manure and fertiliser runoff into waterways, and erosion and loss of topsoil has reduced the productivity of many agricultural areas. Sustainable resource management and farming techniques are being employed to address these issues.

## Farming in China

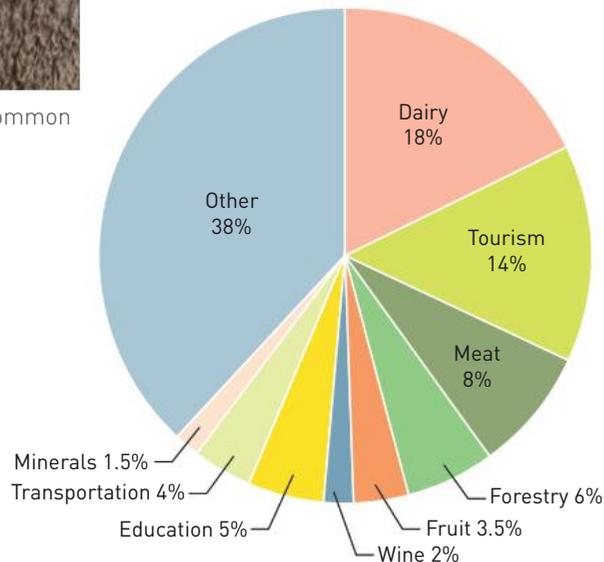
The typical Chinese farm is very small (under one acre), leased from the government and worked by hand rather than machinery. China has a huge land mass but only a fraction of this is usable for agriculture. Many farms are peri-urban, meaning they are located in or near cities. Farms can even be found on the verge of roads, up against factories and buildings, and in any other available fertile space.

The most common use of agricultural land is cropping, and rice, maize and wheat are the three most important grains. China is also a world leader in the production of cotton and many oilseed crops, including soybeans. As the Chinese economy grows and incomes rise, more and more Chinese people are consuming animal proteins. This has increased demand for oilseeds to supply cooking oil.

Traditionally, chickens and pigs have been the most important animal production enterprises. Small, individually owned farms are being replaced by large industrial

Dairy products are New Zealand’s main export, mostly to China, the United States and the United Arab Emirates. New Zealand is the top exporter of dairy products in the world. Figure 1.16 illustrates other significant New Zealand exports.

Horticulture is also a significant industry, with apples, kiwifruit, grapes and wine exported to the United Kingdom



**Figure 1.16** New Zealand’s main exports

### DID YOU KNOW?

The kiwifruit is actually a Chinese gooseberry. It was renamed as a marketing gimmick.

### DID YOU KNOW?

China feeds one-fifth of the world’s population using one-tenth of the world’s arable land.

### DID YOU KNOW?

Cows in mega-dairies are fed grain and pellets and live permanently in sheds.

enterprises such as multi-storey piggeries and intensive, automated egg farms. Industrial dairies housing up to 100 000 cows are outcompeting traditional small dairy herds.

Small-leafed China and large-leafed Assam tea are also grown, mainly on small estates. There are so many different varieties and brands of tea consumed in China that no single tea brand or type dominates the market. Tea plants are grown on sloping terraces and leaves are hand-picked.



Worksheets

Compare Australian agriculture to other countries by completing the worksheet on NelsonNet.



Getty Images/MCT

**Figure 1.17** Vegetable gardening in Longyan Fujian, China



## LET'S REVIEW

### LOOKING BACK

- 1 Describe Maori land management before European settlement in New Zealand.
- 2 Explain why Australia and New Zealand benefit from being 'out of season'.
- 3 Using Figure 1.16, calculate the percentage of New Zealand exports related to agricultural industries.
- 4 Identify the main Chinese agricultural industries.
- 5 Describe a typical Chinese farm.

### FOR YOU TO DO

- 1 Visit the supermarket and investigate the country of origin of imported agricultural products.
- 2 Investigate Australia's main agricultural exports. What do we export, and who do we export it to?

### TAKING IT FURTHER

- 1 Write a report on one other major agricultural economy, such as the United States of America, Indonesia, India or Russia.
- 2 Construct a flow chart showing the marketing chain for tea in China. Include all the steps in growing, harvesting, processing, transportation and selling.



Weblink

Explore information about tea estates

## 1.4 The farm

### Farming systems

The basic unit of agricultural production is the farm. Farms produce different agricultural products or **outputs**, depending on what enterprises they run. You will find information on a number of common enterprises in this textbook, including wheat, cotton, canola, dairy, beef and sheep enterprises. Many farms are involved in more than one enterprise.

**output** anything produced by the farm

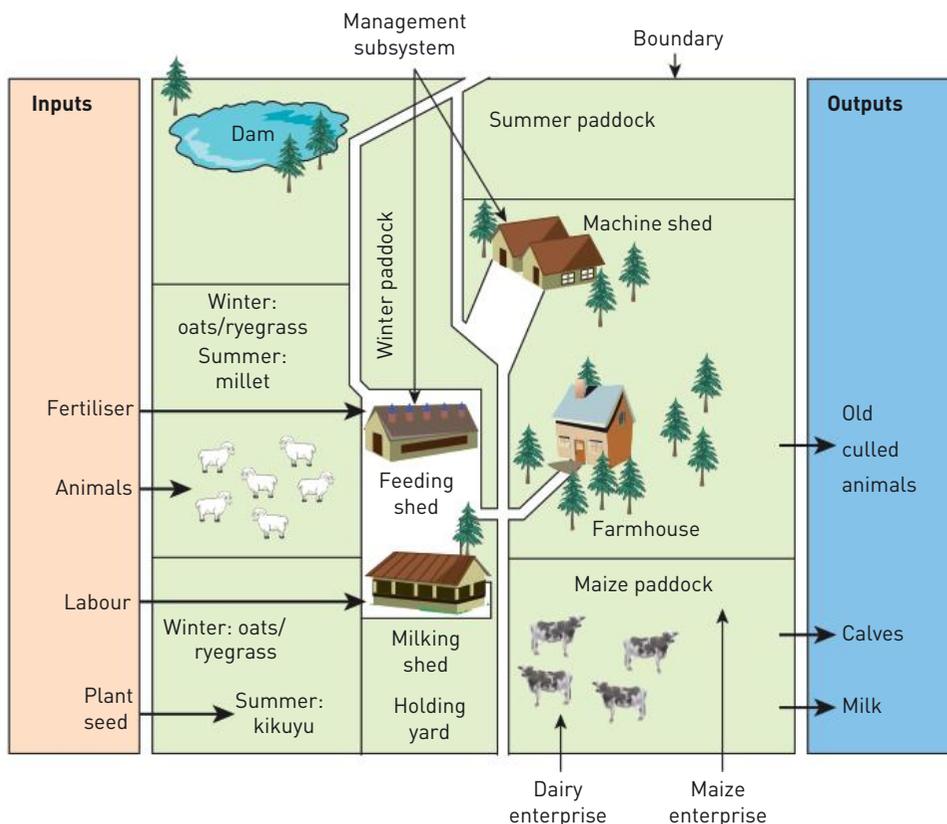
Each farm acts as a system of many smaller, interconnected subsystems. On a beef cattle farm, these subsystems might include cattle, pastures, micro-organisms, soil, water, climate and management. Interactions occur between these subsystems, some of which are helpful to agricultural production. For example, the cattle pass manure onto the pasture subsystem, providing nutrients for plant growth. In return, the pasture provides a source of nutrition for the cattle.

The farm manager organises these subsystems to work together as efficiently as possible to produce agricultural outputs. **Inputs** are brought onto the farm and, through different **processes**, are converted into outputs. For example, pellets brought into a poultry farm will turn into chicken meat through the processes of digestion and growth. Seeds germinate and undergo the process of photosynthesis, resulting in the growth of crops.

The farm manager monitors production and examines feedback, including yields, to help with future decision-making. The yield is a measurement of the amount of output produced, usually per hectare or per animal. For example, a cropping farmer might look at how many tonnes of grain they are producing per hectare of land. If yields are lower than expected, the farmer might decide to alter fertilisers, soil preparation or pest management next season.

Farms have several constraints or **boundaries**. Some of these are physical boundaries, such as the size of a property, type of soil or the steepness of the terrain. Other boundaries might be due to climate (for example, the annual rainfall) or finances (including how much money the farmer has at their disposal for investment and improvements).

Farm systems can be represented as models to show the interactions between the subsystems and how farm enterprises are managed.



**Figure 1.18** A model of a farming system

**input** anything brought onto the farm to be used in an enterprise

**process** actions or activities that convert inputs into outputs

**boundary** limitations placed on a farm, including physical, financial, cultural and legal



Test your knowledge about farming systems by exploring Ravenhead farm in the *Farming systems* worksheet on NelsonNet.



LET'S ENGAGE

## SCHOOL FARM MODEL

### PURPOSE

To construct a model of the school farm.

### METHOD

- 1 Use the online template to conduct a risk assessment before undertaking this activity.
- 2 Conduct a visit to the school farm.
- 3 Make a list of enterprises and subsystems.
- 4 Observe and discuss interactions between these subsystems.

- 5 Explore the processes that convert inputs to outputs.

### DISCUSSION

- 1 Use Figure 1.18 as a guide to draw a model of your school farm.
- 2 Outline three interactions and their effects on agricultural production.
- 3 Investigate the sources of feedback that help the farm manager and teachers make decisions about how to run the school farm.

## Intensive and extensive farming

**stocking density** the number of animals in a given area; for example, per m<sup>2</sup>, per hectare, per km<sup>2</sup>

Intensive animal farming systems usually involve a high **stocking density** of animals on small areas of land. Cage egg production, for example, can involve up to 100 000 birds in a single shed. Another way of defining intensive plant and animal systems relates to how they are managed: intensive systems involve large amounts of labour and other inputs for the land area they occupy. Intensive plant production includes nurseries, market gardens and hydroponic farms.

There are challenges associated with intensive animal production, including nutrition, disease control, the need for careful management of the environment and disposal of wastes. Careful control of the environment to prevent disease and provide adequate nutrition for growth is also essential for intensive plant enterprises.

### DID YOU KNOW?

Anna Creek in South Australia is the world's largest cattle station. It has a stocking density of 0.006 cattle per hectare. (That's one cow for every 1.7 km<sup>2</sup>!)

Extensive enterprises usually involve less inputs and labour for a given area. While extensive farms are usually larger, this isn't always the case. Extensive aquaculture farming occupies relatively small areas, but fish are kept at lower stocking rates and there are less inputs and controls on the environment than in intensive enterprises.

Beef cattle grazing on pastures and broadacre cropping are examples of extensive farming systems. These farms are usually in remote locations where land values are lower. They are generally further away from markets than intensive farms, so transportation of produce can be more expensive and time consuming.



Alamy Stock Photo/Arterra Picture Library

**Figure 1.19** Piggeries are intensive animal enterprises.



Shutterstock.com/THPStock

**Figure 1.20** Sorghum growing in an extensive, broadacre enterprise

## Natural environments

Farms are managed environments where farm managers bring inputs into the system and then remove outputs from the system. Natural environments, on the other hand, are considered ‘closed’ systems where all resources are recycled and reused.

Natural environments consist of several different **ecosystems** made up of all the living organisms (the biotic components) and the non-living components of their surroundings (the abiotic components). Abiotic components include minerals in soil, air temperature, humidity, windspeed and water availability.

**ecosystem** an area containing interacting living things and their non-living environment

## Energy flows and food webs

### Food webs in nature

All the energy in an ecosystem ultimately comes from the sun. Producer organisms, including plants, algae and some bacteria, use photosynthesis to turn energy from the sun into chemical energy in the form of sugar.

The producers are then eaten by consumer organisms. Some consumers are herbivores, meaning they only eat plants. Omnivore consumers eat plants and other animals, while carnivore consumers eat animals. Energy is constantly added to ecosystems via the sun. The energy then flows around the food web due to feeding relationships between organisms.

### DID YOU KNOW?

The Chernobyl nuclear accident of 1986 killed off decomposers in surrounding forests. Radioactive leaf litter and tree stumps remain from that time, unable to be broken down without healthy decomposer organisms.

When plants and animals die decomposer organisms break down and recycle their tissues, making the nutrients available for other organisms. Where energy is constantly added to natural systems, other nutrients must be recycled.

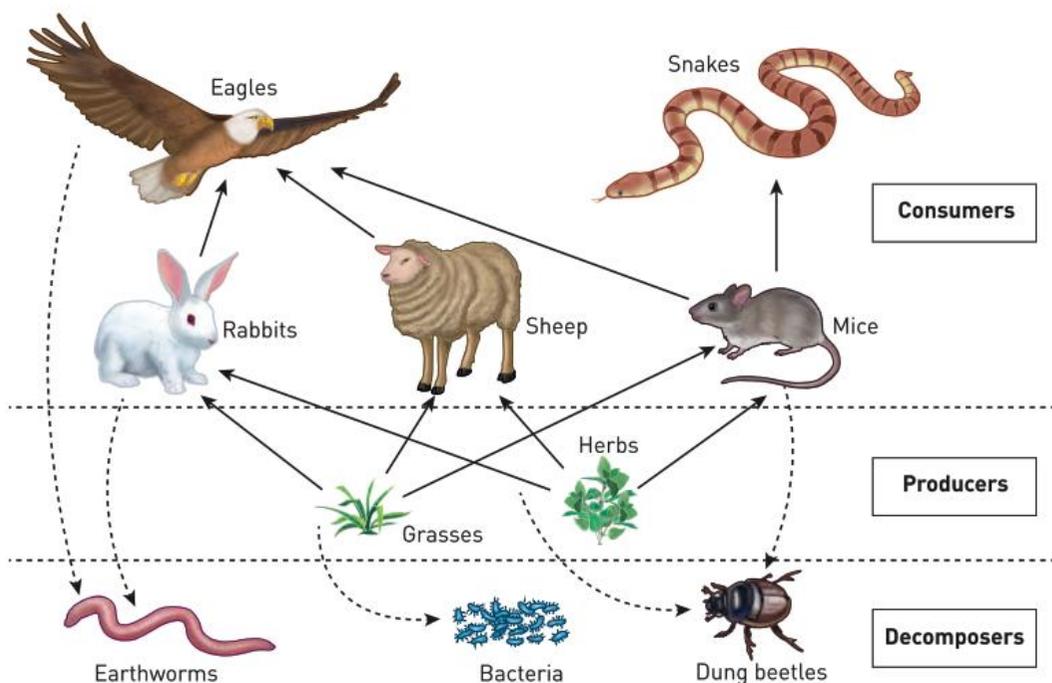


Figure 1.21 A farm food web

## Energy flows and farming

Compared with natural systems, farm food webs are simple and usually incomplete. Crops are harvested from fields rather than consumed by animals. The energy the crops contain might flow on to humans, or to animals at other farms if the crop is to be used as animal feed. Some crops are used to make **biofuel**, with the energy flowing on to power vehicles or industry. The nutrients and energy contained in these crops and harvested products is lost from the farming system and must be replaced.

**biofuel** fuel made from living things



LET'S ENGAGE

### CONSTRUCT A FOOD WEB

#### PURPOSE

To investigate the range of living organisms in a natural or farmed environment and determine the feeding relationships between them.

#### RISK ASSESSMENT



Do not handle or play with insects. Several insects can deliver painful and sometimes venomous bites and stings or cause severe allergic reactions.

#### MATERIALS

- Hand lenses
- Fishing nets
- Jars (specimen containers)
- Camera

#### METHOD

- 1 Visit a local ecosystem and collect information about as many species as possible using the hand lenses, nets and photos.
- 2 Identify the specimens and research their diet.
- 3 Construct a food web, using Figure 1.21 as a guide.
- 4 Label the organisms as producers, consumers and decomposers.

#### DISCUSSION

- 1 Which type of organism was most common: producers or consumers?
- 2 Where did you find the most decomposers?
- 3 Would you expect a natural or farm food web to be more complex? Why?



Worksheets

Use the NelsonNet practical activity worksheet to conduct a biodiversity audit by examining insect populations in monocultures and natural environments.

## Biodiversity

Biodiversity is the variety of living things found in an environment. This includes micro-organisms, plants and animals, and can be measured in different ways.

- 1 Genetic biodiversity: how much variation is there in the genes of a particular species?
- 2 Species biodiversity: how many species are there?
- 3 Ecosystem biodiversity: how many different ecosystems and habitats are there?

Farm systems generally have lower biodiversity than natural systems. Cropping farms, for example, involve the planting of monocultures. Animal enterprises usually have only one or two animal species, with each species consisting of genetically similar animals of the one breed.

Almost 99% of animals are invertebrates such as insects, so pesticide use on farms can have a significant effect on species biodiversity. Some of these insects play agriculturally significant roles, including in the pollination of plants and recycling of nutrients in soils. Several bugs, including ladybirds and lacewings, are predators and can be used as a biological control for insect pests.

Farm biodiversity can be improved by planting shelter belts of trees and shrubs, rotating crops and using chemicals responsibly.



atmosphere as nitrogen gas. Unfortunately, nitrogen gas cannot be used by plants or animals and instead must be converted into other substances.

**rhizobia** nitrogen-fixing bacteria living in symbiosis with legumes

**symbiosis** a relationship between two organisms where at least one obtains an advantage

**leaching** loss or draining away of substances, usually in water

**Rhizobia** bacteria ‘fix’ the nitrogen by converting it into ammonium, a form of nitrogen that plants can use. They live in **symbiosis** with legumes, including peas, beans, lucerne and clover. In return for nitrogen fixation the bacteria receive sugar from the plant roots.

Nitrogen is also cycled through free-living soil bacteria. Nitrifying bacteria convert it into nitrate (which is usable by plants) and nitrite. Nitrate and nitrite are soluble in water and can be lost from soils by **leaching**. Denitrifying bacteria can also return nitrogen to the atmosphere, as seen in Figure 1.23.

**Farming and the nitrogen cycle**

Harvesting animal and plant materials removes nitrogen from the farming system. Nitrogen can be returned to the soil by using fertilisers, but overuse can lead to soil acidification and leaching of nitrogen and other nutrients into waterways. Excess nitrogen can also be converted back into gas by bacteria and lost to the atmosphere.



**EXAMINING RHIZOBIA**

**PURPOSE**

To identify legume root nodules and understand their role in the nitrogen cycle

**MATERIALS**

Various whole legume plants (clover, peas, beans, lucerne)

**METHOD**

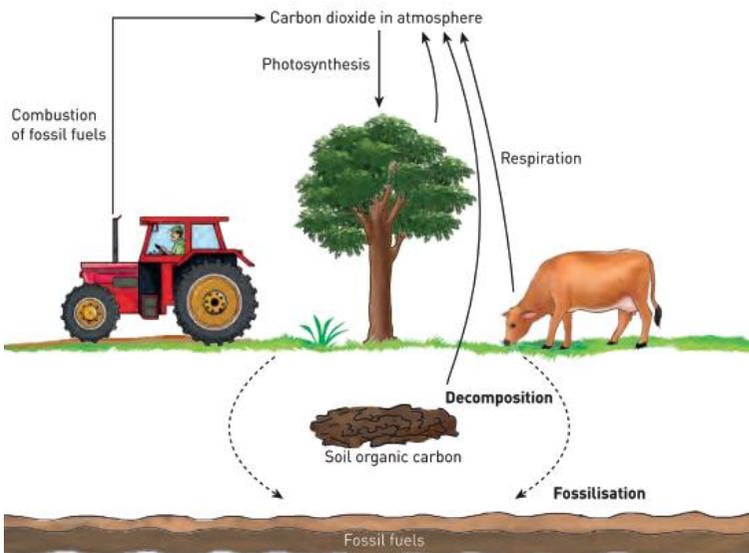
- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Dig up several legumes and brush the soil of the root system.

- 3 Identify the pinkish-grey rhizobium nodules on the roots.
- 4 Crush the nodules and examine the contents.

**DISCUSSION**

- 1 Describe the external and internal appearance of the nodules.
- 2 What role do rhizobium bacteria play in nutrient cycling?
- 3 How can the presence of legumes in pastures and gardens help the productivity of other plants?

**LET'S ENGAGE**



**The carbon cycle**

Atmospheric carbon dioxide is taken up by plants during photosynthesis. Plants use carbon dioxide to make carbon-containing sugar. Animals consume the plants and use the sugar for energy and growth.

Carbon dioxide is released back into the atmosphere by plants, animals and all other living things during respiration. Dead organisms and their waste products are broken down by decomposers, releasing some carbon dioxide and leaving soil organic carbon behind. Under the right conditions, dead organisms can turn into fossil fuels over hundreds of millions of years.

**Figure 1.24** The carbon cycle

Carbon dioxide is a greenhouse gas and increasing atmospheric levels contribute to climate change. Land clearing, combustion of fossil fuels, stubble burning and intensive livestock industries all contribute to greenhouse gas emissions.

### Carbon trading

Agriculture can play a role in reducing atmospheric carbon dioxide and curbing climate change. Soil can store large amounts of carbon and keep it locked up for long periods of time. Some farming methods help with this carbon storage, or ‘sequestration’, including reducing soil disturbance through no-till farming, improving pastures and less land clearing.

The Emissions Reductions Fund is an Australian federal government program administered by the Clean Energy Regulator. Farmers can apply to run carbon storage projects and then trade this stored carbon with the government at auction. Farmers must first apply for approval for these projects, which can take many forms, including changes to grazing practices, the use of biogas and other biofuels for farm electricity, and tree planting.



Weblink

Explore Emissions Reduction Fund projects on an interactive map.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the following terms and give two examples of each: input, output, subsystem, process, interaction, and boundary.
- 2 Identify three biotic and three abiotic factors of a sheep farm and a cage egg farm.
- 3 Explain the role of producers, consumers and decomposers in a food web.
- 4 Outline the importance of nitrogen to plants and animals.
- 5 How does farming affect the carbon cycle?

### FOR YOU TO DO

- 1 Classify each of these enterprises as intensive or extensive.
  - a Cage egg farm
  - b Large merino sheep property in the pastoral zone
  - c Hydroponics vegetable farm in a suburban backyard
  - d Salmon farm
  - e Cattle station in the Northern Territory
- 2 Design an informative poster for farmers about reducing carbon dioxide emissions and storing carbon on farms.
- 3 Construct a farm model for a local farm.

### TAKING IT FURTHER

- 1 Undertake a biodiversity audit. Design and construct an insect trap, then collect, identify and count insects. Compare two locations on the school farm.
- 2 Research the importance of dung beetles in pasture management.

# Let's summarise



Practice quiz

Complete the chapter review test on NelsonNet to review what you've learnt about the development and practice of agriculture.

## What is agriculture, and how does it affect our natural environment?

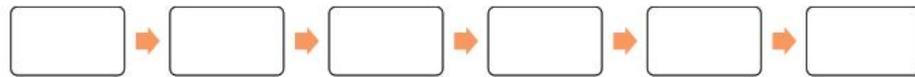
Agriculture is the science, art and practice of growing and harvesting living things for food, fibre and other useful products. Farming takes many different forms but is always based on manipulating the natural world for our benefit.

Create a mind map of how agriculture affects our natural environment using the following key ideas and concepts.

Ecosystems	Energy flows	Mineral cycles
Food webs	Decomposers	Biodiversity
Climate	Soil	Intensive
Extensive	Bushfires	Soil degradation

## How has Australian agriculture changed over time?

Australian land management dates back over 40 000 years. Draw a flow chart showing the changes in Australian agriculture from before European settlement until today.



## How is agriculture conducted in other countries?

Australian agriculture has been shaped by the harsh features of our landscape and climate as well as our history. Compare and contrast Australian agriculture with farming in New Zealand and China. Construct a mind map that includes the following factors:

Culture and population	History	Geography	Government and laws	Climate and soil	Farming enterprises
------------------------	---------	-----------	---------------------	------------------	---------------------



## CHAPTER 2

# Agricultural environment

## CHAPTER SUMMARY

Consideration of environmental influences, such as climate, soils and living organisms, is essential to the successful operation of a farming enterprise. In this chapter you will learn about the aspects of the environment that can influence agricultural production, both positively and negatively.

**How do aspects of climate and weather influence agricultural production?**

**How do physical and chemical soil characteristics affect agricultural production?**

**How can I manage soils most effectively?**

## 2.1 Introduction

**climate** the average conditions of Earth's atmosphere based on records taken over at least a 30-year period

The agricultural environment is made up of many different features working together to create a unique ecosystem. For effective farm operation, farmers need to understand the **climate**, soils and living organisms present, and how they interact with each other. This allows farmers to manipulate the ecosystem to grow plants and animals that are not naturally found there. Two of the main considerations for anyone buying a farm are factors relating to soil and climate.

The physical and chemical characteristics of a soil can be changed over time through farming practices, but this can be costly. The climate in which a farm is situated cannot be readily changed, and a farmer must manage their production system to suit the annual and seasonal rainfall and temperatures. These environments consistently have resources removed as products are grown and harvested, and therefore there needs to be a resupply of certain inputs. Farmers need to develop sustainable management practices to ensure a future for their farm.

## 2.2 Climate and weather

**weather** the daily changes in the atmosphere in precipitation, temperature, wind, pressure, cloud cover and other factors

**Weather** is the current state of the atmosphere – the temperature, humidity, wind and rainfall over hours or weeks. It is influenced by oceans, land surfaces, ice sheets and the atmosphere, all of which form a 'climate system'. The weather patterns in a region over a long period (generally more than 30 years) are considered its climate. Therefore, climate is the long-term pattern of weather for a region.

The short-term and long-term success of agricultural enterprises rely on understanding the climatic conditions for an area and the ability to select appropriate plants, animals and systems to suit these conditions. Understanding short-term weather forecasts and variations in the climate can help producers to plan for and manage enterprises, ensuring they are protected from these changes. Weather can be forecast accurately a week in advance. Short-term variations in an area's climate, such as a **drought**, can be predicted with less accuracy from season to season.

Farmers can access climate and weather information from a range of places including, but not limited to, farm records, the Bureau of Meteorology and the internet. The meteorological conditions that farming enterprises are concerned with can include solar radiation, temperature, precipitation, wind and humidity.

**drought** a prolonged period of abnormally low rainfall, leading to a shortage of water



Worksheets

Learn about weather forecasting with the worksheet on NelsonNet.



### LET'S DISCUSS

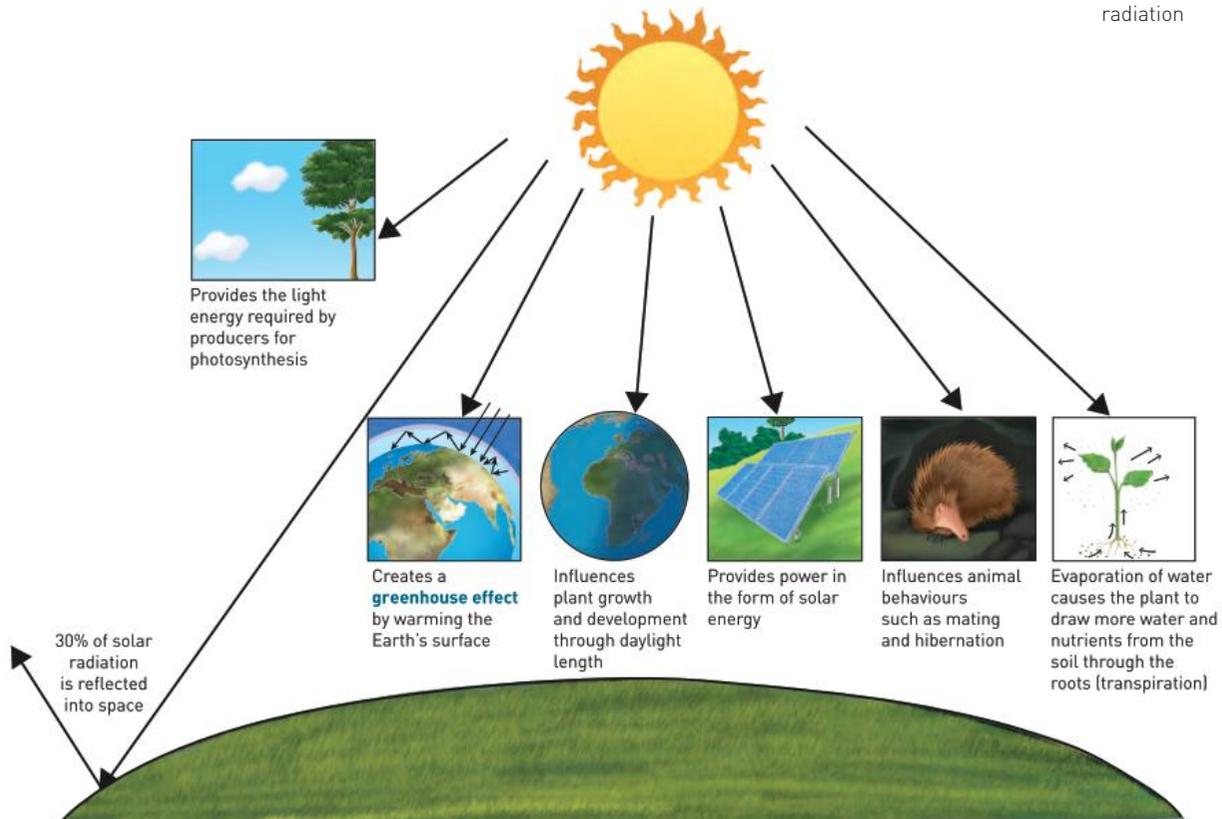
- 1 What types of climates are found in Australia?
- 2 What climate do you live in?
- 3 What are some of the characteristics of this climate?

## Solar radiation

Solar radiation is the light and heat energy that comes from the sun, and there are many different forms of radiation. Not all of the energy emitted from the sun reaches the earth's surface. Clouds, dust, snow and water vapour reflect some of the energy back into space or scatter it into the surrounding atmosphere.

Of the solar radiation that does reach the earth's surface, about 30% is reflected into space. The remaining radiation is of great importance for agricultural production.

**greenhouse effect** the warming effect of the Earth due to greenhouse gases in the atmosphere and solar radiation



**Figure 2.1** Importance of solar radiation in agricultural production

## Temperature

Temperature is the measure of how hot or cold an organism, object or substance is, and can be a direct result of solar radiation. The temperature will vary over a region and depends on the amount of cloud cover, vegetation, surface type, distance from the ocean, altitude, topography and exposure to prevailing winds.

**DID YOU KNOW?**

For every 300 metres above sea level, the air temperature drops by 2°C.



Worksheets

Explore the effect of temperature on seed germination with the practical activity worksheet on NelsonNet.

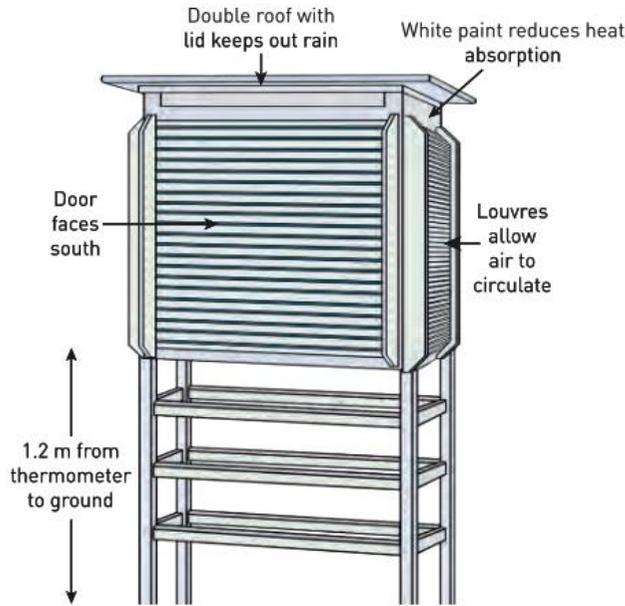
**DID YOU KNOW?**

There can be as much as a 7°C temperature difference between ground level and 2 m above the ground.



Worksheets

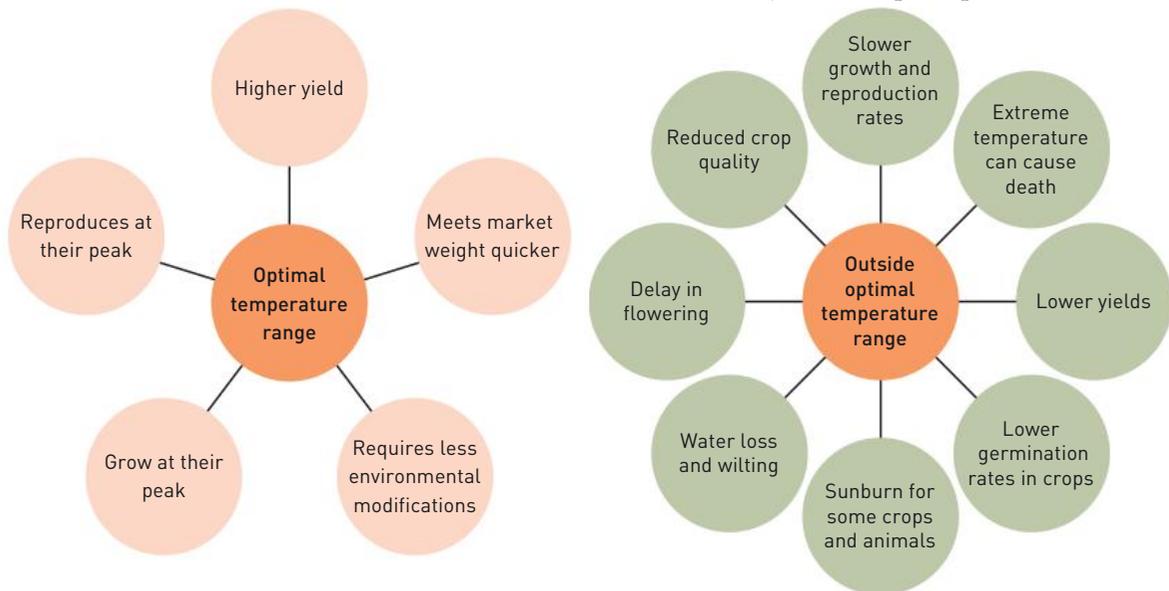
Explore the effect of temperature and light intensity on photosynthesis with the worksheet on NelsonNet.



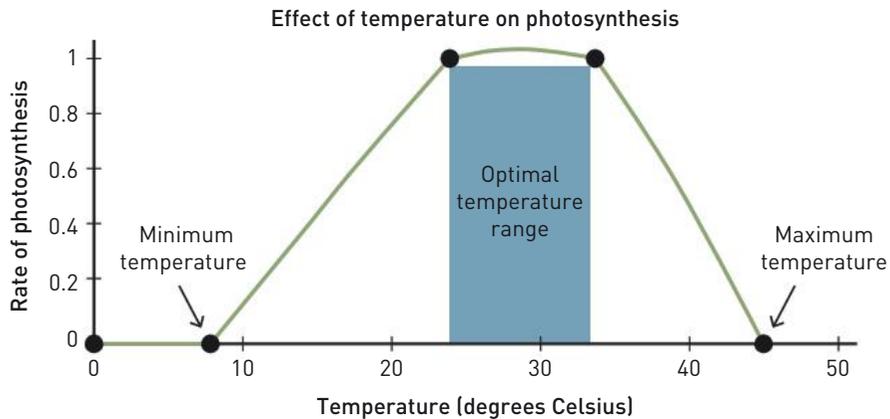
**Figure 2.2** A Stevenson screen showing positioning requirements for climatic control

Temperature is measured using a maximum–minimum thermometer. To prevent false readings of temperature, these thermometers are usually placed in an instrument enclosure called a Stevenson screen.

Temperature is important in agriculture because living organisms exist within a certain range, varying between species and individuals. Between these extremes of minimum and maximum, each species or organism has an optimum temperature range. In plant production, if the temperature is above or below the optimal temperature range, the rate of photosynthesis will decrease, reducing the growth rate and yield of the plant species.



**Figure 2.3** Effects of organisms growing inside and outside the optimal temperature ranges



**Figure 2.4** The minimum–maximum extremes for photosynthesis in plants and the optimal temperature range for maximum photosynthetic production

## Precipitation and evaporation

Precipitation is liquid or solid water particles that are released from clouds and reach the ground. Rain, snow, hail and sleet are all forms of precipitation.

Rainfall is the most likely component of an area's climate to limit the production of enterprises. While a regular rainfall pattern is usually vital for production, too little or too much can be harmful. Droughts can kill crops and reduce the amount of available water to livestock, while overly wet weather can cause fungal growth in plants and foot problems for animals. No farmer would operate an enterprise without knowing the precipitation that falls on their property. Rainfall is measured using a rain gauge.



Worksheets

Analyse and create climate graphs with the accompanying worksheet.

Monthly total and average rainfall statistics of concern to a farmer

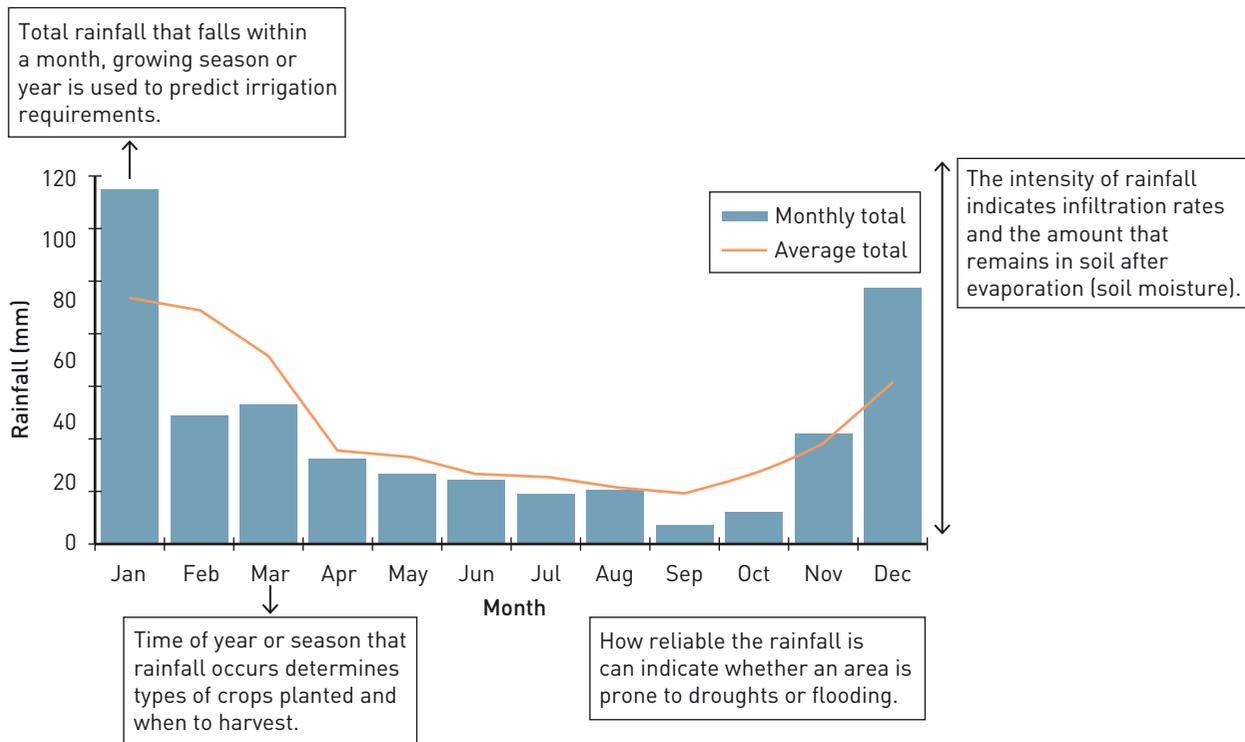


Figure 2.5 Necessary rainfall information for farmers



LET'S ENGAGE

### COLLECTING CLIMATE DATA AT SCHOOL

#### PURPOSE

To collect data on maximum and minimum temperatures and rainfall at the school for a period of six weeks

#### MATERIALS

- Maximum–minimum thermometer
- Rain gauge
- Stevenson screen (if available)

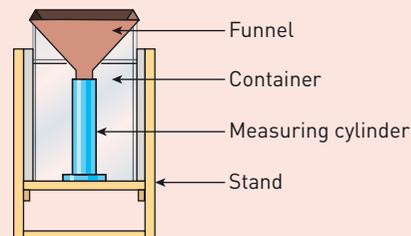


Figure 2.6 Rain gauge





Scaffold

Risk assessment template



WebLink

Bureau of Meteorology

**METHOD**

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Install the thermometer in a location protected from rain and wind. Ideally, a Stevenson screen would be used.
- 3 Install your rain gauge in an open location where there are no obstructions to rain.
- 4 Collect data on maximum and minimum temperatures and precipitation every 24 hours.
- 5 Record data in an Excel spreadsheet.

**DISCUSSION**

- 1 Construct line graphs showing the maximum and minimum temperatures over the six-week period.
- 2 Calculate weekly totals for rainfall and construct a bar graph showing weekly rainfall over the six-week period.
- 3 Compare your results to local climatic data from the Bureau of Meteorology.
- 4 Explain how the temperature and rainfall conditions during this period may have affected plant and animal production in the school agricultural plot.

## AG IN FOCUS

### DROUGHT

#### Identify

Drought is a difficult term to define because it can be used in more than one context. In agricultural terms, a drought is a relatively long time where there is considerably less water than usual for the affected area.

#### Understand

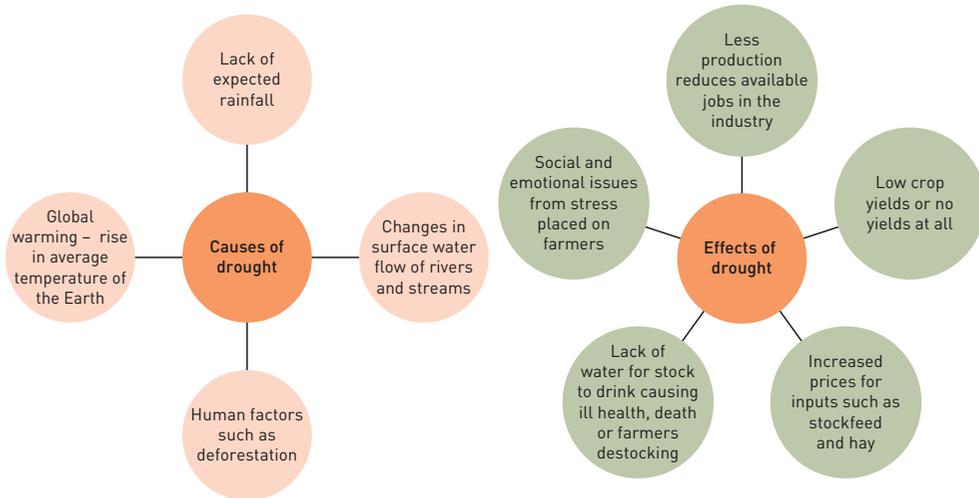


Figure 2.7 Causes and effects of drought

#### Discussion

- 1 What is an agricultural drought?
- 2 Outline the causes of drought.
- 3 Make a list of the effects of drought on farmers and farming practices. Research two more effects not listed in the case study.
- 4 As a class, discuss ways that farmers can minimise the effects of droughts on both cropping and livestock enterprises.



## LET'S DISCUSS

- 1 Australia has experienced many droughts. Is your region experiencing one currently? What types of relief and support can farmers seek in times of drought?

Evaporation occurs when a liquid turns into a gas and rises from the earth's surface. The rate of evaporation depends on factors such as cloudiness, air temperatures and wind speed. Evaporation increases as the air temperature rises and also during periods of dry, windy weather. Evaporation is measured using an evaporimeter, or atmometer.

Farmers are concerned with evaporation for many reasons. The amount of water remaining in the soil after evaporation is an indicator of how effective any rainfall is. Evaporation from the surface of an animal's body causes the body to cool. This is good for older animals on a warm day, but newborn animals with wet bodies can die from exposure if they are not protected from the wind that causes the evaporation and cooling body temperature.

## Wind

Wind is the movement of air across the earth's surface. It is created by uneven heating from the sun. Because the earth's surface is made of various land and water formations, it absorbs the sun's radiation unevenly and some areas are warmer than others as a result. Warm air, which weighs less than cold air, rises. Cooler air particles move in and replace the warmer rising particles. This movement of air is what makes the wind blow.

Wind can be measured using the **Beaufort wind force scale** chart in kilometres per hour or in knots. Using this chart is a simple and effective way to determine wind speed purely by observation of the surroundings. Wind speed can also be measured using an **anemometer** (Figure 2.8).

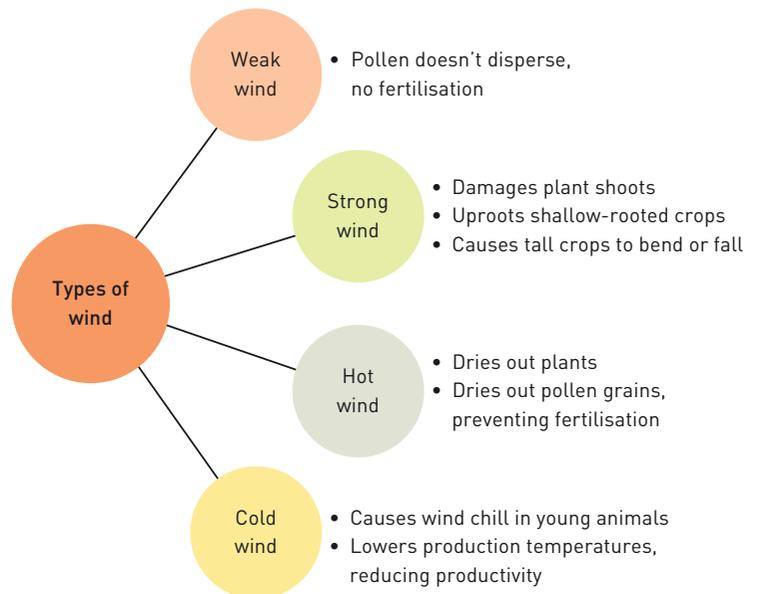
**Beaufort wind force scale** measures wind speed according to what conditions look like at sea or on land

**anemometer** an instrument used to measure wind speed

Shutterstock.com/Natalinosova



**Figure 2.8** Handheld digital anemometer taking a wind speed measurement



**Figure 2.9** Effects of different types of wind on agricultural production



## LET'S ENGAGE

## MEASURING WIND SPEED

## PURPOSE

To build an anemometer and measure wind speed

## MATERIALS

- Tape
- Scissors
- 2 strong drinking straws
- Stapler
- 4 small paper cups
- Pin
- Pencil with a new eraser

## METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Tape two straws into a cross shape.
- 3 Staple or tape the top side of a small paper cup to the end of each straw, so the cups open the same way, as shown in Figure 2.10.



Samantha Jarrett

Figure 2.10 Stapling cup to straw

- 4 Push the pin through the centre of the straws into the eraser of the pencil.
- 5 Mark one of the cups to indicate the beginning of a rotation.
- 6 Take the anemometer outside. Hold it up unobstructed and count how many turns it makes in one minute.

## DISCUSSION

Test the wind speed at different locations throughout the school farm.

- 1 Predict areas you think will have higher wind speeds and lower wind speeds. Explain why you have made these predictions.
- 2 Locate on a map the wind speed for each area tested, and identify areas of higher and lower wind speeds.
- 3 Propose reasons why these areas have high or low wind speed and mark significant features on your map that would affect wind speed (for example, windbreaks or buildings).



Scaffold

Risk assessment template

## Humidity

**relative humidity** the amount of water vapour present in air, expressed as a percentage of the amount needed for saturation at the same temperature

**dew point** the atmospheric temperature below which water droplets begin to condense and dew can form



Worksheets

Use the NelsonNet practical activity worksheet to make your own wet-and-dry-bulb thermometer and test the relative humidity around your school.

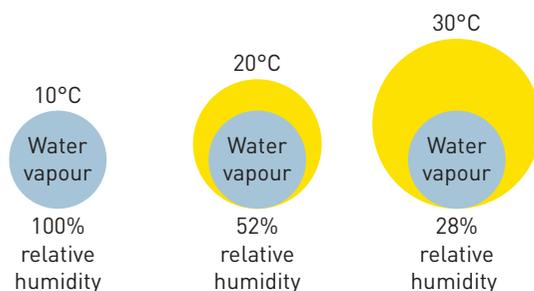
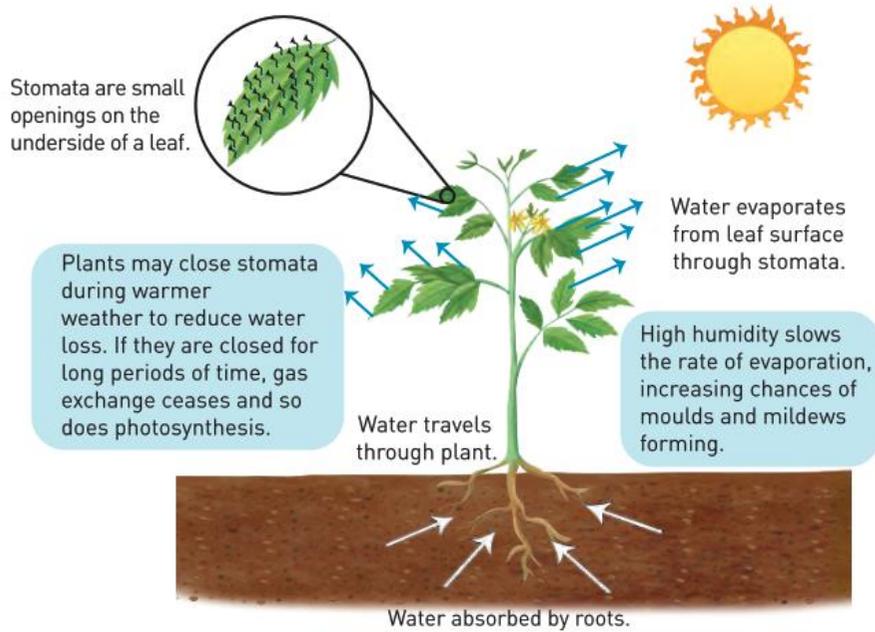


Figure 2.11 Relative humidity refers to how much water is in the air, relative to how much the air could hold, at a given temperature

Moisture evaporates from the oceans and other bodies of water into the atmosphere. The measurement of this water vapour is referred to as humidity. Very humid days have high amounts of water vapour in the air. Humidity is measured in either relative terms (**relative humidity**) or absolute terms (**dew point** temperature).

Relative humidity is measured by a wet-and-dry-bulb thermometer or hygrometer and is expressed as a percentage.



**Figure 2.12** Process of transpiration and the negative effects of relative humidity

High humidity can also reduce the ability of livestock to use evaporation to dissipate heat. Evaporative cooling happens when sweat or moisture evaporates from the respiratory tract or skin. Evaporation is the primary means by which some livestock, such as cattle, cool themselves at higher temperatures.

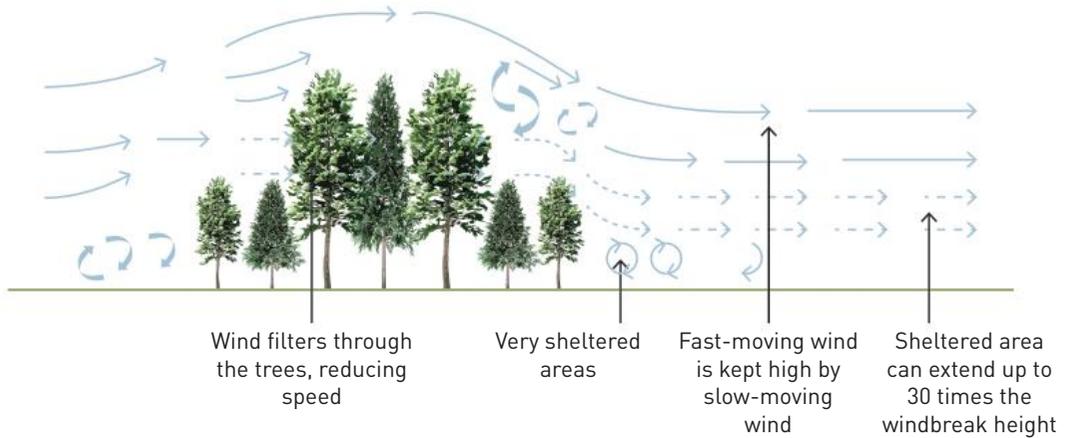
## Modifying the climate in extensive agricultural industries

The climate and weather of an area can have a direct effect on the yield and consequently the profit of an enterprise. While a farmer will generally choose what animal or plant species to grow based on the climatic conditions of an area, there is always room for improvement. Controlling the environment in **extensive industries** is not possible, but there are many measures farmers can take to manipulate the environment their product grows in and minimise risk.

### Windbreaks and stock shelters

Windbreaks are natural or artificial barriers used to reduce and redirect wind. Reducing the wind speed behind the windbreak can change the environmental conditions in the sheltered zone. Some of the approaching wind flows through, some goes around the ends, but most is forced over the top, making the height of the windbreak the most important factor in determining whether it will be effective.

**extensive industry**  
growing animals or plants over large areas of land, and aquaculture with low stocking rates



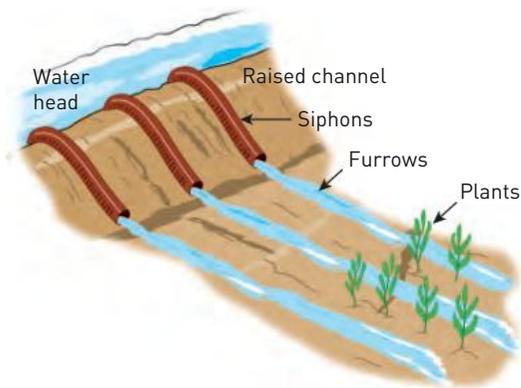
**Figure 2.13** How a windbreak works to redirect and reduce wind in the sheltered zone

### Irrigation

Irrigation is applying water to the land for growing plants and crops in agricultural enterprises. Farmers use irrigation to maximise the growth of plants and improve their ability to produce quality crops and produce. Animal farmers use irrigation to ensure they can grow enough feed for their animals and maintain the health of their pastures. Table 2.1 details some types of irrigation systems.

**Table 2.1** Examples of irrigation systems

Irrigation system	Description
Furrow systems	Parallel channels, carrying water to crops. Crops are grown on ridges between furrows. Water flows along furrows and wets the bottoms and sides. Used in crops such as rice, cotton and sugarcane.
Flood or border check systems	Parallel ridges or border checks divide paddocks into bays. Water flows down the slope guided by the ridges. Used in orchards, vineyards and some grain crops and pastures.
Centre pivot sprinkler systems	Self-propelled with a single pipeline supported by wheeled towers. Sprinkler nozzles are mounted or suspended from a central line. The towers rotate around the pivot point, and a large circular area is irrigated. Used in crops such as lucerne and perennial pastures, cotton and soybeans.
Low-flow irrigation systems (including drip and trickle)	Small-diameter tubes placed above or below the soil's surface with small holes or emitters to allow water to flow slowly at low pressure. Used in orchards, vineyards, or high-valued vegetable crops.



**Figure 2.14** A furrow irrigation system

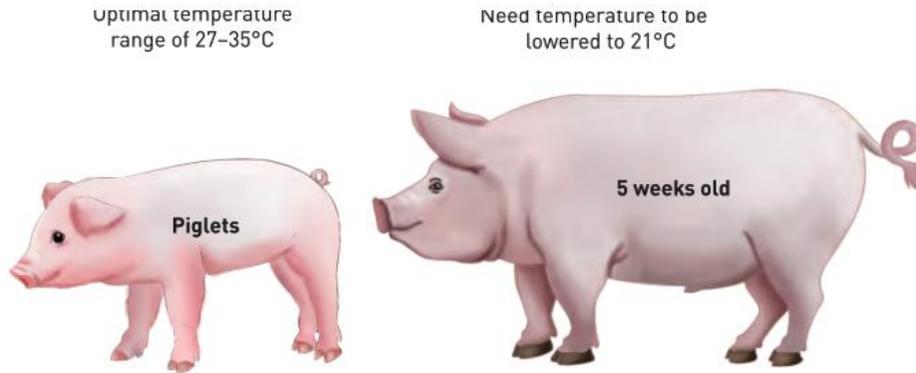


**Figure 2.15** Centre pivot irrigation system

Shutterstock/Cecilia Lim H M

## Modifying the climate in intensive agricultural industries

One of the most important features of **intensive farming** systems is the attempt to control the environment in which the plant or animal grows. This requires specialised knowledge of the species grown and how production can be improved by controlling factors such as temperature, length of daylight and carbon dioxide concentrations.



Keeping the temperature at the optimal growing and/or breeding ranges can directly affect the growth rate and maturity of the animal.

**Figure 2.16** Optimal temperature ranges for intensive pig production

Modifying the amount of artificial lighting to increase daylight hours can increase animal production. Increasing the simulated day length for laying hens to 15–16 hours can encourage hens to lay eggs more consistently and not reduce production over the winter period as they would naturally do. In a hydroponics system, the colour of the light influences the rate at which the plants will grow.

In intensive plant enterprises, other factors can be controlled, such as:

- availability of water
- soil moisture levels through irrigation and mulching
- nutrient availability from fertilisers and composting
- physical protection from severe weather events such as wind and hail by using netting, shade cloths and glasshouse buildings.

Climate control in this type of farming can range from completely environmentally enclosed loop systems in automated glasshouses with computer-controlled watering systems, lighting and ventilation, through to simple low-tech solutions such as shade cloth over plants or plastic film over ridges to increase soil temperatures.



**Figure 2.17** Plastic film over ridges growing strawberries



**Figure 2.18** Automated glasshouse controlling temperature and water supply

**intensive farming** the use of a controlled environment to produce large amounts of product in a smaller area than extensive farming



Worksheets

Explore other methods of controlling the climate by conducting the Water as a limiting factor experiment with the practical activity worksheet on NelsonNet.



## LET'S REVIEW

### LOOKING BACK

- 1 What does the term 'climate' mean?
- 2 Complete a table with examples of how temperature affects plant and animal production.
- 3 Which aspects of rainfall would a farmer be interested in?
- 4 Describe the conditions that cause an increased rate of evaporation of water from a plant's surface.
- 5 What effect on agricultural production could the following climatic factors have:
  - a wind
  - b high rates of evaporation?
- 6 Define the term 'relative humidity'.
- 7 What agricultural problems are associated with conditions of high humidity?
- 8 What is the purpose of windbreaks?
- 9 Describe how farmers alter the following factors in an intensive plant system: temperature, humidity, water supplied and wind effects.
- 10 Describe three ways a farmer can overcome climatic uncertainty.

### FOR YOU TO DO

- 1 From your local area, collect the following data and graph it.
  - a Average monthly rainfall for one year
  - b Average monthly minimum temperatures for one year
  - c Average monthly maximum temperatures for one year
- 2 Visit both an intensive and extensive farming system in your local area. Record all the methods used at each farm to control or manipulate the climatic conditions.
- 3 Build a mini-greenhouse using recycled materials.

### TAKING IT FURTHER

- 1 Rainfall varies with a region, even within a distance of 50 km. With reference to the average rainfall (mm) from January to December for Australia and New Zealand (you can get this data at the BOM for Australia and NIWA for New Zealand), answer the following.
  - a In your own words, describe the trends in distribution of rainfall.
  - b Research what agricultural enterprises are grown in the areas with the highest average rainfall for both countries. Are there similarities?
  - c Research the agricultural enterprises grown in the areas with the lowest average rainfall for both countries. Are there similarities? Why or why not?



Web link

Bureau of Meteorology



Web link

Bureau of Meteorology

NIWA

#### inorganic particles

unrelated to organic matter or organic life, not animal, vegetable, or a chemical compound that contains carbon

**organic matter** the matter that has come from living organisms

**pores** the space between soil particles, usually containing air or water

## 2.3 Soils in agriculture

Soil is the thin layer of **inorganic particles** and **organic matter** that covers the Earth's surface. It provides the structural support and source of mineral nutrients required by plants as well as a habitat for many insects and other organisms. Soils act as filtration systems for surface water.

There are four main components that make up a soil: rocks (minerals), water, air and organic matter. The rock or mineral component of soil is the largest and consists of a combination of sand, silt and clay. Small **pores** or holes in the soil allow air to be present and water to pass through. The water in soil usually contains dissolved nutrients. Some soils, such

as clays, hold more water than others for longer periods. Decayed plants, animals and microbes make up the organic matter of a soil. The decayed organic materials are broken down into nutrients that can be used by the vegetation growing in the soil. The product of decomposition is called **humus**, a black crumbly material. Humus is a complex chemical substance with the ability to attract and store water and minerals and improve soil structure.

There are many types or classes of soils and these are based on colour, profile, structure, texture and composition. This is the result of variations in the process of soil formation and the wide range of locations on Earth.

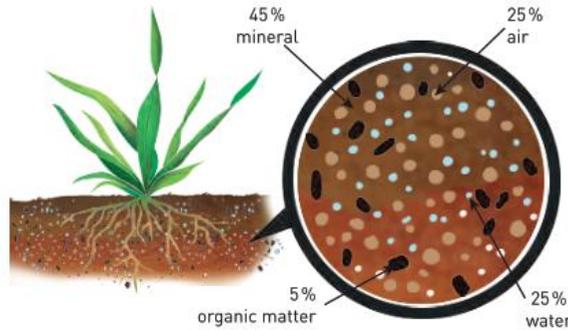


Figure 2.19 Components of soil

**humus** a stable product in soil formed through the breakdown of organic matter

## Soil formation

Soil forms from the breakdown of rocks, minerals and sediments from physical and chemical **weathering**. Physical weathering causes a decrease in size of rock and mineral particles while chemical weathering produces definite chemical changes.

Five factors control the degree of weathering and the type of soil that will form. There are three active factors (climate, living organisms and time) and two passive factors (**parent material** and **topography**, or relief).

**weathering** the breakdown of rock to form the mineral fraction of soil

**parent material** the rock that lies beneath the subsoil that weathers to form soil

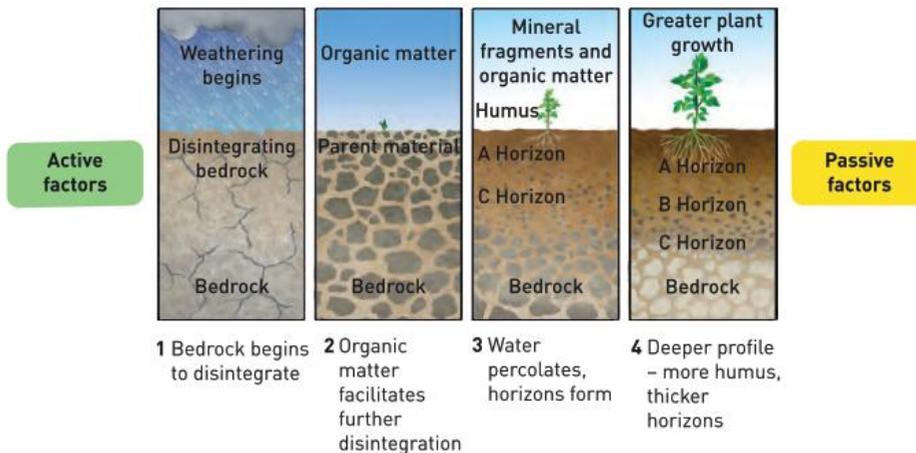
**topography** the shape, slope and contour of the Earth's surface

### Climate

- Temperature and precipitation control:
  - weathering rate
  - movement of substances through soil profile
  - vegetation that becomes established.

### Parent material

Parent rock type determines the types of minerals present, as well as soil colour, texture and structure.



### Living organisms

- Humus binds soil particles, affecting soil structure, porosity, water-holding capacity and nutrient storage.
- Plant roots hold soil together, reducing erosion.

### Topography

Steep slopes erode more easily and rainfall runs off. Valleys tend to have deeper, more mature soils.

### Time

Layers form as soils develop from parent materials. Soil horizons become more defined and recognisable.

Figure 2.20 Factors that contribute to the formation of soil

## Soil profile

**soil horizon** the layers parallel to the soil surface, whose physical characteristics differ from the layers above and beneath

**eluviated horizon** the dissolved or suspended material within the soil that has been transported to this layer by the flow of water

A soil profile is a vertical section of soil beginning at the surface and continuing through to the parent material layer. Soil profiles are divided into layers called **horizons**. Each horizon may be slightly different or very different and each tells a story about the make-up, age, texture and characteristics of that layer. As shown in Figure 2.21, most soils have three major horizons (A, B, C), while some have an organic horizon (O) and others have **eluviated** (E) and bedrock (R) horizons.

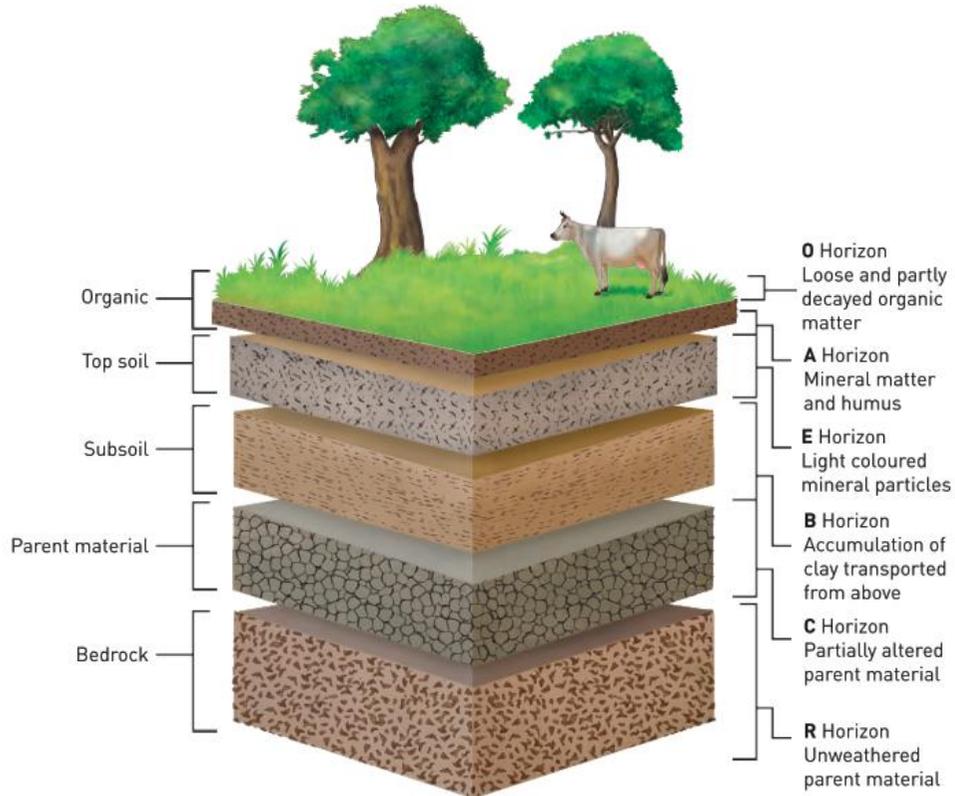


Figure 2.21 Soil profiles with horizons



Worksheets

Explore the best soil profile for growing plants with the *Soil profile* worksheet on NelsonNet.



### LET'S DISCUSS

- 1 Where in the local area might you see a soil's profile?
- 2 What human activities exposed these profiles?

## Soil characteristics

### Texture

Soil texture refers to the size and proportion of sand, silt and clay particles that make up the minerals of a soil. This is usually determined by the parent material; for example, sandstones will produce sandy soils with large particles. Soils are graded into one of six groups: sands, sandy loams, clay loams, light clays and medium to heavy clays. Each group of soils behaves in particular ways.

**Table 2.3** Soil texture properties

Properties	Sandy soil characteristics	Loamy soil characteristics	Clay soil characteristics
Particle size	Large	Medium	Fine
Pore spaces	Large	Medium	Very small
<b>Permeability</b>	Very good	Average	Very little
Drainage rate	Fast – holding very little	Average	Slow
Nutrient-holding capacity	Hold very few nutrients	Hold adequate nutrients	Hold lots of nutrients

**permeability** the ability of a substance to allow another substance to pass through it



## LET'S DISCUSS

- 1 How does soil texture influence agricultural production?



## LET'S ENGAGE

### SOIL TEXTURE RIBBON TEST

#### PURPOSE

To determine the texture of a soil using an in-field test

#### MATERIALS

- Soil sample
- Small amount of water

#### METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Take a small handful of soil, about the size that would cover a large coin.
- 3 Add enough water to make it into a ball. If you cannot make a ball, the soil is very sandy.
- 4 Feel the ball with your fingers to find out if it is gritty (sand), silky (silt) or sticky (clay).
- 5 Roll the ball and with your thumb and forefinger, gently pressing it out over the forefinger to make a hanging ribbon or snake.
- 6 Keep pressing the soil into the ribbon shape until it breaks.
- 7 Measure the length of the ribbon and determine texture based on the information in Table 2.4.

**Table 2.4** Interpreting soil texture from ribbon test results

Field texture grade	Texture features and behaviour	Ribbon length (mm)
Sand	Coarse and gritty, cannot be moulded into a ball	Nil
Sandy loam	Less gritty, moulds together loosely and will form a short ribbon	15–25
Loam	Little grit, smoother feel, forms a ribbon	25
Clay loam	Smooth to feel, sticks together well in a ball, crumbly ribbon	40–50
Clay	No grit, smooth and very sticky, creates a ribbon easily	>75



Scaffold

Risk assessment template



Video

How to read a texture triangle



## DISCUSSION

- 1 Determine the texture of your soil sample.
- 2 Identify some of the characteristics that make up this soil texture.
- 3 Draw a labelled diagram to represent your soil texture, showing relative sizes of the mineral particles and predicted size of the pore spaces between these particles.
- 4 Evaluate the characteristics of this soil for growing a crop local to your area.
- 5 Investigate how to do a texture test using the texture triangle.
  - a Carry out the texture triangle test and draw a profile of your soil.
  - b Evaluate the water-holding capacity, porosity and nutrient-holding capacity of the soil sample based on its texture.

## INDUSTRY IN FOCUS

### AGRONOMIST

#### Identify

Agronomists are agricultural scientists who study commercial plants, animals and cultivation techniques. They look for ways to improve crop and pasture production by increasing soil productivity, and conduct tests on soils and plants to determine where the limiting factors may be in a system. They devise plans and advise farmers on how to manage the soils and plant the right varieties for agricultural areas and individual farms.



Shutterstock.com/Nolanberg11

**Figure 2.22** An agronomist working in the field

Typical duties for an agronomist include measuring soil salinity and nutrient levels, performing statistical analysis, planting crops, land appraisals and writing management plans. Agronomists can work directly for farms as farm managers, field or lab technicians, consultants for rural stores or private companies, inspectors for government bodies, and even as soil and water conservationists. A four-year university degree in agronomy is often required for those interested in becoming an agronomist.

#### Discussion

- 1 List typical duties carried out by agronomists.
- 2 Explain how agronomists can help farmers improve yields.
- 3 Where do agronomists work?
- 4 Research the pathway to becoming an agronomist, including the names of education facilities that offer training.

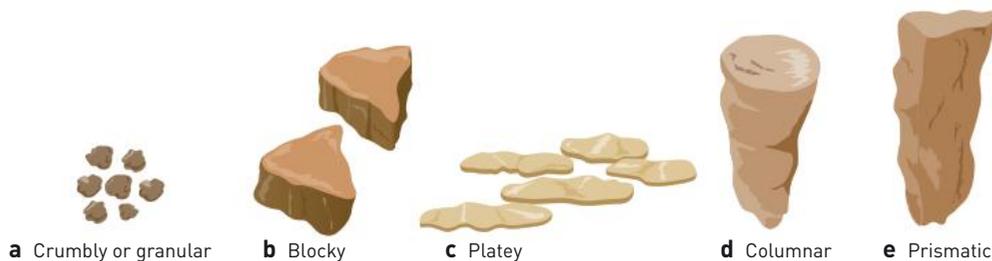
## Soil structure

Soil structure is the way the particles of a soil group together to form **aggregates** (or **peds**) and pore spaces. Particles in a soil bind together to form aggregates of varying sizes, from small crumbs to large blocks. The appearance of the aggregate determines the structural appearance of a soil, such as blocky, columnar, massive, single grain or platy.

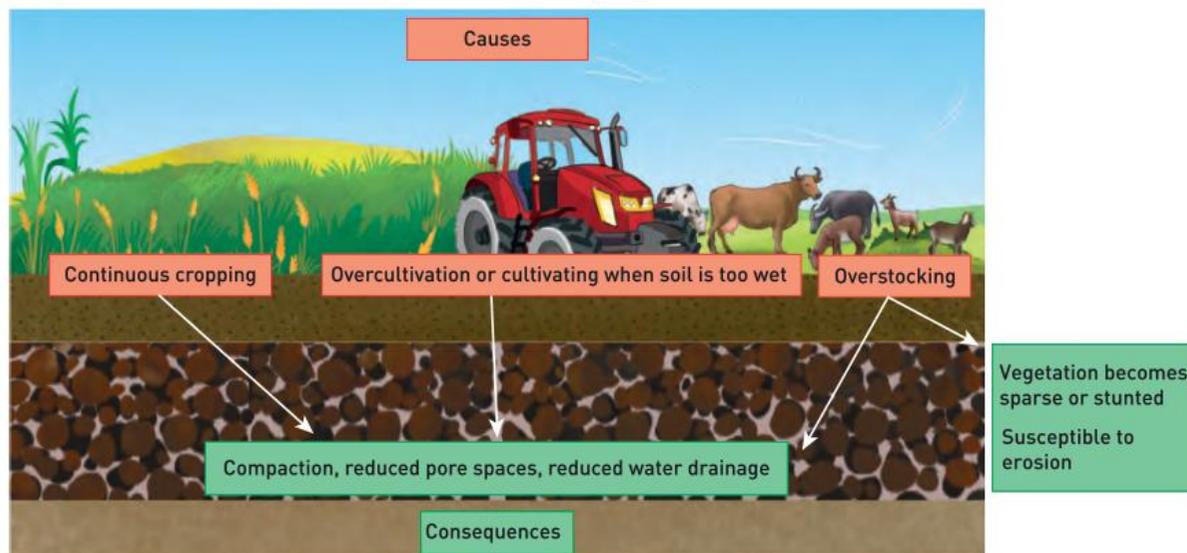
Good soil structure has enough pores between aggregates to allow air and water to enter and adequately drain, but still hold enough moisture. Well-developed soil structure assists to prevent wind and water erosion as peds are heavier than individual particles. A soil with poor structure has less defined aggregates, more individual grains and hence fewer pore spaces. This makes it difficult for plant roots to penetrate and machinery needs to work harder to cultivate the soil.

**aggregate** the material or structure formed from a mass of fragments or particles loosely compacted together

**ped** the unit of soil structure



**Figure 2.23** Various types of soil aggregate



**Figure 2.24** Causes and consequences of poor management practices in soil structure

Enhancing soil structure can be achieved through:

- deep ripping of compacted layers
- reducing the amount of tillage, especially when soils are wet
- maintaining appropriate stocking rates
- increasing organic matter through stubble retention, green manuring and maintaining plant cover.



## LET'S ENGAGE

**compaction** the process by which the pressure on soil causes the material to stick together and pore spaces to be squeezed together

## TESTING AREAS OF COMPACTION

## PURPOSE

To compare areas for rates of **compaction**

## MATERIALS

- Large tin can open at both ends
- 1 L water
- Stopwatch

## METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Locate an area of possible compaction (such as around a water trough/feeding area) and a soil nearby that is not compacted.
- 3 Insert tin can 1 cm into the compacted soil.
- 4 Pour 1 L of water into the can.

- 5 Record how long it takes to completely drain.

- 6 Repeat steps 2–4 in a non-compacted area.

## DISCUSS

- 1 Identify which soil allowed the water to drain the fastest and explain why you think this happened.
- 2 What was the cause of the compaction in the area tested?
- 3 How could the compaction in this area be prevented or reduced?
- 4 Predict what you think would happen in a cultivated garden bed if you were to do this activity.
- 5 Explain why gardens are maintained in a very loose, uncompacted state.

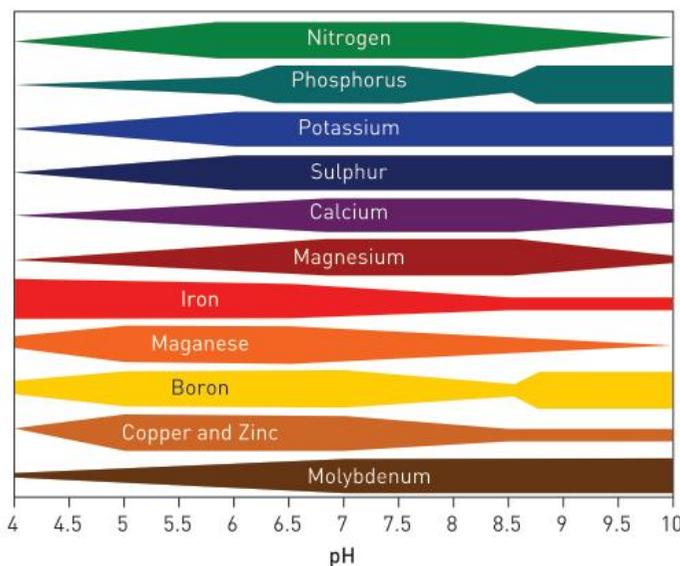
## Soil pH

The pH scale is used to measure acidity or alkalinity. It runs from 0 to 14, indicating the concentration of positively charged hydrogen ions in the soil. The neutral point on the scale is at pH 7; anything below 7 is acidic (more hydrogen ions present), while above 7 is alkaline (fewer hydrogen ions present).

Soil pH is important because it influences the availability of essential nutrients for plants, giving rise to nutrient deficiencies (too little) or toxicities (too much). Figure 2.25 shows how pH can impact uptake of specific **macro** and **micro nutrients**.

**macronutrients** chemical elements (e.g. potassium, magnesium, calcium) required in large amounts for plant growth

**micronutrients** chemical elements or substances required in trace amounts for the normal growth and development of plants



**Figure 2.25** The nutrients a plant receives are affected by pH. A nutrient is more easily available to a plant when the above coloured bands are thicker.

The aim of managing soil pH is not to achieve a particular number, but to manipulate soil to a point where the availability of nutrients is at its highest for the crop being grown. Treatments such as adding lime to soil can raise pH, while some fertilisers can lower the pH.



## LET'S DISCUSS

- 1 What other areas of agriculture rely on knowing and understanding the pH of a substance?



## LET'S ENGAGE

### SOIL pH TESTING

#### PURPOSE

To determine the pH of a soil

#### MATERIALS

- Soil sample
- pH testing kit OR universal indicator, barium sulphate powder and pH colour chart for universal indicator
- Spoon
- Piece of white plastic or white tile

#### METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Using a clean spoon, place a sample of soil about the size of a large coin on the white plastic or tile. If using a pH testing kit, follow the enclosed instructions and proceed to the discussion.
- 3 If not using a pH testing kit, add enough universal indicator onto the sample to moisten it.
- 4 Sprinkle the barium sulphate powder over the moistened soil sample. You

may need to add more indicator if the sample was not moist enough to create a colour change in the powder.

- 5 Compare the colour of the barium sulphate powder with the pH colour chart.

#### DISCUSSION

- 1 What was the pH of your soil sample?
- 2 Is this soil suitable for growing the main crops found in your local area? Explain why or why not.
- 3 What factors affect the pH of soils?
- 4 With reference to the location from which your soil sample was taken (such as a paddock or vegetable garden), outline a range of agricultural practices that could be implemented to change the soil's pH if it became too high or too low for production.
- 5 Design and conduct an experiment to determine if adding fertiliser to the soil affects the pH of the soil.



Scaffold

Risk assessment template

## Managing farm soils

Degradation of soil is the physical and chemical decline in soils, causing them to become less vigorous or healthy. It can be caused by poor management or use of the soil.

There are many practices farmers can implement to reduce soil degradation and even begin to restore soil fertility. Depending on the type of degradation and the enterprises conducted, some or all of these methods could be used.

### Conservation tillage systems

The following practices can all be considered conservation tillage.

- Stubble retention or mulching is the process of leaving the stalks from the harvested crop in the paddock until the next planting when it is either mulched in or left as is.
- Reduced tillage is the process of using one or two cultivations of the whole seedbed before seeding.

- Direct drill is when a new crop or pasture is sown directly into uncultivated soil by a pair of v-shaped discs creating a furrow for the seed. Less than 40% of topsoil is disturbed during this method.
- Zero or no-till is when the soil is broken once by a knife-like blade and seeds are planted concurrently in that area. Less than 25–30% of the topsoil is disturbed during this method.



Figure 2.26 Crop stubble left in a paddock after harvesting.

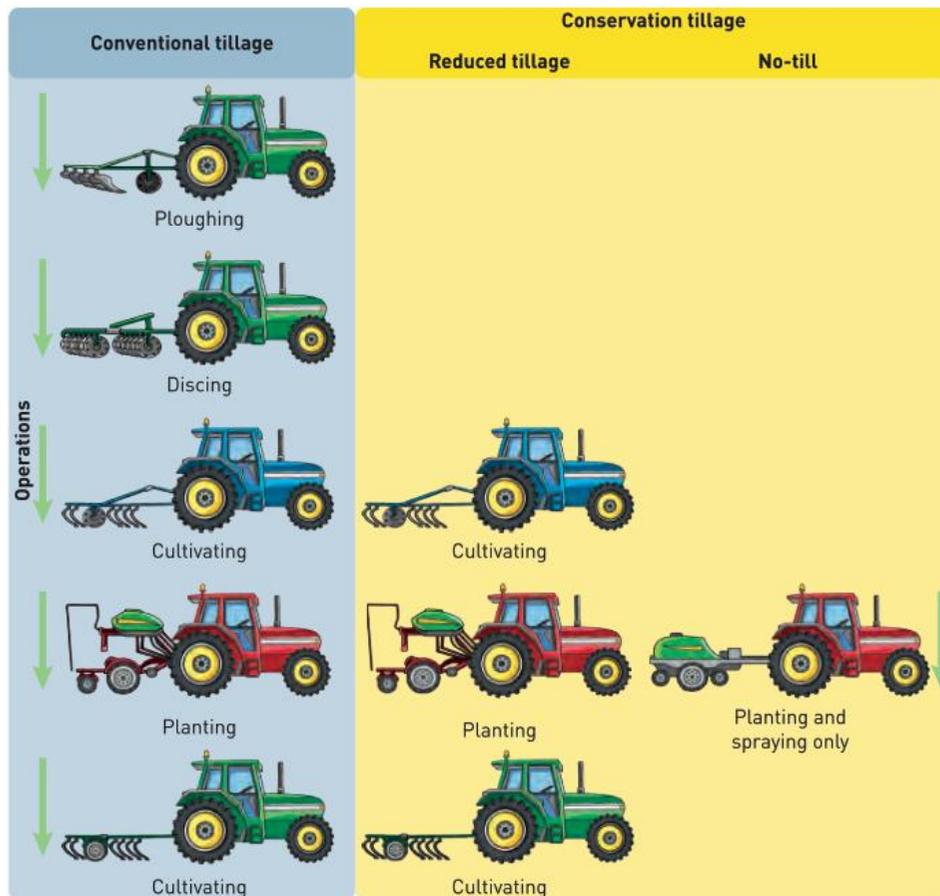


Figure 2.27 The difference between conventional tillage and conservation tillage methods

## Crop rotation

Crop rotation involves growing different crops in planned sequences, such as corn-soybean-wheat. It is more complex than changing crops based on the economic market available. Crop rotation is a long-term plan designed to improve farm management, reduce market risks and improve soil. Well-planned crop rotations help manage weeds, insects and diseases, reduce soil erosion and maintain levels of organic matter in soil. If legumes are used within the rotation, increased levels of naturally sourced nitrogen become available to plants. These benefits increase crop yield and profits.

### AG IN FOCUS

#### SOIL DEGRADATION: EROSION

##### Identify

One of the most common forms of soil degradation is erosion. Erosion is the movement of soil materials from one place to another. It can be caused by natural elements such as water or wind. Removal of the topsoil – the most productive part of the soil – via erosion results in lower yields and higher production costs in agricultural enterprises.

##### Understand

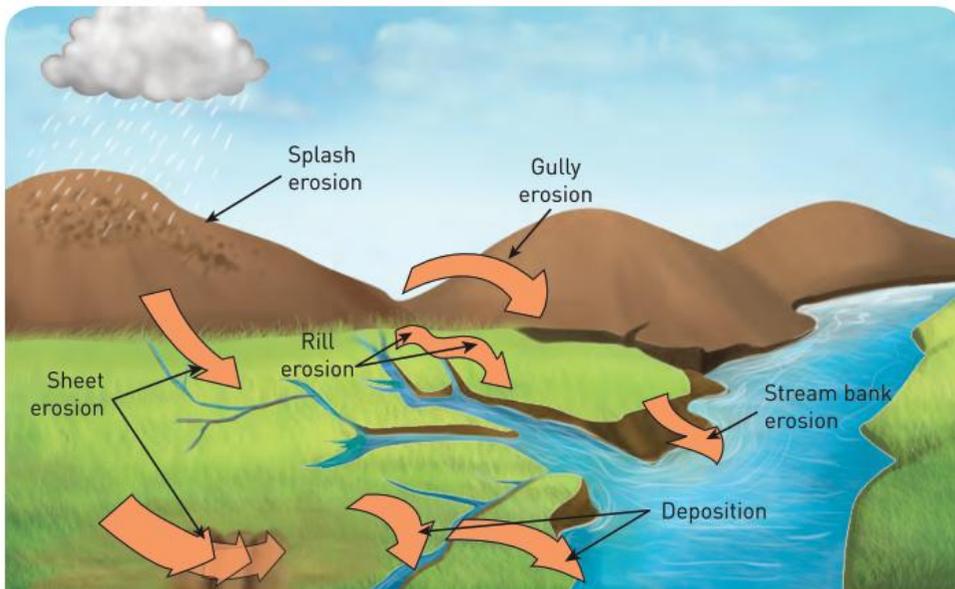


Figure 2.28 Types and causes of water erosion

Wind is a powerful agent in the process of erosion. It can move loose soil particles from one place to another in small bursts over short distances or large dust-storm events can carry soil particles over many kilometres. Wind erosion occurs in semi-arid and arid areas and is accelerated by overgrazing and poorly structured soil with little or no vegetation.

Loss of soil organic matter from land clearing, over-cultivation and overstocking is a major factor increasing the rate of erosion. Soil structure and fertility become compromised and degrade, which exposes the soil to erosion by wind and water. Leaving crops **fallow** between harvests, loss of natural vegetation cover from overstocking, and clearing and conventional farming methods all contribute to this degradation issue.

##### Discussion

- 1 Analyse Figure 2.28. Describe three different types of erosion.
- 2 Identify factors that influence the rate of soil erosion.



Worksheets

Explore soil erosion caused by water and rainfall with the NelsonNet practical activity worksheet.

**fallow** land that has been cultivated but left unseeded for a period of time between growing seasons

- >
- 3 How can livestock contribute to the rate of soil erosion?
  - 4 Describe the traditional system of land cultivation for crops.
  - 5 What management options exist for a farmer wanting to improve the level of organic matter in soil?
  - 6 Design and conduct a practical experiment to show how replanting vegetation in an area can reduce erosion.
  - 7 Collect two soil samples, one of topsoil and one of subsoil.
    - a Using a commercial soil nutrient test kit, test the amount of nitrogen, phosphorus and potassium in each sample.
    - b Compare and contrast the results in a table.
    - c Identify which soil is the most fertile. Explain your finding.
    - d With reference to your experiment, discuss why erosion causes losses in production for agriculture.



## LET'S REVIEW

### LOOKING BACK

- 1 Draw and label a soil profile diagram.
- 2 Define the following terms: soil texture, soil structure, soil ped.
- 3 Which properties of soil do texture influence?
- 4 Can the texture of a soil be easily changed?
- 5 Describe two ways in which a farmer could improve soil structure.
- 6 How does the size and number of soil pores affect soil properties?
- 7 How does soil pH affect agricultural production?

### FOR YOU TO DO

- 1 Place soil thermometers at various depths in the soil. Measure the soil temperature at each depth and graph the results.
- 2 Mark out a series of metre-square grids in an open area of bare soil. Place different types of coverings over each grid square: black plastic, hessian, sugar cane mulch, bark mulch, etc. Leave for approximately two weeks and then measure the soil temperature (using a soil thermometer) at the same depth in each square.
  - a Determine which covering most affected the soil's temperature.
  - b Describe how this information could be used by farmers to benefit plant production.
- 3 Survey your school farm or a local area and on an aerial map record places that show signs of erosion and the types identified.
  - a Identify the likely cause of erosion in each area.
  - b Propose strategies that could be put in place to prevent further erosion in these areas.

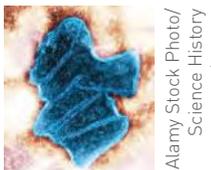
### TAKING IT FURTHER

- 1 Create a model of three different soils (sandy, loamy and clay) using three different sized rounded materials such as small round beads, marbles, and ping-pong balls or golf balls. Use your model to explain how soil texture affects porosity and water drainage.
- 2 Research the term 'eutrophication'.
  - a What is eutrophication?
  - b Explain the causes of eutrophication.
  - c Analyse the effects of eutrophication on farm production and natural ecosystems.
  - d Evaluate management practices that can be used in agricultural production to prevent eutrophication.

## 2.4 Microorganisms and invertebrates

Microorganisms and invertebrates play a crucial role in agriculture and can have a beneficial or detrimental effect on production in enterprises. Some organisms are considered pests and can cause physical damage or can carry or cause disease in plants and animals. Other organisms can be beneficial to the agricultural environment, such as those responsible for decomposition, those that inhabit the stomachs of ruminant animals or those that assist in the making of saleable products such as silage and cheese.

**Table 2.5** Five major groups of microorganisms

Microorganisms	Bacteria	Viruses
<p>Microorganisms (also called microbes) are the simplest form of living being and are so small they can only be seen with the aid of a microscope. Microbes make up the largest number of living organisms on Earth, with billions inhabiting every environment. Microbes can be beneficial in our lives and agriculture; for example, some are used to make medicines and vaccines, while others are used in food production. Other microbes can be potentially harmful in agriculture, such as those that cause disease and spoil our food.</p>	<p>Single-celled organisms that come in a range of shapes, from which scientists classify them into groups. Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• <b>vaccines</b></li> <li>• silage-making</li> <li>• ruminant digestion.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• food spoilage</li> <li>• animal and plant <b>diseases</b></li> <li>• bacterial infections</li> <li>• blue-green algal blooms (cyanobacteria).</li> </ul>  <p><b>Figure 2.29</b> Nitrogen-fixing bacteria, Rhizobium</p>	<p>Infectious agents smaller than bacteria that are only able to live and reproduce inside another organism. Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• control of damaging pests.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• animal diseases including foot-and-mouth</li> <li>• plant diseases including tomato-spotted wilt virus.</li> </ul>  <p><b>Figure 2.30</b> Virus causing ephemeral fever</p>
<p>Single-celled organisms that commonly show characteristics of animals but are not classified as animals. Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• providing a food source for soil organisms and small aquatic species</li> <li>• mineralising nutrients, making them available for plant use</li> <li>• helping ruminant animals digest the cellulose into carbohydrates that the animal can use.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• animal diseases including coccidiosis.</li> </ul>	<p>Plant-like organisms that contain chlorophyll and perform photosynthesis. Found in both fresh and saltwater ecosystems and range from single-celled organisms through to large multicellular forms. Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• seaweeds and kelps used as fertilisers</li> <li>• human food (seaweed, nori), food supplements (such as spirulina) and biofuels.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• micro-algal blooms, toxic algae, or red tides, contaminating aquaculture industries and natural waterways.</li> </ul>	<p>Plant-like organisms that lack chlorophyll to make their own food through photosynthesis, and instead get their energy from the decomposition of organic matter. Fungi range from single-celled yeasts through to multi-cellular mushrooms. Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• decomposition of organic matter</li> <li>• food production and consumption.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• plant and animal disease</li> <li>• food spoilage</li> <li>• producing <b>mycotoxins</b>, or poisons that can cause death when consumed.</li> </ul>

**vaccine** a substance prepared from the disease-causing agent or a synthetic substitute; used to provide immunity against one or several diseases

**disease** any condition that produces a change in the normal functioning of an organism



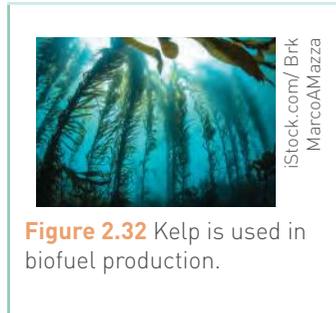
Worksheets

Test your knowledge with the *Microorganisms* worksheet on NelsonNet.

**mycotoxin** toxic substances produced by fungi



**Figure 2.31** Zooplankton is used as live fish feed in hatcheries.



**Figure 2.32** Kelp is used in biofuel production.



**Figure 2.33** Brewer's yeast

## DID YOU KNOW?

One teaspoon of fertile soil can hold as many as 500 million bacteria.



## LET'S ENGAGE

### GROWING AND OBSERVING MICROORGANISMS IN A HAY INFUSION

#### PURPOSE

To observe microorganisms under a microscope

#### MATERIALS

- Microscope
- Microscope slide(s)
- Coverslip(s)
- Pipette(s)
- Small handful of hay
- Pond, stream or trough water
- Large jar with lid

#### RISK ASSESSMENT



Wear safety glasses when preparing slides. Wash hands thoroughly after activity

#### METHOD

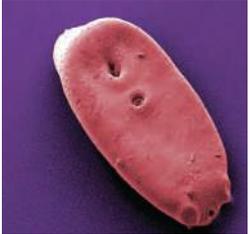
- 1 Place the hay and pond water in the jar, secure the lid.
- 2 Place the jar in a well-lit area at room temperature (do not place in direct sunlight).
- 3 Allow the hay infusion to sit undisturbed for one week.
- 4 Take a clean glass slide and, using the pipette, take one drop of water with visible clumps of suspended material from the jar and place this on the slide.

- 5 Gently place the cover slip over the water and flatten with your finger if necessary.
- 6 Wipe off excess liquid from around the cover slip.
- 7 Observe first with the 4x lens to centre the clumps and focus the microscope.
- 8 Change to the 10x lens and attempt to distinguish the various forms of microbes: algae and protozoa.
- 9 Change to the 40x lens when a suitable cell has been located to examine it in close detail.

#### DISCUSSION

- 1 Draw a diagram of at least two algae and two protozoa at the 40x magnification.
- 2 Identify if and how the microorganisms are able to move within their environment.
- 3 Describe the different shapes of microorganisms present within the sample and create a tally of how many you see.
- 4 Re-do this practical over several weeks using the same water and keep tallies. Discuss the changes in populations of the different microorganisms.

**Table 2.6** Five major groups of invertebrates

Invertebrates	Molluscs	Nematodes
<p>Invertebrates are animals that lack a backbone and can be put into different classes based on their physical and physiological characteristics.</p>	<p>Soft-bodied invertebrates, usually with an external shell, characterised by soft unsegmented bodies and a large muscular foot used for movement. Examples include snails and slugs, oysters and mussels.</p> <p>Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• edible protein sources.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• damage to vegetable crops</li> <li>• carriers of diseases and parasites such as live flukes.</li> </ul>  <p><b>Figure 2.34</b> A snail</p>	<p>Characterised by long, unsegmented bodies that are pointed at each end. Can be parasitic or free-living. Examples include roundworms, threadworms and eelworms.</p> <p>Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• recycling organic matter</li> <li>• mineralisation</li> <li>• biological pest control.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• loss of plant production</li> <li>• loss of animal production, including Barber's pole worm infestation.</li> </ul>  <p><b>Figure 2.35</b> A Barber's pole worm</p>
<p><b>Insects</b></p> <p><b>Arthropods</b> including flies, ant and butterflies, with bodies divided into three main sections: head, abdomen and thorax. The thorax usually has three pairs of legs and may also have wings attached.</p> <p>Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• animal protein source</li> <li>• pollination</li> <li>• pest control.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• plant damage including fruit fly infestations</li> <li>• carriers of diseases that infect livestock, including blowflies, which cause flystrike in sheep.</li> </ul>  <p><b>Figure 2.36</b> An ant</p>	<p><b>Arachnids</b></p> <p>Arthropods including ticks, mites, spiders and scorpions, with bodies divided into two sections: the cephalothorax and abdomen. They have four pairs of legs and no antennae.</p> <p>Beneficial uses include:</p> <ul style="list-style-type: none"> <li>• biological pest control.</li> </ul> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• plant damage including red-legged earth mite infestations</li> <li>• external parasites on livestock, including cattle tick and red mites on poultry.</li> </ul>  <p><b>Figure 2.37</b> Cattle tick</p>	<p><b>Platyhelminths</b></p> <p>Characterised by flattened bodies with definite reproductive and excretory organ, but no distinct circulatory or respiratory organs. Two significant platyhelminths include flukes and tapeworms, both endoparasites (i.e internal parasites).</p> <p>Non-beneficial effects include:</p> <ul style="list-style-type: none"> <li>• internal parasites in livestock, including liver flukes.</li> </ul>  <p><b>Figure 2.38</b> Liver flukes</p>



Worksheets

Explore different invertebrates on your school farm with the worksheet on NelsonNet.



Worksheets

Complete the *Microorganisms* and *invertebrates* wordsearch on NelsonNet.

**arthropod** (jointed legs) the largest grouping of organisms in the animal kingdom, includes insects and arachnids

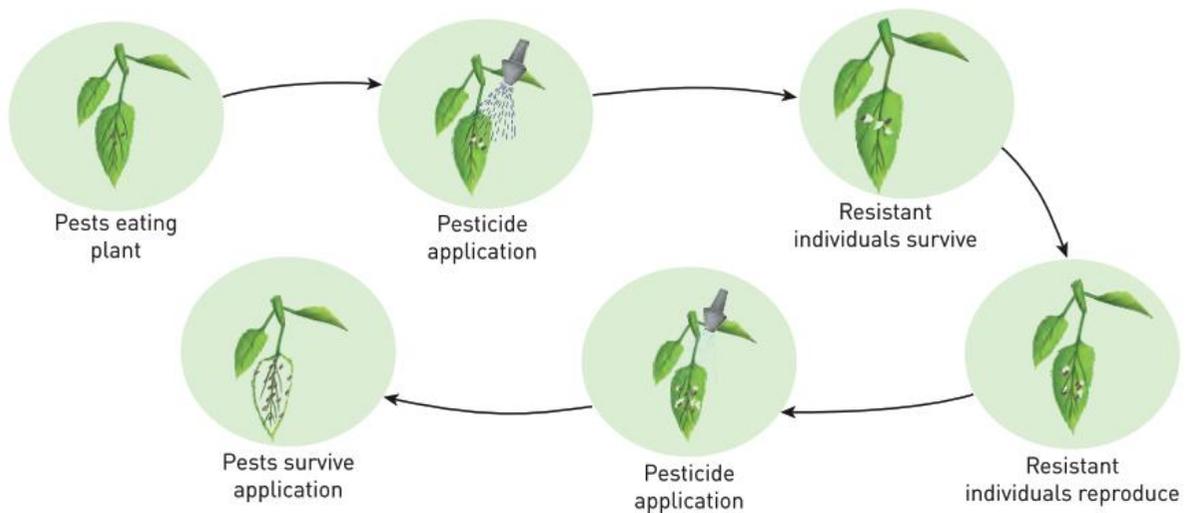
## Pests

A pest refers to a harmful invertebrate or other animal that affects plants or animals, rendering them unsuitable for harvest or reducing growth and production. Examples of pests in different enterprises are:

- vegetable production – snails, potato tuber moth
- orchard production – tephritid fruit flies, apple maggot
- cropping – red-legged earth mite, locusts
- sheep production – Barber's pole worm, *Lucilia cuprina* or primary green blowfly
- cattle production – cattle tick, flukes
- poultry production – coccidiosis and red mites.

## Integrated pest management

Integrated pest management (IPM) is an environmentally sensitive form of pest or disease control. It is widely accepted as a method of dealing with and preventing further chemical resistance in pest species and diseases, and involves using two or more compatible control methods with the aim of preventing problems from occurring, while reducing the need for chemical application. It relies on controlling pests or diseases only when they are causing a financial loss to the farmer. IPM practices rely on forward planning and regular monitoring of pest populations and disease prevalence.



**Figure 2.39** How chemical resistance occurs

### DID YOU KNOW?

More than 500 species of insects, spiders and mites worldwide have developed some form of pesticide resistance. *Bacillus thuringiensis* (Bt) is a naturally occurring bacterium in the soil that produces insect-killing proteins. Developments in biotechnology have created insect-resistant crops such as cotton and corn by inserting genes for Bt proteins created by these bacteria. When targeted insects consume plants with these proteins, they die.

**Table 2.7** Methods of control used in IPM and examples

Method of control	Definition	Examples
Physical	Prevention of pests from entering the agricultural environment through physical barriers and traps	<ul style="list-style-type: none"> <li>• Use of traps, including sticky and pheromone traps</li> <li>• Mulching and trenches</li> </ul>
Cultural/managerial	Managing the environment to discourage pest establishment	<ul style="list-style-type: none"> <li>• Crop rotation</li> <li>• Cultivation techniques</li> <li>• Controlling worm infestation through controlled grazing</li> </ul>
Genetic	Use of specific breeds or cultivars that have either natural resistance to pests/diseases, or have been genetically modified to have this resistance	<ul style="list-style-type: none"> <li>• Use of genetically modified crop species such as Bt cotton</li> <li>• Use of <i>Bos indicus</i> cattle in tick-prone areas</li> </ul>
Biological	Use of predatory or parasitic insects and mites (beneficials) to help control pests that affect quality and productivity of the product	<ul style="list-style-type: none"> <li>• Release of sterile male fruit fly in orchards and vegetable crops</li> <li>• Release of parasitic wasps to control aphids</li> </ul>
Chemical	Used when other forms of control have not been successful enough to protect the product	<ul style="list-style-type: none"> <li>• Selective insecticides, herbicides and pesticides are chosen to target the pest, leaving the 'beneficials' unharmed</li> </ul>
Exclusion/regulatory	Isolation or quarantine of new or infected stock to prevent pests/diseases from coming into contact with the product	<ul style="list-style-type: none"> <li>• Quarantining new livestock in secluded yards until any signs of disease can be ruled out</li> </ul>

## Infectious disease

Infectious diseases are disorders that can be passed from one organism to another and can be caused by bacteria, viruses, fungi or parasites. Microbes causing disease are called **pathogens**. Some infectious diseases can be passed from organism to organism through contact with bodily fluids such as saliva, while others are transmitted by bites from insects or animals. Ingesting contaminated food or water, or being exposed to organisms in the environment can also cause infectious disease. Examples of infectious diseases in different enterprises include:

- orchard production – black spot, apple scab
- cropping – yellow spot, cereal smut, cereal bunt
- sheep and goat production – blackleg, listeriosis, foot rot
- cattle production – Johne's disease, bovine respiratory disease, brucellosis
- poultry production – avian influenza, fowl pox, chicken anaemia virus infection
- aquaculture – white spot, infectious haematopoietic necrosis virus, mycobacteriosis.

**pathogen** a bacterium, virus or other microorganism that can cause disease

### AG IN FOCUS

#### FOOT-AND-MOUTH DISEASE

##### Identify

Foot-and-mouth disease (FMD) is a highly contagious disease in animals and causes considerable loss of production and profit.



## Understand

Currently, Australia is FMD-free and has been since 1872. There have, however, been recorded outbreaks in FMD-free countries causing large socio-economic impacts. In 2001, an outbreak occurred in the United Kingdom that cost an estimated \$AUD19 billion.

The Australian government maintains strong biosecurity programs at its borders to manage FMD risks. It undertakes extensive planning and preparedness strategies to ensure that, should FMD occur on Australian soil, the disease could be contained and controlled as quickly as possible. Australia has a nationally agreed prevention and response plan for animal emergency diseases, including:

- strict vaccination plans
- diagnostic tools and farmer-led surveillance systems for early detection
- decision support tools for decision makers during outbreaks
- controlled movement of livestock and their products
- strict hygiene processes when working with livestock and their products
- slaughtering of infected animals.

## Discussion

- 1 Outline some of the impacts of FMD on agriculture and the economy.
- 2 Research the cause and symptoms of FMD.
- 3 Explain using diagrams how FMD is transmitted between individuals.
- 4 Research the process a farmer would be required to follow if they suspected their animals had FMD.

## Soil-borne diseases

All soils host a range of permeant soil-borne disease organisms; however, they are usually contained at an acceptable level. Plants will only show symptoms of disease when the balance between the environment, soil conditions and host is disrupted and the pathogen organism becomes dominant.

Examples of soil-borne diseases include:

- pre-emergence damping-off (such as fusarium), occurring when young seedlings decay in the soil before they emerge above the surface. Poorly drained soils, presence of undecayed organic matter and compacted soils all increase the chances of this condition occurring.
- root rot, caused by invading fungi in the internal root tissues. These fungi interfere with the supply of water and nutrients causing loss of vigour, leaf yellowing and drop and can cause sudden death.
- vascular wilt, caused by bacterial invasion of the plant's vascular system. It is characterised by the plant wilting and discolouration of the vascular system.

Farmers can overcome soil-borne diseases by improving plant conditions, creating a hostile environment for the disease and stimulating the growth of beneficial soil organisms. This can be done through crop rotation to reduce the length of time a suitable host is available as well as increasing manures and composts that are rich in nitrogen. Improving biosecurity measures in production areas of the farm can ensure new diseases are not introduced to the soil.

## Beneficial microbes and invertebrates

While many microorganisms and invertebrates cause disease and production loss, there are many beneficial organisms used in agriculture.

### Decomposers

Decomposers are organisms that break down dead and decaying organisms. They are an essential link within nutrient cycles in an ecosystem as they return nutrients to the soil for further use. There are many kinds of decomposers, including bacteria, worms, snails and fungi. They each recycle food in their own way. Fungi release chemicals to break down decaying matter, while earthworms digest rotting matter by eating it.

#### DID YOU KNOW?

Worms have five hearts and no lungs; they breathe through their skin as long as it stays moist.

### Rumen microbes

Ruminant animals such as cows and sheep do not have the enzymes required to digest the fibre they consume. Microorganisms including protozoa, bacteria and fungi all live inside the rumen and help to break down this fibre. The microbes work together to turn the food into energy, protein and some vitamins that the animals use for bodily maintenance, growth, lactation and reproduction.

#### DID YOU KNOW?

In just 1 mL of rumen fluid there are approximately 1 billion bacteria, 10 million protozoa and 10 000 fungi.

### Microbes used in production

Microbes play an important role in production from value-adding to make cheese from milk or wine from grapes, through to biofuel production. Research into these microbes is helping to make production more efficient, solve environmental issues and create new products and processes.

The yeast *Saccharomyces cerevisiae* is used in biofuel production to ferment the sugars obtained from plant materials such as corn and turn it into ethanol. Current biofuel production methods are expensive and are surrounded by ethical issues. Researchers are exploring new possibilities of using microbes rather than plants to make biofuels.

Bacteria are added to warm milk to consume the lactose or sugars that help preserve the milk as cheese. A product called rennet is also added to help curds form so that the cheese can be pressed into moulds and stored to mature. During the maturing phase, the bacteria continue to work, using the sugars as a food source. The longer a cheese matures, the more flavour or stronger taste it has. Different bacteria cultures create different flavours.



Worksheets

Experiment with decomposers by creating and monitoring your own worm farm. You can use the liquid produced to fertilise your school agriculture plot.



Worksheets

Find out how algae can be used to create biofuel.



Video

Find out more about how microbes are used in cheese production.



## LET'S REVIEW

### LOOKING BACK

- 1 List five ways in which microorganisms interact with living systems, both positively and negatively.
- 2 Why are algae important in agricultural systems?
- 3 Outline two ways that bacteria can be beneficial in agriculture.
- 4 Outline how yeast is used in biofuel production.
- 5 Outline one beneficial and one negative effect that insects have on agricultural systems.
- 6 How are infectious diseases passed from one organism to another?
- 7 Explain what integrated pest management is and how it is used in farming.

### FOR YOU TO DO

- 1 Research the main invertebrate pests within a plant production enterprise located in your school or local area.
  - a Collect and preserve examples of these invertebrates at different stages of their life cycles.
  - b Label your collection with the common name, scientific name, stage of maturity and effect on plant production.
- 2 Moisten three slices of bread with tap water. Leave one piece exposed to the air at room temperature, one exposed to the air in the refrigerator and one exposed to the air in a science laboratory incubator, for four days to allow mould to grow. Examine the fungi using a hand lens or microscope.
  - a Use the risk assessment template found online for this exercise.
  - b Draw the microorganism, include labels showing the hyphae, mycelium and spores.
  - c Estimate the percentage of bread surface covered in fungi for each environment.
  - d Discuss how each environment encourages or inhibits growth of microorganisms.
  - e Evaluate why refrigeration is used as a method of food preservation.



Scaffold

Risk assessment  
template

### TAKING IT FURTHER

- 1 Identify an infectious disease that affects an important agricultural enterprise in your local area. Create a fact sheet about this disease, including the following:
  - a the industry affected
  - b name of the disease
  - c the organism responsible for the disease
  - d how the disease is spread
  - e signs of infection
  - f an explanation of current methods used to control the disease.
- 2 Create a labelled diagram of the lifecycle of an invertebrate that causes significant production losses in agriculture.
  - a Identify at what point in the life cycle the invertebrate can be targeted for control purposes.
  - b Outline the six practices used in IPM.
  - c For all areas identified in part a, propose methods (using the principles of IPM) that could be used at these stages and evaluate their effectiveness.
- 3 Research what 'zoonoses' are and explain why they can be a serious problem for agricultural workers.

# Let's summarise

## How do aspects of climate and weather influence agricultural production?

The natural environment plays a major role in agricultural production. It affects how a farmer uses and manipulates the land to create a sustainable and profitable enterprise. Weather, climate, soils and living organisms all influence agricultural ecosystems. How a farmer manages each one and the farming practices they employ to do so, in return, affect the natural environment.

Using your knowledge and understanding gained from this chapter, create a poster identifying key environmental factors that affect agriculture, and detailing how agriculture is affected.



Practice quiz

Complete the chapter review test on NelsonNet to review what you've learnt about managing the environment for agriculture.

## How do physical and chemical soil characteristics affect agricultural production?

Soil has lots of characteristics such as texture, moisture and pH levels. These characteristics influence the rate at which plants and animals can grow. For example, soil pH affects what nutrients can be taken up by a plant.

Create a mind-map diagram showing how physical and chemical soil characteristics affect agricultural production.

## How can I manage soils most effectively?

Land management practices can have good and bad effects on soils. In agriculture, we can often degrade the soil structure through land management practices such as overstocking, tillage and excessive pesticide use.

Using what you've learned in this chapter, copy the following table and describe how a land management practice would affect the soil.

Land management practice	Effect on soil
Minimum tillage	
Overstocking	
Pesticide use	



## CHAPTER 3

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# Farm resources and technology

## CHAPTER SUMMARY

Everyday management practices are an essential part of farm operations. Farmers sometimes need to supply extra nutrients to the soil by using fertilisers or use chemicals to control pests and weeds. They must ensure that when chemicals are used, they are applied in a safe manner to minimise any risk of harm. Farm machinery plays an important role in the daily operations of a farm. Tractors are used for many tasks, including ploughing, cultivating, planting and harvesting. While many farms rely on the use of traditional equipment, technology is available that assists farmers to closely monitor crops and livestock in remote areas, saving valuable time and resources.

**How can farmers use resources to help them manage their enterprise?**

**How can farmers improve their production with the help of technology?**

**How can farmers keep themselves, their family and their workers safe?**

## 3.1 Agricultural chemicals

### Uses of chemicals

Chemicals are a valuable resource for farmers to help them control and manage pests that affect their crops and livestock. For example, chemicals can be used to:

- eliminate weeds before sowing a crop
- control weeds that compete with a crop while it is growing
- prevent insects from attacking crops
- kill insects that are attacking crops
- control diseases that may affect a crop
- provide nutrients to plants when the soil is deficient
- eliminate internal and external parasites in livestock
- treat diseases in livestock
- prevent grains from insect damage and spoiling in storage.

Chemicals have often been viewed in a negative light but used correctly and efficiently, they can help farmers improve their farm's production. There are many types of chemicals,

but it is important to remember that there are chemicals all around us, some occurring naturally in the environment. Plants naturally produce chemicals that can deter insects from eating them. Caffeine, nicotine, pyrethrum and neem oil are all examples of chemicals produced by plants to help protect them from insect attack. Pyrethrum extracted from the pyrethrum daisy and neem oil from the neem tree have been extracted, refined and sold commercially as insecticides.

There are several options when it comes to chemicals, including natural and organic options. When selecting chemicals to use, it is imperative to think about every aspect of using the chemical and the impacts it may have.



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**Figure 3.1** Pyrethrum daisy, a natural source of insecticide extracted from flowers



Worksheets

Complete the *Uses of chemicals* worksheet on NelsonNet to make sure you know when and how to use chemicals on the school farm.



### LET'S DISCUSS

- 1 Why is it important for farmers to think about the following factors:
  - *situation* – to what size area will the chemical be applied?
  - *cost* – does the cost of applying the chemical outweigh the increased production?
  - *ease of application* – do you have the right equipment for the area to be treated?
  - *toxicity* – how harmful is the chemical to humans and the environment?
  - *biodegradability* – how long will the chemical take to break down in the environment?

## Pesticides

Pesticides are a broad term for a group of chemicals that kill pests; that is, organisms that harm or interfere with crop and livestock production.

Insecticides are specifically targeted towards insects. They can be applied in two different ways:

- *contact insecticides* are applied to kill insects or insect larvae already on the crop. Once the insecticide comes into contact with the insect, it is either absorbed through the insect's skin, called a cuticle, or it is ingested by the insect.
- *systemic insecticides* are absorbed by the plant and distributed to all parts of the plant. The chemical affects the insects or larvae that consume the plant.

Other forms of pesticides used on farms are chemical baits that are used to control rats, mice and foxes. Extreme care should be taken when using any baits because they are toxic to humans and easily consumed by domestic cats and dogs. These types of baits are generally held in specialised containers or buried so that only the target organism can access them.



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**Figure 3.2** A rat bait station protects native wildlife and domestic animals from accessing poisoned baits contained within it.

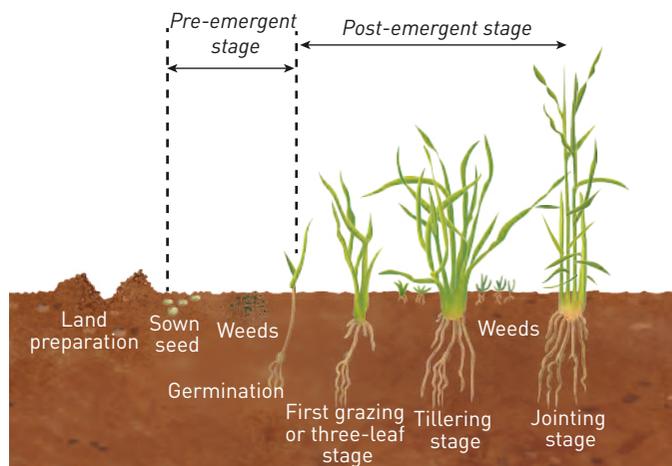
## Herbicides

Herbicides are a class of chemicals that are specifically designed to kill plants. Weeds are plants that grow where they are not wanted and compete with crops for water, sunlight and nutrients. Herbicides can be used to:

- clear weeds or remnants of a previous crop in preparation for sowing a new crop
- eradicate weeds within crops and between crop rows
- destroy weeds that are toxic to livestock in a pasture
- clear weeds that interfere with fence lines.

Herbicides act on a plant by interfering with its growth and development. They can be applied to the soil before a crop is sown (pre-emergent herbicide) or after the crop has started to grow (post-emergent herbicide). Some herbicides attack specific plants and are called selective herbicides, while others will kill all types of plants (non-selective herbicides). Selective herbicides are commonly used to eliminate broadleaf weeds, such as clover in lawns. Some commercially grown crops have been bred to be resistant to non-selective herbicides.

An example of this is Roundup Ready crops, developed by the Monsanto company, that are resistant to the non-selective herbicide glyphosate. Roundup Ready soybean and canola are examples of crops grown to withstand spraying with a non-selective herbicide. This means a farmer can plant these crops and spray them to eradicate all the weeds that could potentially compete with the crop.



**Figure 3.3** Pre- and post-emergent herbicide spraying



## LET'S DISCUSS

- 1 What are the implications for surrounding farms if a farmer grows a Roundup Ready crop?
- 2 Will the use of Roundup Ready crops increase or decrease herbicide use in plant production?

## Bactericides and fungicides

Bactericides and fungicides are chemicals used in both plant and animal production to control disease. Depending on where the plant is affected by a bacterial disease, the bactericide can be applied as a spray directly to the plant or drenched into the soil. Fungicides such as copper sulphate have been widely used to control a variety of diseases on fruit trees, grape vines and ornamental plants. **Antibiotics** are chemicals that are often used to treat livestock injuries and disease. They can be applied as sprays or creams on wounds, or given orally to control infections.

**antibiotics** chemicals that kill certain microorganisms, mainly bacteria



## LET'S ENGAGE

### CALIBRATING SPRAY EQUIPMENT

#### PURPOSE

To calibrate spray equipment with water. Most chemicals used on farms must be mixed with water before application. It is important to ensure the correct amount of chemical is mixed for a specific task. This ensures there is no wastage and no unnecessary mixing.

#### RISK ASSESSMENT



Never use chemicals to calibrate equipment, only water. Ensure the sprayer contains no chemical residue before use.

#### MATERIALS

- Pegs to mark out an area
- Handheld or knapsack sprayer
- Water
- Pen and paper for calculations
- Measuring jug of same capacity as sprayer

#### METHOD

- 1 Measure out a designated spraying area of 10 m<sup>2</sup> (10 m x 1 m), preferably on concrete or a surface where the water is easily visible.
- 2 Fill the sprayer with water to its measured capacity.



Alamy Stock Photo/Nigel Cattlin

**Figure 3.4** Knapsack sprayer used for spot-spraying weeds

- 3 At a moderate walking pace, spray the marked area and time how long it takes to cover the area with spray, making sure that the area is evenly covered. Record the time.
- 4 Spray into the measuring jug for the amount of time recorded. The volume of water is the amount of chemical mixture required for a 10 m<sup>2</sup> area.

#### DISCUSSION

- 1 Explain why it is important to ensure that the correct amount of chemical is applied.
- 2 Describe two problems associated with applying too much or too little of the chemical.

## Chemical resistance

Resistance to a chemical in a population of organisms can build over time, making the chemical less effective until it is completely useless against the target pest or weed. In every population there will be individuals that are resistant to that chemical. When the chemical is used repeatedly, those resistant individuals will survive, breed and increase in numbers in each successive generation.

There are several ways to reduce chemical resistance. A chemical should not be used repeatedly each season. A different type of chemical or a chemical with a different **active ingredient** should be used in rotation. Another method of reducing chemical resistance would be to incorporate IPM. It is a strategy that employs a range of methods to control pests and disease. You can learn more about IPM in Chapter 2.

### active ingredient

the specific ingredient or substance that causes the desired outcome of using the chemical



Worksheets

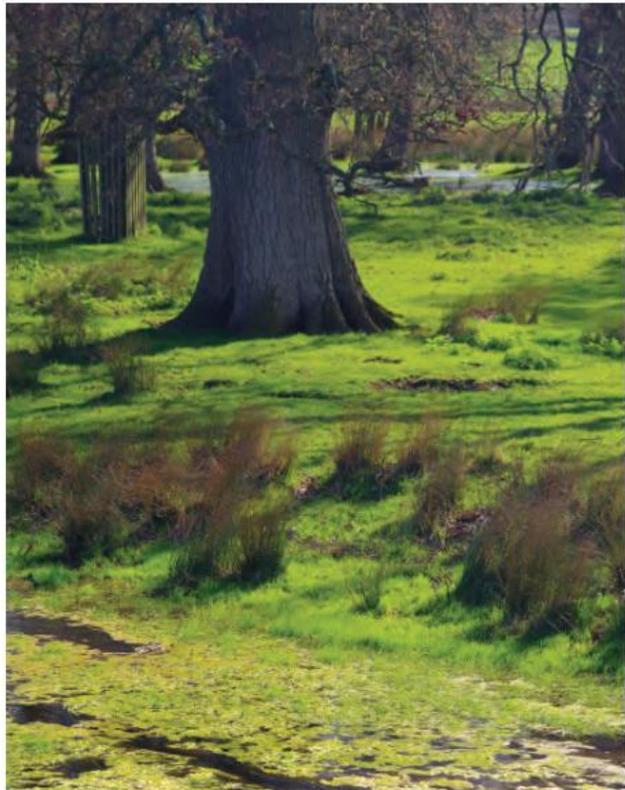
Find out more about IPM by completing the *Integrated rabbit management case study* on NelsonNet.

## Fertilisers

Fertilisers are used by farmers to provide additional nutrients to the soil. The most widely used are nitrogen and phosphorus. Urea is the most common form of nitrogen used in agriculture, and superphosphate is the most common form of phosphorus. These fertilisers assist to maximise plant production, but when used excessively can have detrimental effects on the surrounding environment. When too much nitrogen is applied it is easily leached from the soil. This can result in **soil acidification**, which prevents future plant growth. Excessive use of phosphorus-based fertilisers in the soil can create fertiliser run-off, which can cause **eutrophication** in waterways, resulting in algal blooms.

**soil acidification** a process whereby the soil pH decreases and becomes increasingly acidic

**eutrophication** when there is an excessive amount of nutrients in a body of water, it can result in extreme algal growth, called an algal bloom



Alamy Stock Photo/Jack Barr

**Figure 3.5** Phosphorus-based fertiliser run-off can cause algal blooms in dams.

### AG IN FOCUS

#### HOW MUCH IS TOO MUCH?

##### Identify

When too much fertiliser is added to the soil, any excess amount is easily leached because only a specific amount can be retained for use by plants. When this happens, fertilisers (nitrogen and phosphorus in particular) run off into waterways such as dams, rivers and streams.



Weblink

Approaches to monitoring, control and management of harmful algal blooms



## Understand

Waterways with too many nutrients can encourage the rapid growth of algae, called an algal bloom. Algal blooms cover the surface of water, limiting the amount of light available, and can rapidly decrease water quality. Fish and other aquatic life can be negatively affected as a result. Blue-green algae are types of cyanobacteria that are toxic to humans and livestock, causing skin irritation and poisoning if ingested. This is a big problem for farmers, where dams may be the only supply of water for a farm.

## Discussion

- 1 What are the impacts of an algal bloom on a farm that relies on dam water to feed their livestock?
- 2 Are there any alternatives to traditional fertiliser application that could reduce the occurrence of algal blooms?
- 3 Algal blooms occur more in times of drought. Using the weblinks provided on NelsonNet, research why this is the case, and prepare a report outlining management practices a farmer could use to limit this situation.
- 4 How can the quality of dams and waterways be monitored to guard against algal blooms?



Weblink

How blue-green algae blooms are handled



Weblink

Blue-green algae and Commonwealth Environmental Water



Weblink

Monitoring farm run-off

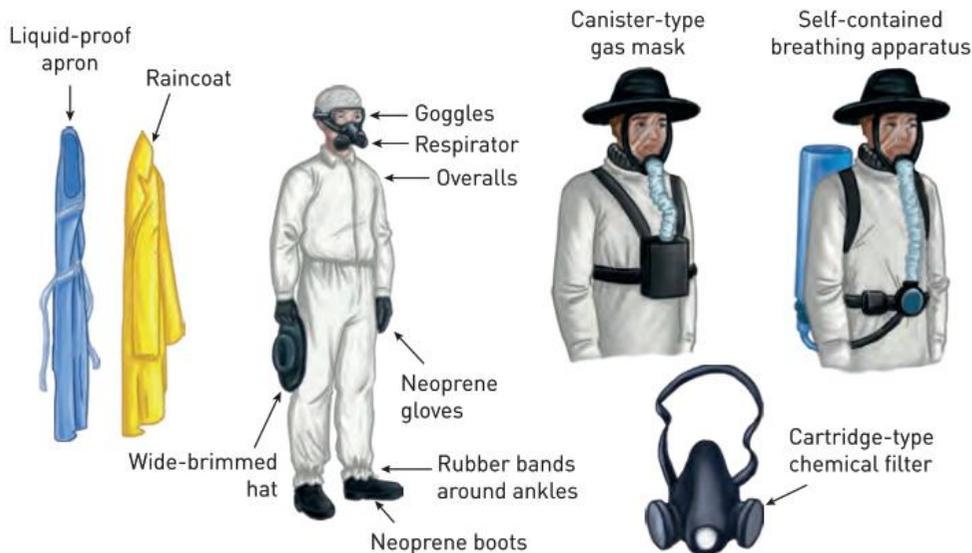
## Chemical safety

When applying chemicals, it is important to make sure the chemical is used according to the manufacturer's directions. All chemicals must come with a safety data sheet (SDS). This provides valuable information regarding the chemical's ingredients; how to safely use, store and dispose of the chemical; and medical and emergency procedures should poisoning occur. It is also important to wear the appropriate personal protective equipment (PPE) to ensure that there is minimal contact with the chemical. These details are also found on the SDS.



Worksheets

Practise analysing safety data sheets by completing the NelsonNet worksheet.



**Figure 3.6** Personal protective equipment is required to be worn when applying chemicals.

## Environmental considerations

Farmers must determine which chemicals to use on their farm based on the situation, cost of the chemical and its potential toxicity (measured by the  $LD_{50}$ ). The  $LD_{50}$  is the median lethal dose – the amount of the material or chemical required to kill 50% of animals in a test situation. Another factor to consider is how long the chemical persists in the environment. Chemicals that take a long time to break down can build up in the environment and cause illness and disease in land-based and aquatic wildlife and may adversely affect humans as a result. It is therefore essential that chemicals are selected and used as instructed to ensure minimal effect on the environment.

## Storage and disposal of chemicals

More often than not, a larger amount of a chemical is purchased than can be used in one application. Storage and disposal details are contained in the SDS and should be followed. As a general rule, chemicals should always be stored in labelled sealed containers, away from light and out of reach of children. When chemicals are past their use-by date or can no longer be used, there are specialised programs to dispose of them. ChemClear and DrumMuster are programs that provide communities with safe disposal of agricultural chemicals.

**withholding period** the minimum period of time from when a chemical was applied to when an area can be accessed, or a plant or animal can be processed and/or consumed



### LET'S ENGAGE

## IMPORTANCE OF CHEMICAL LABELS

### PURPOSE

To investigate the importance of chemical labels. They provide important usage information about:

- application rate
- safety directions
- **withholding period.**

They also indicate the chemical's active constituent or ingredient and the amount contained in the chemical.

### METHOD

- 1 Read the example of a chemical label and answer the following:
  - a What are the active ingredients or constituents?
  - b What pest(s) does the chemical control?
  - c What PPE should be worn when mixing and applying this chemical?
  - d If a person accidentally splashed some of the chemical on their skin, what should they do?
  - e If the chemical is sprayed on a cabbage crop, how long must you wait until you can harvest the crop?

### DISCUSSION

- 1 Select an insecticide and herbicide that is currently used on your

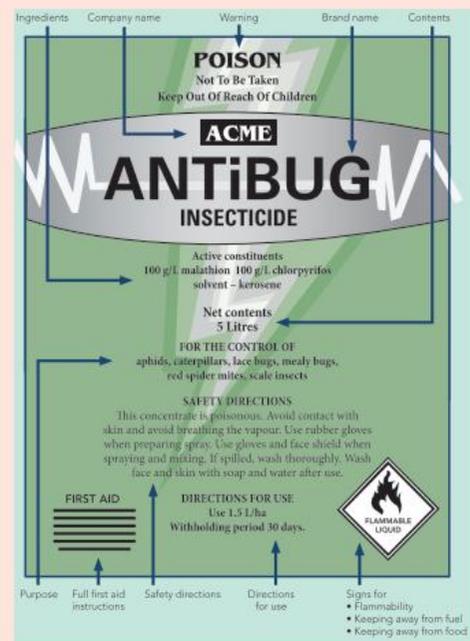


Figure 3.7 Chemical labels provide valuable information about usage.

school farm or vegetable plot. Using the label, find out its  $LD_{50}$  and withholding period. Evaluate the use of the chemical.

- Is the chemical the most appropriate for the situation?
- Are there any alternatives that could be used instead?



Weblink

DPI – Chemicals



Weblink

ChemClear



Weblink

DrumMuster



Worksheets

Chemical label





- What are the safety precautions that should be taken when applying the chemicals?
  - What is the first aid treatment if poisoning occurs?
  - Is the chemical stored appropriately after being used?
- 2 It is important for a farm to keep chemical application records. This includes an inventory of all chemicals used on a property and a copy of each chemical's SDS. For your school farm or vegetable plot:
- a Write down a list of 10 chemicals currently used.
  - b Download the SDS for each chemical. A copy of the SDS must be kept with the stored chemicals and at an additional location.
  - c Create a database that links the list of chemicals with their SDS.



The DrumMuster Program



Practise reading other chemical labels with the NelsonNet worksheet.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify three ways chemicals can be used on farms.
- 2 Explain the action of contact and systemic insecticides.
- 3 Explain how herbicide resistance could build up in an oat crop over time.

### FOR YOU TO DO

- 1 Identify any pests in your home, garden, school farm or vegetable plot. Which chemicals could be used to control those pests?
- 2 Describe a scenario in which a post-emergent and pre-emergent herbicide would be used.
- 3 A chemical label states that the person applying the chemical should avoid contact with skin and eyes. What PPE should be worn when applying the chemical?

### TAKING IT FURTHER

- 1 RoundUp Ready crops are designed to resist the effects of glyphosate, a non-selective herbicide. Discuss the implications of continually sowing a RoundUp Ready crop.
- 2 Describe any safety hazards that could potentially be present when spraying a lettuce crop for aphids.

## 3.2 Farm machinery

### Tractors

Tractors are vital to farm operations. Tractors have assisted farmers for many generations, and were used initially to replace livestock for heavy manual labour tasks. Tractors come in a range of sizes and power depending on the needs of the farmer. Because tractors are a significant investment for farmers, it is important that farmers select the most



**Figure 3.8** Tractors are used for a variety of different farm tasks.

appropriately sized and powered tractor for their farm. Tractors are used for a variety of farm tasks, including:

- spraying
- sowing
- cultivating
- planting
- harvesting
- moving heavy objects
- towing other machinery or equipment
- front-end loader work.

Depending on the farm size and budget, there are tractors that suit every operation. Like motor vehicles, tractors range from small and basic to large and luxurious. There are even options for farmers to lease tractors, which enables them to regularly upgrade their equipment to keep up-to-date with current technology.

**power take-off (PTO)**

a device that supplies power to operate a tractor implement

**three-point linkage**

a method of securely attaching a tractor implement via three points of contact

## Tractor implements

There are a variety of attachments or implements available for tractors to cover a multitude of uses. They range from mowers to cultivators, and are attached to the tractor via a **power take-off (PTO)** shaft or adaptor, and a **three-point linkage** system. The PTO shaft is the mechanism that provides power from the tractor to operate the implement. The three-point linkage system is activated by hydraulics to raise and lower the tractor implements as required.



**Figure 3.9** Power take-off and three-point linkage system used to attach tractor implements

## Tillage

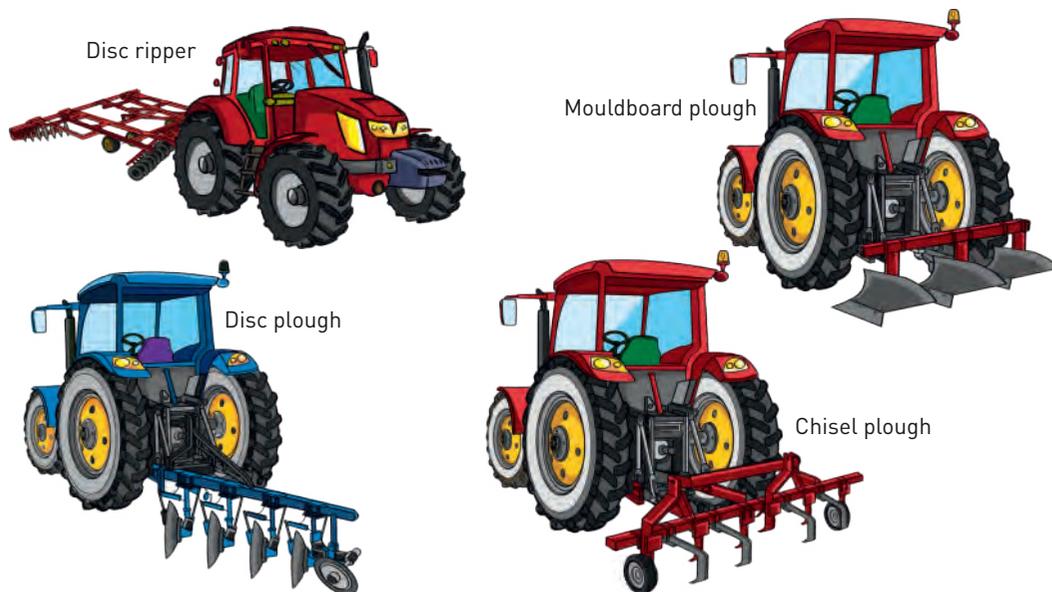
Cultivating, or tilling, the soil is generally completed before planting a new crop or following the harvest of a crop. Tillage implements are used to:

- assist with managing crop residues
- control weed growth
- break up compacted soil
- prepare seedbeds for sowing.

When selecting tillage implements, the soil type and quality must be considered because it can be quite damaging to the soil if tilling is undertaken on unsuitable soils. Tillage implements

work best on sandy and silty soils because the soil must have an appropriate level of moisture for tilling to be effective. Tillage implements use teeth, discs or shanks to cultivate the soil and the most common items used are:

- *mouldboard plough* – completely turns over the soil as it goes through. It can provide effective weed control because it buries weeds and weed seeds. It is the most destructive method of tillage for the soil and as such is a high erosion risk.
- *disc ripper* – breaks up compaction layer, and can manage crop residue by burying and mixing it
- *disc plough* – a row of discs flips most of the soil in a similar fashion to the mouldboard plough; the biggest benefit is that it is easier to pull because there is not as much drag on the tractor
- *chisel plough* – breaks up the soil to a medium depth. It provides good seedbed preparation and helps to level the soil profile. It does not completely turn over the soil like the mouldboard plough and disc plough so there is less risk of erosion.



**Figure 3.10** Tillage implements used to cultivate the soil

Modern tillage implements incorporate technology that enables depth settings to self-adjust, depending on the amount of crop residue, and can also adjust to suit the texture of the soil.

## Planting

Once the seedbeds are prepared, there are a variety of ways a farmer can plant their crop. As farmers move towards no-till and minimal cultivation practices to maintain the integrity of the soil, there are options available to plant seeds directly into the residue of the previous crop using a direct drill seeder. This method ensures minimal soil disruption and is particularly suited to drier areas to maintain moisture and where previous crop residue can minimise evaporation. Other options for seed-planting equipment are:

- *broadcast seeders* – use spinning discs or plates to distribute the seed from a hopper. Seed can be mixed with fertiliser and can easily cover large areas. This is a cost-effective option where accurate seed placement is not essential.
- *air seeders* – use air pumps to distribute the seed in a similar fashion to the broadcast seeder. Air seeders are generally used for smaller seeds.

Specialised planters are available for specific crops. Seedling planters can plant seedlings directly into the ground and are capable of planting thousands of seedlings per hour. Likewise, potato-planting machinery can also be used to plant garlic, onions and flower bulbs.

## Harvesting

There are specific harvesting implements and machinery available to the farmer depending on what crop is being produced. The most common are:

- *combine harvesters* – used specifically for grain crops, they harvest, separate the seeds from the seed heads and clean the grains
- *threshers* – used to separate grains from stalks and seed heads
- *augers and conveyors* – used to fill silos for storage of grain.

There are also highly specialised harvesters for specific crops, such as sugarcane, corn and cotton. These machines can also partially process the crop by stripping outer leaves and stems. Equipment for vegetable harvesting may contain conveyors to assist pickers on the ground, while fruit-harvesting equipment generally consists of shakers or pulsators (which encourage the fruit to drop), and sweepers that collect the fallen fruit.



Alamy Stock Photo/Edwin Remsberg

**Figure 3.11** A specialised corn harvester

## Hay and silage

For livestock enterprises, it is advantageous for a farmer to utilise their pasture for hay and silage. When producing hay, pasture is cut and left to dry until it has a moisture content of about 25% before it is baled. For silage, the pasture is baled with a much higher moisture content and wrapped in plastic to allow anaerobic fermentation. There are many implements that can assist farmers with this including:

- *hay and silage balers* – these come in many shapes and sizes, from rectangular to cylindrical. The small rectangular baler is generally the most popular because it is easy to handle and store the hay.
- *slashes and rakes* – these slash the pasture first, then rake the pasture into rows to dry out prior to baling
- *loaders* – front-end loader or buckets to move large volumes of soil and mulch; pallet fork that can act as a forklift for lifting and moving large haybales and silage.



Worksheets

Review your knowledge about tractor implements by completing the NelsonNet worksheet.



Shutterstock.com/B Brown

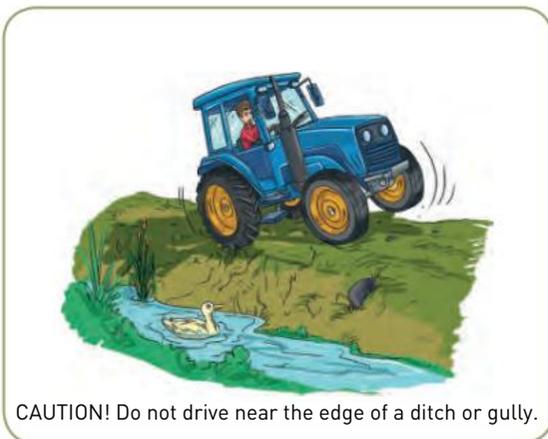
**Figure 3.12** Windrowing hay for baling

## Tractor safety

All tractors must be fitted with specific features to ensure safety of the driver. These include:

- seatbelt
- roll-over protection structure (ROPS), which is a structure that protects the driver in case the tractor flips or rolls over
- power take-off cover or shield that ensures the auger blade is securely covered.

When operating a tractor, it is important to follow specific safety procedures.





**Figure 3.13** Tractor safety rules

### Tractor maintenance and servicing

Pre-operational checks of the tractor must always be carried out before use to ensure that all the tractor mechanisms are functioning correctly. The following points should be checked to ensure they are all functioning correctly and are not damaged in any way:

- all controls and indicators
- all tractor guards
- seatbelt, ROPS, PTO
- three-point linkage hydraulic system
- oil filters and air filters
- all fuel, lubricants and coolant levels.

To maintain the life and the function of the tractor, it is important that it is serviced regularly according to the manufacturer's instructions and vehicle service log.



## LET'S REVIEW

### LOOKING BACK

- 1 What do ROPS and PTO stand for?
- 2 Which tractor implement would be the most appropriate for sowing small seeds?
- 3 Which tillage implements are suitable for sandy and silty soil?
- 4 Outline the basic tractor safety rules.

### FOR YOU TO DO

- 1 Explain how a combine harvester operates.
- 2 Research three specific fruit and vegetable harvesters used in commercial enterprises and identify which harvester is used for specific crops.
- 3 Conduct a class debate on the benefits and detriments of using tillage machinery, considering the short- and long-term effects on sustainability.

### TAKE IT FURTHER

- 1 Research and identify smaller types of commonly used farm machinery.
- 2 Outline the type of tractor implements a farmer would use on an enterprise that:
  - grows oats for silage and wheat for export
  - grazes sheep for meat and wool
  - has a small orchard.

## 3.3 Farm technology

A great deal of current research and development is devoted to farm technology. With a dwindling labour force and more demands placed on farmers, technology allows them to increase the efficiency and the quality of their production systems. Farming requires constant monitoring and gathering of information to ensure that farmers can make appropriate decisions regarding operations. Sensor technology allows information to be collected from a variety of sources including satellites and aircraft for remote sensing, and personal sensors and smart cameras for close monitoring of crops and livestock. The use of this type of technology is known as precision agriculture and provides farmers with a means to more accurately control their crop and livestock production.

### Remote sensing

Remote sensors gather information from either satellite or aircraft. The data received from these sensors can cover vast areas of land and water. Using satellites and sonar, areas can be mapped and images can be generated to create an accurate representation of an area that may otherwise be inaccessible.

#### AG IN FOCUS

#### FUTUREPROOFING WITH REMOTE SENSORS

##### Identify

Managing grazing areas to minimise environmental impact is the aim of holistic grazing, but its use is limited by time and labour constraints. Remote sensors can alleviate this problem.

##### Understand

Holistic farm management is a system that encourages farmers to replicate nature by creating a farm ecosystem with minimal inputs. It relies on looking at an individual farm as a whole unit with management strategies revolving around mimicking natural cycles to reduce environmental as well as financial inputs. This method is designed to preserve farm resources and increase sustainability as well as productivity.

A strategy currently employed by many farmers in New South Wales and Queensland is holistic grazing. This method relies on strategically grazing livestock in smaller areas for shorter periods resulting in a faster recovery time for pastures. It can increase the quality of pastures and help them recover, particularly in times of drought, resulting in long-term farm sustainability.

Employing this type of grazing can be extremely time-consuming because it relies on thorough planning and consistent close monitoring of the grazing areas, meaning a farmer must apply a more hands-on approach. However, remote sensing technology solves some of these problems by monitoring areas and gathering the data required. This is achieved through:

- satellite mapping used in the planning stages to map out soil type and detect any degradation issues or deficiencies
- optical sensors in satellites and drones that can detect pasture growth and development by measuring the wavelengths of light reflected from leaves
- thermal images taken by satellites and drones indicating areas of compaction or plant stress that may require a longer recovery time before being grazed again.

Farmers can use this information to plan their grazing strategy. Remote sensors can play an integral part in holistic farm management, resulting in environmental, social and financial benefits.

### Discussion

- 1 Holistic grazing is said to increase the carrying capacity of an area. What does the phrase 'carrying capacity' mean, and what are the implications for graziers?
- 2 Suggest two other ways that remote sensors can be used to increase the efficiency of holistic grazing.
- 3 Research another holistic farm management strategy. How can remote sensors promote farm sustainability in other farm enterprises or areas?

## Satellites

Satellite remote sensing has been used for many years for various applications. It can be used by farmers to:

- estimate soil moisture content, especially in times of drought
- monitor the effectiveness of irrigation on a property
- map soil to ensure the right crops are planted in the most appropriate soil type
- assess and estimate crop yields
- monitor and assess crop health
- estimate weather patterns to plan for ideal times for sowing and harvesting crops.

## Drones

Drones, or unmanned aerial vehicles (UAVs), are a popular choice for farmers to access remote sensing technology. They come in a range of sizes and can be fitted with cameras to enable a farmer to monitor crops and livestock without leaving the comfort of their home. Drone technology is particularly useful for smaller areas and is cheaper than satellite remote sensing. Drones can assist a farmer with a number of day-to-day farm duties, saving valuable time and labour, including:

- monitoring calving or lambing operations – drones can check to see whether there are birthing difficulties or the health of a newborn lamb or calf
- herding livestock – larger drones can be used to move small numbers of livestock around a property
- checking irrigation systems
- spraying crops for pests and disease
- mapping of specific areas.



**Figure 3.14** Drones can be used to monitor crop health and disease.

## INDUSTRY IN FOCUS

### DRONE PILOT – FLYING AN AIRCRAFT WITHOUT LEAVING THE GROUND

#### Identify

A drone pilot can be employed to fly drones to perform a variety of tasks. They must have good knowledge of how drones operate and can be required to conduct repairs or maintenance on the drones. A drone pilot gathers data to be analysed and processed, so must have good hand-eye coordination to ensure accurate data collection. Depending on the size of the drone and the area in which it is flown, a more thorough knowledge of aviation legislation and regulation may be required.

#### Discussion

- 1 What training is required to become a drone pilot?
- 2 What are some career pathways for a drone pilot?
- 3 Identify three to five key skills that would be valuable to have as a drone pilot.

## AG IN FOCUS

### CROPS THAT USE TECHNOLOGY

#### Identify

A farmer in South Australia has employed a range of sensor technologies to improve production while reducing costs and effect on the environment.

#### Understand

Mark Branson operates a mixed enterprise of approximately 80% livestock and 20% cropping. Since the late 1990s, Mark has been incorporating the use of digital technology in his farm management. Mark uses precision agriculture across all farm operations. It is targeted to find and solve specific problem areas, an approach that moves far beyond the traditional blanket approach to nutrition and weed management.

Mark first used a grain-harvester-mounted yield sensor connected to a GPS to map crop yields. The sensor established areas of crop variability and was initially used for targeted phosphorus fertiliser application so that only losses were replaced. Soon after, Mark started to use GreenSeeker technology whereby small strips of a crop were treated with high rates of nitrogen fertiliser. The GreenSeeker sensor determined the crop response by analysing the amount of healthy green vegetation present (measured by the Normalised Difference Vegetation Index). If the crop did not respond to the application then no additional nitrogen fertiliser was applied. However, if a difference was detected between the nitrogen-rich strip and the rest of the paddock, nitrogen fertiliser was applied and the difference in the values then determined the rate used. For smaller areas and cloudy days when satellite systems are not accessible, Mark uses a CropSpec scanner attached to his tractor that can provide on-the-go measurements across a whole paddock. Following this, the paddock can be fertilised at a variable rate according to the values taken from the sensor.

Drones are also used on the farm to detect weed patches in his crops. Drone sensors detect extra biomass in crops that indicate background weeds, enabling them to be dealt with early in the crop's growth. Mark has used drones to detect herbicide-resistant ryegrass that can be an issue at harvest. In the past the ryegrass would have contaminated the crop, resulting in the entire crop being cut for hay. Now he can patch out and cut areas for hay, leaving the rest of the crop intact. Mark also uses an auto-steering tractor that provides controlled machinery traffic over fixed drive lines. This style of tramline farming ensures compaction is limited because the same wheel tracks are covered every single time, year after year, leading to improvements in soil structure and yield gains over time.

Digital technologies, used efficiently, result in long-term sustainability with positive impacts on the environment and long-term financial savings for the farmer.

### Discussion

- 1 How can digital technologies assist farmers with daily management practices?
- 2 With technology advancing so rapidly, analyse the short- and long-term benefits of an investment in a variety of digital technologies for a farm. Research the limitations of satellite technology vs drones vs tractor sensors to assist with your analysis.
- 3 Mark believes the selection of technology must depend on each individual farm situation. 'Different problems require different solutions.' Discuss this statement and explain why adopting technology for technology's sake may result in farmers turning away from digital technology.

## Personal livestock sensors

Can you imagine being present for the birth of every calf on your property? Or instantly knowing when one of your sheep is unwell in the herd? Personal livestock sensors allow farmers to closely monitor the health and welfare of their livestock. These can take the form of ear tags or collars that can collect data that can alert a farmer if there is an issue. Livestock sensors can be used to:

- track an animals' specific location – a farmer can be alerted if an animal has broken through a fence and wandered outside of the property
- monitor an animal's temperature and heart rate to indicate stress or illness
- monitor behaviour – a livestock sensor that detects when an animal has been lying down for an extended period or if the animal has not accessed food and water for a period, both of which can be early indicators of illness
- track reproductive cycles – sensors can be attached to the tail, alerting a farmer of an impending birth or when females are in heat.



**Figure 3.15** Farmers can use sensor technology to closely monitor their animals.

These types of sensors save a farmer valuable time and resources and can increase production and decrease livestock mortality.

## Decision-making technology

In conjunction with the vast array of sensors available to collect data on every aspect of farm production, a farmer must be able to access, understand, dissect, analyse and use this data. The right technology will enable a farmer to make informed decisions and manage all aspects of the business, including:

- orders and sales
- farm records including financial, chemical, livestock and crop yields
- chemical use and recording
- pest and disease control
- machinery maintenance and purchase
- automated feeding
- irrigation
- information regarding the health of the farm (pests, soil conditions, weather, dam levels).

Portable devices such as smartphones or tablets loaded with the right applications can be indispensable because they allow the farmer to access and record data, and undertake these functions whenever needed, wherever they are. Apps can analyse livestock data, provide weather forecasts, calculate feed rations and evaluate market trends.



### LET'S DISCUSS

- 1 How will apps on smart devices help farmers work smarter not harder?

## Robotic technology

Since the Industrial Revolution, machinery has replaced the work of humans and livestock in agriculture, making manual tasks easier and able to be completed more efficiently. Robotic technology is automated machinery that has programmed actions. This technology has been developed for agriculture and is particularly suited to repetitive tasks such as:

- *milking* – robotic milking systems allow cows to be milked multiple times a day, at any time without the need for human involvement
- *harvesting and picking* – robots are programmed to carefully harvest fruits that are easily bruised or damaged, and can be programmed to only select fruit at optimum ripeness for specific markets
- *automated garden systems* – the robots scan the garden bed, water and fertilise the plants, remove weeds, and detect and spray pests as required
- *driverless tractors* – self-driving tractors that follow a pre-mapped course
- *power-assist suits* – specialised suits that can be worn by workers and used to provide additional strength and support when lifting objects or completing repetitive manual tasks in areas difficult for robots to travel, such as on uneven ground.

Agricultural robots mean less labour costs and can achieve consistent results compared to humans. Robots can access areas that are deemed difficult or unsafe for a person to access and have the potential to minimise environmental disturbance where other practices in the past have been quite destructive.



Shutterstock.com/Suwin

**Figure 3.16** Fruit-picking robots select fruit that is ready for harvesting.



## LET'S DISCUSS

- 1 Will robots ever completely replace humans in the agricultural workplace?



## LET'S REVIEW

### LOOKING BACK

- 1 What does UAV stand for?
- 2 Identify three ways in which drones can be used in the management of a farm.
- 3 Describe three different types of robotic technology available to farmers.

### FOR YOU TO DO

- 1 How might a farmer use information from a personal livestock sensor in the form of a collar that monitored the movement of a sheep?
- 2 Explain how robots can improve farm sustainability.
- 3 Select an enterprise at your school. Research an app that could assist in the management of the farm in some way. For example, an app that will provide a record of planting and harvesting times and generate notifications when weather patterns may affect crops. Prepare a report that justifies your school's use of this app and explain how it would increase production.

### TAKING IT FURTHER

- 1 Evaluate the use of remote sensing technology on either a crop or livestock enterprise.
- 2 The use of technology saves a great deal of labour for a farmer. What are the implications of this on the wider farming community?
- 3 Research the aviation regulations when it comes to flying drones on a property. Explain the limitations posed by these regulations for a farmer wishing to use a drone.

## 3.4 Health and safety

Farms are one of the most dangerous workplaces and agriculture accounts for some of the highest rates of fatalities and injuries of any industry. The greatest risks for injury on a farm are from:

- machinery and equipment – tractors, quad bikes and chainsaws
- chemicals – pesticides, fertilisers and household chemicals
- water storage – dams and tanks
- grain storage facilities – silos
- livestock – injuries from being crushed or trampled
- manual handling – lifting and moving heavy objects
- extreme weather conditions.

### DID YOU KNOW?

Did you know that 10% of all serious farm injuries reported are from being hit by an animal?

It is important that everyone living on, working at or visiting a farm is aware of the risks to health and personal safety so that accident and injury can be prevented.



### LET'S DISCUSS

- 1 What are the impacts of farm injuries on the wider community?

## Managing hazards

On any farm, risks to safety must be identified and controlled to ensure a safe working environment for everyone involved. It is important that anyone who works on a farm is trained appropriately before undertaking a task such as working with cattle, driving a tractor or spraying weeds. For more complex tasks, a **Safe Operating Procedure (SOP)** provides step-by-step instructions on how to safely perform an activity. Effectively managing hazards can be achieved through the following process:

- 1 Identify the hazard.
- 2 Assess any risks the hazards pose.
- 3 Suggest ways to manage the risk.

It is important that this process is regularly reviewed and updated whenever any aspect of the activity is altered.



Worksheets

Conduct a farm safety assessment of your school farm using the NelsonNet worksheet.



Weblink

Farm Safety Facts

**Safe Operating Procedure (SOP)** a document that provides step-by-step instructions on how to safely complete an activity



Video

Assessing Stockyard Risks



Weblink

Safework Australia



LET'S ENGAGE

## WHAT'S THE RISK?

### CREATING A RISK ASSESSMENT FOR HAZARDS ON THE FARM

#### METHOD

- 1 Select an activity that you may perform on a farm, such as digging a trench.
- 2 Draw up a table with the headings 'Hazard', 'Risks' and 'Management'.
- 3 Identify any hazards encountered when performing the activity, such as a mattock or similar tool.
- 4 List any risks the hazard may pose. Using the example of a mattock, a risk of injury could be cuts, bruises or foot injuries.
- 5 Think of ways the risk can be managed, for example:
  - ensure there is no-one in close proximity when using the mattock
  - wear leather gloves and sturdy boots.
- 6 Remember, if the activity changes in any way, a new risk assessment should be created.

## Personal protective equipment

The final option for managing a hazard, after all risks are assessed, should be the use of PPE. It is essential for many day-to-day farm activities and can protect the wearer from a number of farm hazards. The most common items of PPE are:

- hat for sun protection
- safety goggles and/or respirator to protect the wearer from chemical contact with eyes and face
- overalls to protect the body from chemicals and from dirt contacting the skin
- safety boots to protect feet from heavy objects falling or livestock treading on feet
- gloves to protect hands from chemicals, heat and sharp objects
- hearing protection devices such as earmuffs and earplugs to protect hearing from loud machinery or equipment.



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Weblink

Personal Protective Equipment (PPE)



Worksheets

Make sure you know when to use PPE by completing the NelsonNet worksheet.

**Figure 3.17** Personal protective equipment symbols



## LET'S REVIEW

### LOOKING BACK

- 1 Identify three to five risks that are found on a farm and place them in order from most to least dangerous.
- 2 What do SOP and PPE stand for?

### FOR YOU TO DO

- 1 Describe the process involved in managing risks on a farm.
- 2 A farmer wishes to drench a mob of sheep after herding them into livestock yards. What PPE must the farmer wear when completing this activity?
- 3 Explain why it is important that appropriate training should be provided for a person undertaking a potentially dangerous farm activity for the first time.

### TAKE IT FURTHER

- 1 Write an SOP for one of the following activities:
    - driving a tractor
    - vaccinating cattle
    - spraying a vegetable crop for aphids.
  - 2 Conduct a farm safety review of your school farm. Identify three to five hazards and suggest ways to manage them.
  - 3 Describe any preventative actions that can be taken to ensure that farms are safe for everyone.
-

# Let's summarise



Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about farm resources and technology.

## How can farmers use resources to help them manage their enterprise?

Agricultural chemicals are effective resources used by farmers to prevent and control pests and diseases in their crops and livestock. Copy and complete the table below to explain how chemical resources can help farmers best manage their enterprises.

Resource	Use	Benefits of use	Detriments of use
Herbicides			
	To kill organisms that harm or interfere with crop or livestock production		
Antibiotics			
Fertilisers			
Resistant crop			

## How can farmers improve their production with the help of technology?

Farm machinery plays an important role in the operations of a farm. Tractors perform a multitude of duties from sowing and planting to lifting and loading. Meanwhile technology such as sensors and smart devices can monitor and control aspects of farm operations from any location. Create a mind map describing how each technology can be used to improve production of an enterprise.

Mouldboard plough	Chisel plough	Self-drive tractors	Drones	Reproductive sensors
Satellites	Automated garden system	Combine harvester	Broadcast seeder	Slashers and rakes

## How can farmers keep themselves, their family and their workers safe?

Farming is a high-risk industry. There are many hazards that can cause injury or illness and it is important these hazards are identified and managed to reduce this risk. Using a Venn diagram, identify the safety measures required when using chemicals and machinery for plant and animal enterprises.



# Agricultural business

## CHAPTER SUMMARY

An agricultural enterprise must be managed as a business, making profit for the farm owner. Farm businesses can be affected by many market factors such as imports and exports, climate events and consumer preferences. Farmers have different marketing opportunities and use various forms of advertising to sell their goods. A farmer must know how to sell and market their product in order to make profit. They must also know how to manage finances, costs and schedules to make their businesses as profitable as possible.

**How does multiculturalism influence Australian agricultural production?**

**How can Australian farmers market their products?**

## 4.1 Introduction

The Australian agriculture industry plays a significant role in our society by providing the food and fibre that we need in our daily lives. Agriculture connects both urban and rural communities, as well as numerous businesses across the supply chain: farms, manufacturers, transport companies, technology companies, marketers, shops and finally the consumer at the end of the chain. Many businesses rely on agriculture as much as agriculture relies on them.

Australian farmers produce 93% of our daily domestic food needs – with estimates that one Australian farmer feeds 600 people, 150 domestically and 450 overseas. Agriculture is extremely important for the Australian economy, with 2019–20 forecasts predicting a value of \$59 billion. In 2017, the agriculture industry directly employed 217 000 permanent workers and 87 200 casual workers, increasing to 1.6 million over the whole supply chain, approximately 13% of the Australian workforce at the time.

## 4.2 Agriculture and the economy

### Australian farms

Currently there are 394 million hectares of agricultural land in Australia, supporting approximately 85 000 farm businesses. Forty-eight per cent of Australia's landmass is used for agriculture. These farming businesses include grazing land, cropping, horticulture, and intensive plant or animal production.

Australian farms come in all shapes and sizes ranging from large, extensive cattle grazing in the north of the country, to smaller, intensive poultry sheds in the south near urban areas. The majority of farms in Australia are considered small farms. Only 10% of farms are considered large, making more than \$1 million in one year.

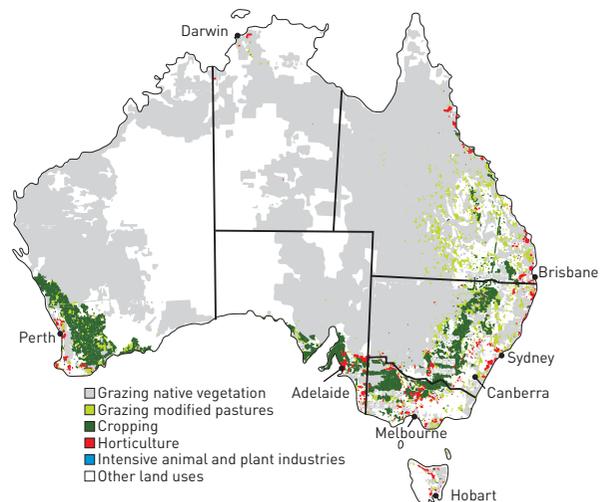


Figure 4.1 Agricultural land use in Australia

Table 4.1 Breakdown of Australian farms

Size of farm	Number in Australia	Annual sales	Capital value	Percentage of Australia's total farm income	Ownership
Small	70%	< AUD\$450 000	< AUD\$5 million	24%	Mostly family-owned
Medium	20%	AUD\$450 000–\$1 million	AUD\$5–9 million	27%	Mostly family-owned
Large	10%	> AUD\$1 million	> AUD\$9 million	49%	Complex ownership and operating arrangements



## LET'S DISCUSS

- 1 What kind of enterprises would be considered small farms?
- 2 What kind of enterprises would be considered large farms?
- 3 Where would each of these types of farms be located, and why?
- 4 The average farm size is increasing but over the same time, the number of farms has declined. Why do you think this is?

## Farm ownership

Australian farms are mostly owned by Australians. Some other countries, such as the United States, China, United Kingdom and the Netherlands, own farmland in Australia, but only very small percentages.

### Sole traders/individual businesses

These are farms that are owned and operated by families or individuals. The farm is owned and the management activities are organised by the same people, often family members. About one-third of all farms in Australia are individual businesses.

## AG IN FOCUS

### FAMILY FARM

#### Identify

Bellview Farm is a third-generation family farm, now owned by the Johns family. The 600-acre farm was purchased in 1939 and has grown to 1500 acres.

#### Understand

Edward Johns implemented a suitable succession plan to pass the farm on to future generations. Succession planning is a complex part of running a family farm. To ensure the farm continues to operate profitably, the retiring farm owner must choose who to pass the farm to. Edward has two children. One child had worked on the farm alongside Edward for three years, while the other child was at university studying medicine. Edward needed to arrange a succession meeting with his children to discuss who the farm will pass to on his retirement. In this case, the child who had worked on the farm for three years was the obvious choice. Since the succession has been activated, the farm has increased in size and is now operating a fine wool merino and lamb feedlot operation. However, having seen the success of the farm, the second child is now annoyed at the succession decision and is questioning whether they can be more involved in the future.

#### Discussion

- 1 What are the benefits of running a family farm?
- 2 What are the detriments of running a family farm?
- 3 Listen to Fledging Farmer founder, Alana Black, talk about gender and succession in agriculture on the Triple J Hack podcast.
  - a What are the key tips Alana suggests for discussing succession?
  - b Discuss the impact of gender on succession.



Weblink

Alana Black

## Share/lease farms

Share, or lease, farms are those where one party works and operates the farm on land that is owned by a second party. Similar to housing rental agreements, the second party, the owner, leases the land for agriculture. Costs and income are shared between the two parties. Problems can arise when the arrangements are not professionally drafted and have inadequate measures in place to protect both parties.

### AG IN FOCUS

#### SHARE FARM

##### Identify

The owners of Collector Creek have retired and leased their land to a neighbour.

##### Understand

The owners decided to put their farm up for lease, so they could stay in the region and be part of the community without needing to work as much on the farm. Their neighbour owned a small farm and wanted to increase land size and farming enterprises. Leasing the land from the owners of Collector Creek allows the neighbour to increase their business without providing upfront capital. They would usually have to pay a large sum of money to buy a farm. The risks and gains of running a farm are shared between the two parties, with both costs and income usually shared between the two. In-depth contracts are required to stipulate exact shares of risk and profit. The dairy industry has a particularly high number of share farms.

##### Discussion

- 1 Explain how a share farm operates in your own words.
- 2 Compare the differences in share farming with a family-owned farm.
- 3 Discuss the advantages and disadvantages of a share farm for both the landowner and the share farmer – use the NelsonNet weblink to help you.



Weblink

Share farming

## Community farms

Community farms are owned by the community and allow individuals to work together on the same farm. Community farms are often located in urban areas that lack green space and encourage urban communities to be involved in growing their own food. Some examples include Canberra City Farm, Camden Town Farm Community Gardens and Camperdown Commons.

### AG IN FOCUS

#### CERES COMMUNITY ENVIRONMENT PARK

##### Identify

CERES Community Environment Park is a not-for-profit farm that was created in 1982 on 4.5 hectares of degraded land near the Merri Creek in East Brunswick, Melbourne. CERES is a learning and action area that operates educational programs, urban agriculture projects, a community kitchen, cafe and permaculture nursery.



## Understand

The area was originally home to the Wurundjeri people. After the European invasion and gold rush, it was quarried for bluestone before being turned into a landfill site. A small group transformed the site into a place to showcase sustainability, protect the Merri Creek and develop an area where community groups come together. Groups such as the Bee Group operate plots and allow the community to learn about agriculture and help look after the bees. The CERES Community Food System is an example of urban agriculture where seeds are propagated locally, grown, harvested and sold. CERES allows city people the opportunity to learn how to grow their own food using sustainable practices.



© CERES Community Environment Park



Figure 4.2 CERES before and after

## Discuss

- 1 Outline three different food systems at CERES.
- 2 CERES uses several sustainable technologies. Research one of the 'green technologies' used at CERES.
- 3 Discuss the short- and long-term effects of using this green technology for both CERES and the local community.
- 4 Discuss the community benefits of CERES for inner-city Melbourne.



Weblink

CERES Farm food



Weblink

CERES Green Technologies

## Corporation farms

These farms are owned by large companies or corporations and employ managers to operate the farm. For example, Webster's (an Australian company) owns 220 000 acres and is Australia's largest walnut producer. The farm is managed by employees who take pride in their work and enjoy the lifestyle offered by farming but don't have the direct liability of the ownership. The corporations have the money to purchase the latest technology and ensure sustainable practices are implemented.

## AG IN FOCUS

### AUSTRALIAN AGRICULTURE COMPANY

#### Identify

The Australian Agriculture Company (AACo) is Australia's largest cattle and beef producer.

>

## Understand

AACo was established in 1824 and still operates today in Queensland and the Northern Territory, owning 7 million hectares and specialising in grain-fed beef and Wagyu beef production. As a large corporation, it receives investment that enables it to purchase innovative technologies. AACo can purchase state-of-the-art genetic technology to breed its cattle, which is particularly important for the Wagyu beef cattle. The Wagyu herd at AACo contains the most 'highly credentialed full-blood Japanese Black Wagyu sires and breeding females to ever leave Japan'. It is therefore essential that AACo uses its genetic technology to ensure line diversity of these cattle – enabling it to continue producing award-winning Wagyu beef.

## Discussion

- 1 What are the benefits of running a corporation farm?
- 2 Discuss the statement: 'It is the responsibility of large agricultural corporations to implement sustainable technologies.'

## Cooperatives

Cooperatives are businesses or organisations that are owned, controlled and used by the members who invest in them. Farmers create cooperatives to share resources and improve their bargaining power in the marketplace. Cooperatives are controlled by the members who have an input in the operation, direction and distribution of profits. For example, Yenda Producers Cooperative is a group of farmers around the Yenda township that formed a cooperative to meet a vision of sharing their farming needs.

## AG IN FOCUS

### MOUNTAIN MILK COOPERATIVE

#### Identify

Farming Together is a government initiative aiming to provide farmers with better knowledge and practice in running cooperative and collaborative agricultural business models.

#### Understand

One such cooperative using the Farming Together pilot project is the Mountain Milk Cooperative. They are a group of dairy farmers located in the Alpine valleys in Victoria who initially came together after a local milk processing plant looked like it would close, affecting all dairy farmers in the region. They applied to Farming Together to analyse the market and assist them in starting their own cooperative business. With the help from Farming Together, cooperative members (the dairy farmers in the Alpine valleys) now work together on issues of farming costs and issues. They have been able to negotiate a milk processing agreement with another plant, from which all the cooperative members now benefit. The cooperative gets money from their members to solve issues such as the processing plant negotiations, so they can increase profit, which is then divided amongst the membership.

## Discussion

- 1 What is a cooperative farming model?
- 2 Discuss the advantages and disadvantages to the farmers in the Alpine valley of being part of this cooperative model.
- 3 Investigate another cooperative case study on the Farming Together website. Discuss how being part of a cooperative model positively affected their farms.



Weblink

Farming Together case studies



Worksheets

Analyse different types of farm ownership in Australia with the NelsonNet worksheet.

## Farming businesses

Farms act as both producers and customers – they provide jobs directly in farming (producers), as well as through businesses who offer services to farmers (customers). These can include fuel depots, tractor and machine mechanics, tractor and car dealerships, seed merchants, rural supplies, vet services, contractors such as hay or shearing contractors, and consultants such as agronomists or genetic specialists.

## The economy

The economy is a system of producing and trading goods and services for monetary returns. Domestic markets are the markets that operate within Australia. Countries trade with each other in international markets, where goods or services are exported (sent to overseas countries) or imported (brought into Australia). Most of the agricultural contribution to the Australian economy comes from exports.

A large variety of goods are produced in Australia. Cattle and calves (including live export) are Australia's top product, accounting for \$12.5 billion of agriculture's contribution to the economy.

**Table 4.2** The value of Australia's major agricultural commodities, 2018-19 ABARES estimate

<b>Crop</b>	Wheat \$6.354 billion 	Barley \$3.08 billion 	Canola \$1.325 billion 	Cotton \$1.372 billion 	
<b>Produce</b>	Apples/pears* \$564.3 million 	Citrus fruit* \$797.8 million 	Bananas* \$484.2 million 	Vegetables* \$4.148 billion 	
<b>Animal products</b>	Cattle/calves \$12.596 billion 	Sheep and lamb \$4.818 billion 	Milk \$4.071 billion 	Wool \$4.542 billion 	Eggs \$846 million 

\*2017-18 Hort Innovation Australian Horticulture Statistics Handbook

**domestic market**

the goods grown and sold within a country

**imports**

products brought into one country from another country

## The domestic market

The **domestic market** is the food and fibre that is grown and sold in Australia. The vast majority (93%) of Australia's daily food supply is grown and supplied by Australian farmers. Of the foods **imported** into Australia, a substantial proportion comprises highly processed foods, specialty branded spirits, seafood, and processed fruit and vegetables. Processed seafood is Australia's biggest imported product. Australia imports from many countries, including New Zealand (the biggest supplier of food to Australia), the United States, Thailand, Singapore, Malaysia and China.

## Imports

All food that is brought into Australia, either commercially or privately, needs to pass through Australian biosecurity checks. Australian produce is sought after around the world because of the strict biosecurity regulations. Many diseases and pests common in other countries have not entered Australia because of the biosecurity rules. The *Biosecurity Act 2015* states that all fresh food imports must comply with the Australian biosecurity conditions. There are restrictions that apply to many raw foods and certain processed foods. Some pork products, such as pork jerky, fall into this category.

## AG IN FOCUS

### AVOCADOS FROM CHILE

#### Identify

The Department of Agriculture is conducting a risk assessment on the possibility of bringing in fresh avocados from Chile. Australia imports avocados from New Zealand, but only if they meet strict biosecurity guidelines.

#### Understand

Chile is a large producer of avocados, producing 215 000 tonnes and exporting approximately 147 000 tonnes each year. Australia has 850 avocado producers that grow 66 000 tonnes each year. Australia has a good trade relationship with Chile, with Australia exporting coal to Chile, and in return, Chile exporting copper, zinc and frozen fruit to Australia.

Importing avocados from Chile to Australia would enhance this trade agreement and develop another market for Chile to sell to. The risk assessment involves:

- identifying any potential pests or disease that may pose a risk to Australian agriculture and environment
- ensuring that the produce being imported does not carry an identified pest or disease
- identifying risk management measures that may already exist in relation to the identified pest or diseases
- developing risk management measures to effectively manage the risk
- verifying production, packing and export practices in the source country to ensure that the risk management measures can be suitably implemented.

#### Discussion

- 1 Which countries already produce avocados for the Australian market?
- 2 Describe the five steps in the risk assessment process in your own words.
- 3 Why might Chilean avocados not be allowed into Australia?
- 4 Explain why, considering the risks, Australia is considering importing avocados from Chile.
- 5 Discuss the impact on Australian avocado growers of importing Chilean avocados.

## Exports

Exporting is when an agricultural product or service is sold to international markets. Figure 4.3 shows the main countries to which Australia exports produce.



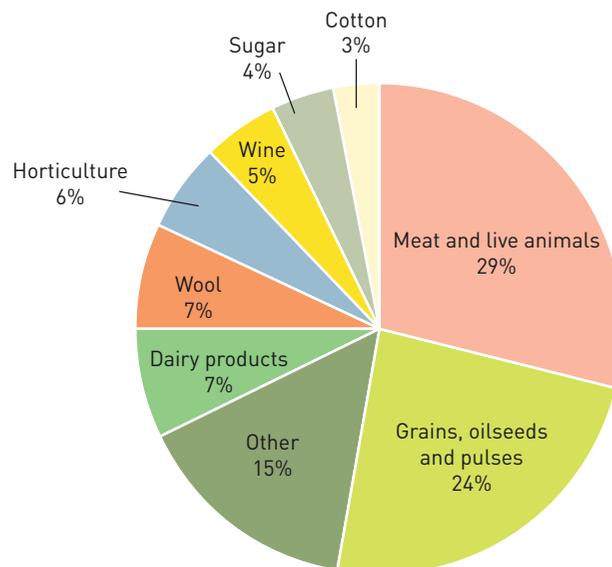
**Figure 4.3** Australia's main export markets

Australia is in a good position to export products produced in safe, reliable and sustainable production systems. ABARES (the Australian Bureau of Agricultural and Resource Economics and Sciences) forecast 2019–20 agricultural export earnings to be around \$45 billion. Exporting products from Australia has issues such as distance and cost of travel, but because of the excellent biosecurity measures, the produce can sell at higher prices in the export market.

Australia exports many types of products. Figure 4.4 shows the different products exported.

### Live animal trade

Australia also exports live animals. The Australian live animal trade was worth \$1.628 billion in 2018–19, exporting sheep and cattle to countries such as Indonesia, New Zealand, the United States and India. Each year Australia exports between 2 and 3 million head of sheep, cattle, goats and buffalo. Kuwait is the largest market for sheep and Indonesia is the largest market for cattle. The live animal trade is a vital market, meeting the needs of trading partners that lack refrigeration to deal with frozen or chilled meat products.



Source: ABARES, Australian Commodities June Quarter, 2017  
CC-BY-4.0

**Figure 4.4** Australia's export commodities



Worksheets

Investigate the Belle Bears case study on NelsonNet and find out how Australia was able to export this product to China.

## Factors influencing international trade

Many factors can influence international trade; some are related to the value of currencies and some come from the agreements and regulations imposed by countries on themselves and their trading partners.

### Tariffs and subsidies

Tariffs are special taxes imposed on goods imported into a country. When the price of imported goods is higher, consumers are more likely to buy a locally made alternative. Subsidies are special payments made by the government to help farmers who are selling their goods overseas. They make exports cheaper in other countries, meaning more overseas consumers are likely to buy them.

Australia is a free market economy. This means we do not place tariffs on imported goods or subsidise our exports.

## AG IN FOCUS

### THE EUROPEAN UNION EXPORT MARKET

#### Identify

The European Union is a market in which a trade agreement exists between all member nations, meaning extra costs (tariffs) are given to outside countries wanting to import into the EU market.

#### Understand

In 2010, Australian beef producers gained access to the EU market. They could export 20 000 tonnes of grain-fed beef tariff-free, provided they met the requirements around traceability and being free from hormone growth promotants (HGP-free). This was driven by a decrease in beef production within the EU while consumption remained steady.

Beef producers aiming for the EU export market must supply the beef through an EU-accredited supply chain, including producers, feedlots and saleyards, and be HGP-free. HGPs are supplements used to accelerate weight gain in cattle. They are used in many countries, including Australia and the United States, with approximately 40% of Australian cattle given HGPs.

#### Discussion

- 1 Why would Australian beef producers want to access the EU market?
- 2 Explain what an HGP is and why it is used in beef production.
- 3 Discuss the factors Australian beef producers needed to consider when exporting to the EU.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the following types of farm ownership: sole trader or family farm, share farm, community farm, corporation farm and cooperative farm.
- 2 Define exports and imports.
- 3 Which three agricultural products contribute most to Australia's economy?



### FOR YOU TO DO

- 1 Visit the ABARES or National Farmers Federation website. Review the latest facts and figures on Australian agriculture and the commodities that are produced. Create a PowerPoint presentation to highlight the position of Australian agriculture.
- 2 Using the data in Figure 4.4, draw a graph showing the contribution of agricultural enterprises to the Australian economy.
- 3 Create a poster promoting the importance of agriculture to your local region.
- 4 Make a list of local businesses that rely on agriculture. Visit a business if possible and interview them about the importance of agriculture to their business.
- 5 Visit a grocery store and identify some imported products. (Hint: supermarkets usually have overseas sections.)

### TAKING IT FURTHER

- 1 Investigate the animal welfare concerns of the live trade industry.
- 2 Using the Australian Bureau of Statistics website, research and draw three graphs to represent the change that has occurred over the last 10 years in:
  - a agricultural employment
  - b the value of Australian agriculture
  - c the number of farms.
- 3 Research an example of each of the types of farm ownership in your local community: family farm, share farm, community farm, corporation and cooperative.
- 4 Conduct a survey with class members, staff or your family about their attitudes to where food comes from. Some questions you could ask are:
  - What percentage of Australian farms do you think are owned by Australians?
  - How much of our produce gets sent overseas?
  - How much of our daily food supply is made in Australia?



ABARES



National Farmers Federation



Australian Bureau of Statistics

## 4.3 Marketing

### What is a market?

A market can be defined as any place, real or virtual, where suppliers and consumers come together to exchange goods or services.

### Supply and demand

Supply is the amount of product that a farmer or grower is willing to produce and supply to the market at a particular price. A supply graph shows the relationship between the price of a product and the amount producers are willing to supply. At low prices, supply is usually also low. As price increases, producers are generally willing to supply more of the product.

Demand is the amount of product consumers are willing to purchase

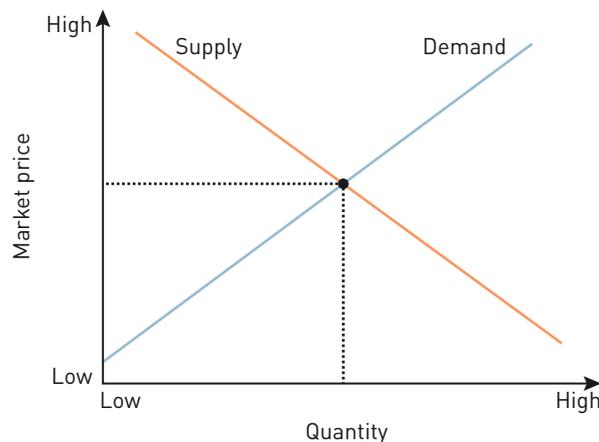


Figure 4.5 Supply and demand graph

at a particular price. A demand graph shows the relationship between price and the amount consumers are willing to purchase. Consumers usually demand more when prices are low and less when prices are high.

When we draw the supply and demand lines on a single set of axes, they intersect at a point we call the 'equilibrium price'. At this price, the amount producers are willing to supply exactly matches the amount consumers are willing to purchase.

## Factors affecting demand

Many factors affect demand, because consumers are influenced by external pressures.

### Price and income

Price is the most important factor on demand. Consumers generally prefer to pay less for a product. Whether they want the cheapest salmon available, or the lowest price for a piece of very high-quality salmon, the same reasoning applies. Other products might be available at a better price than the product that was desired. For example, acrylic jumpers are much cheaper than wool jumpers, so consumers may purchase an alternative product than desired because of pricing.

Income also affects demand. Household income will determine how much money a consumer has to spend on a product.

### Consumer preferences

Consumer preferences for certain foods cover a wide range of reasons, ranging from religious requirements, such as halal or kosher food, to ideological reasons, such as veganism or vegetarianism. Sometimes the media can drive demand for certain foods, such as the trend for 'superfoods' that led to an increase in Australians purchasing products such as kale, blueberries and avocados. Due to production cycles, a farmer can take 12 months or longer to respond to changing consumer preferences. For example, an animal welfare campaign increased consumer awareness about mulesing. Consumers responded by decreasing their demand for wool from mulesed sheep. This led to an increase in research and development funds to find a solution, but it will take time to research and develop a suitable solution that wool producers can implement.

### DID YOU KNOW?

Australia owns 53% of the world's organically managed farmland but it is still not enough to meet the demand for organic food. As a result, a major supermarket chain launched a \$30 million fund in 2018 to help farmers produce organic food.

### Population changes

As Australia's population changes, so does the demand for different foods. The increase in immigration from Asia and the Middle East brings an increasing diversity in the types of foods that consumers demand and are therefore now available. Some of these changes are due to religious reasons, so the market, from farm gate through to the processing stages, responds to these demands, resulting in the production of halal and kosher products. Multiculturalism opens up new markets and opportunities for growth for Australian producers.

## AG IN FOCUS

### AUSTRALIA'S MULTICULTURAL SOCIETY: ASIAN VEGETABLES

#### Identify

An increase in multiculturalism in Australia results in two key opportunities for Australian producers: the opportunity to meet the demands of the new migrants, and an opportunity to bring new products to the Australian population.

#### Understand

In the most recent census, the Australian Bureau of Statistics found that 10.3% of Australian residents were born in an Asian country. They also noted the increase in immigration from Asian countries. Farming has expanded to meet the demands of this growing market.

Asian vegetables are the fastest growing vegetable market in Australia, with sales growing 17% in 2017 and another 11.8% in 2018. Every state found an increase in sales and volume growth of leafy Asian vegetables such as bok choy, pak choi and choy sum, with the biggest sales growth found in South Australia. Victoria purchases the most Asian vegetables, with 40% of households purchasing in 2018. The sales in NSW and Victoria account for almost two-thirds of the total sales of Asian leafy vegetables in Australia.

The growth seems to be driven by mainstream supermarkets picking up these vegetables and selling to new consumers who wouldn't normally shop elsewhere. This is reflected in a decrease in sales of Asian vegetables sold through speciality Asian stores.

Source: Heyhorn, B, *Green Eaters: Asian vegetables on the rise in Australia*, 12 May 2017 and The Nielsen Company, Harvest to Home website, 2019

- 1 Name the two new market opportunities increased multiculturalism brings to Australian farmers.
- 2 How has Australia's multicultural society affected sales of leafy Asian vegetables? Use statistics in your answer.
- 3 Do you expect the sales of leafy Asian vegetables to continue to grow? Give reasons for your answer.
- 4 Investigate the rise of veganism in Australia. How will this affect the future market for Asian-style foods such as tofu and Asian vegetables?

### Advertising

Advertising can take many forms, such as television, radio, posters, social media and email campaigns. It aims to target specific groups of individuals, convincing them to buy a product. Advertising identifies a unique selling point (USP), to show consumers why one product is different to all the other products on offer. An extremely successful advertising campaign will drive increased demand for a product. There is more information about different types of advertising later in this chapter.

### Seasonal demand

Consumers prefer different foods in different seasons. For example, hearty carbohydrate-based foods are preferred in winter, while fresh salad-based items are preferred in Australia's hot summer. Sales of turkey and prawns go up at Christmas, while the sale of chocolates increases before Valentine's Day and Easter.

## Factors affecting supply

### Production costs

Farmers must outlay a lot of money to generate produce for a market. They must buy things like seeds, animals, feed and labour, and all of this is paid before they can sell a product. More expensive products tend to have higher production costs, so some farmers cannot afford to produce them. This results in less supply of those products, further driving up the prices.

### Climate conditions

Climatic conditions such as droughts will affect availability of a product. Extreme weather usually inhibits production. Australia experiences particularly extreme weather conditions due to its location between the two major weather systems, El Niño and La Niña. (See Chapter 1.)

## AG IN FOCUS

### CYCLONE YASI



Alamy Stock Photo/Suzanne Long

**Figure 4.6** Cyclone Yasi devastated the Queensland banana crop.

### Identify

Climatic conditions such as floods and cyclones can severely damage agricultural enterprises. Cyclone Yasi drastically affected the banana growers in North Queensland, causing damage to the banana trees and future harvest. This resulted in an undersupply to the market and banana prices increased.

### Understand

Cyclone Yasi hit North Queensland in 2011 as a Category 5 severe tropical cyclone. Due to its size, it travelled further inland than cyclones usually do, wreaking havoc across large areas of Queensland. Cyclone Yasi caused enormous damage to sugar and banana producers in Queensland. The cyclone is the costliest ever to hit Australia, causing \$3.5 billion damage. Of that figure, \$2 billion was lost in the agriculture, forestry and fisheries industries. Ninety per cent of the supply of Australia's bananas comes from North Queensland. It was estimated that 75% of the banana crop in this region was destroyed. The total devastation of these crops resulted in an undersupply to the market and increased banana prices. Farmers were without income for up to 8 months, until another crop could be harvested. The cyclone also affected the cattle industry, rendering cattle stations such as Anna Creek unreachable and isolated a week after the cyclone had dissipated.

## Discussion

- 1 How did Cyclone Yasi affect supply of products?
- 2 What was the impact of Cyclone Yasi on the farmers in North Queensland?
- 3 Research another extreme weather event in Australia and prepare a report detailing how it affected agriculture. Some events you could research are Cyclone Debbie, the Black Friday bushfires or Townsville flooding.

## Competitors

The number of competitors in the market also affects supply. The more producers, the greater supply there is to the market. More competitors can result in price drops as suppliers try to out price each other to get the biggest share of the market.

## Locality

The location of an enterprise can affect supply – when a producer is closer to markets, the supply is greater. Costs increase the further away from a market a producer is, because the cost of transport increases. Farmers need to weigh up the benefits of being close to urban areas (where larger markets exist) against the benefits of good farming land, such as large country spaces.

## Seasonal supply

Seasons also affect supply. Production cycles differ for each product, so there is more supply at key harvest dates for each different enterprise. Major supermarkets such as Woolworths often produce television advertisements showing what is in season, as well as discussing the same in detail on their website. This helps consumers find the cheaper products more easily (due to the high supply).

## Methods of marketing

Marketing is the steps taken to get the product from the farm gate to market, including advertising and promotion. There are a number of different methods that a farmer can use to market their products.

### Direct selling

Direct selling is where the farmer sells their product directly to the consumer. This trend has been increasing over the last ten years, with more fresh food markets established in local towns and communities. The consumer can have more direct contact with the farmer, understand how the food product is produced and develop a connection with the product.

### Internet selling

Internet selling is a form of direct selling. Producers create their own brand and sell via their own website. An example is Saltbush Lamb, a producer with a website to promote the product, and consumers can buy directly from them.

### Contract selling

Some farmers choose to enter into a contract, where there is an agreement between the two parties to supply an agreed quantity of the product to the buyer's specification. Some of the companies involved in contract selling are Coles, Woolworths and McDonalds.

## Auction systems

Auction systems are generally livestock sales. The livestock are either transported to regional saleyards or sold via an on-property sale to the highest bidder. This method of selling reflects the supply and demand of the market on a specific day. Auctions can also happen online, where bidders read data about the livestock without physically seeing them.

## Marketing bodies

Marketing bodies can be established by the government or the producers to regulate the buying and selling of a product. The marketing board acts on behalf of the producers to ensure that the interests of the producers are looked after and the best possible price is received.

**DID YOU KNOW?**

The first marketing board in Australia was the Rice Marketing Board.

## Vertical integration

Vertical integration is where the farmer owns more than one of the steps in the marketing chain. This allows the farmer direct control over the product from farm gate to the consumer. The farmer can value-add the product to increase the value. One example from the dairy industry is where the milk is processed on-site into yoghurt, butter and ice cream. The farmer is involved in both milk production and the processing of the product. Some farmers may also then sell direct to consumers, staying involved in all steps of the process.

## AG IN FOCUS

### COMMUNITY-SUPPORTED AGRICULTURE

#### Identify

Based on Japanese principles and refined and expanded in the United States, community-supported agriculture (CSA) is a form of direct marketing that gives small-scale farmers income security and a chance to plan ahead for expected demand.

#### Understand

LocalTable is a modified CSA, with founder Kate Raymond coordinating the supply of locally grown produce from several market gardeners and fruit growers to local consumers.

Customers pay a monthly subscription fee and receive a box of fruit and vegetables every week, the contents of which vary depending on the season, what growers have available, and local conditions.

CSA connects farmers with their customers, who take a share of the farm's financial risk. Drought, floods, heat waves, pests and diseases can affect the quality and the quantity of produce. Rather than lose income during these times, CSA farmers continue to be paid, with the understanding that conditions will usually improve and that there will also be times of plenty where customers receive more than their fair share.



Kate Raymond

**Figure 4.7** CSA is a pact between growers and consumers.

## Discussion

- 1 What is community-supported agriculture?
- 2 What are the benefits of CSA to the farmer? Use specific examples from the above case study in your example.
- 3 Pretend you are a marketer for LocalTable. Design a poster marketing LocalTable to your school community.
- 4 Discuss the advantages and disadvantages of CSA as a way of marketing farm produce.
- 5 Research other examples of CSA in Australia and New Zealand at the CSA Network website.



Weblink

CSA Network

## Advertising and promotion

The purpose of advertising and promotion is to showcase the unique selling point to the target market to make a consumer buy the product. The advertisement should showcase a USP to highlight how this product is different to other products on the market.

The target market refers to the entity to whom a producer is selling. Different groups of people have different preferences, therefore a target market identifies which group the producer wants to sell to. This group could be as broad as ‘men’ or ‘youth’, or more specific such as ‘women aged between 18 and 25, living in urban areas’. For the creation of any advertisement, it is therefore important to identify who the market is and what the USP of the product is before developing a strategy.

### Methods of promotion

#### Television

Television advertisements are a very popular way of marketing. Producers pay to have their advertisement shown in commercial television advertisement breaks. It is more expensive to show an advertisement during prime time television shows, which are generally considered to be shown between 8 p.m. and 11 p.m., because this is the time most people will sit down to relax after work. Television advertisements can often only be afforded by large marketing bodies or corporations who can both create a high-quality video and pay to broadcast it.

#### Social media

Social media is increasingly a significant source of promotion for many producers, both small and large scale. It is particularly useful for small-scale producers because it allows them to reach a large audience for a relatively small cost. Producers can create their own brand and logos and attract ‘followers’, who then share and market the brand organically. It is important to market using the right social media channel. Ask your target audience what social media platform they use to ensure your message reaches the right people.

#### Print

Print promotion encompasses any physically printed material. This can include magazine or newspaper advertisements, leaflets, cards and posters. Print promotion can be very useful when attending events such as conferences or markets because consumers can pick up the material and come back to it later. Advertising in a magazine can be useful because magazines usually have very clear target audiences, and it can be easier to reach a certain audience with the appropriate magazine choice. However, with print costs always increasing, this is becoming an expensive method of promotion.



Video

View the 2018 ‘Put some pork on your fork’ television advertisement for Australian Pork. Can you identify who the target audience is?



Weblink

The #agchatoz Twitter feed



Worksheets

Practise your marketing skills by creating a promotional video to market kangaroo steaks to an export country. Use the NelsonNet worksheet to assist you.



Weblink

Watch the 'How do you hommus' advert with celebrity chef Manu Feidel.

## Radio

Producers can pay for short advertisements or on the radio. This tends to be much cheaper than promotion on television or in print. However, a producer should consider whether their target audience is a regular listener, and if so, to which radio station they are most likely to listen.

## Celebrity sponsorship

One of the best ways of increasing demand is by enlisting a celebrity to endorse your product. Celebrities require a high price for sponsorship but often have a significant following.

## Instore promotions

Instore promotions are used as a tool for marketing to consumers actually in a physical shop. These can involve promotions created by shops and supermarkets, such as '2-for-1' deals or special discounts. Instore promotion can also be done through the packaging design. Packaging needs to entice a consumer to choose that product from a shelf surrounded by many other products. When designing packaging, keep in mind that you are promoting your product and make sure it stands out.



LET'S ENGAGE

## MARKETING AN AGRICULTURAL PRODUCT

### PURPOSE

To design the packaging and develop a marketing campaign for an agricultural or horticultural product produced on the school farm or in the school garden

### MATERIALS

- Computer
- Paper
- Sample labels
- Video
- Camera
- The product

### METHOD

- 1 Select the agricultural or horticultural product. What is the unique selling point of your product?
- 2 Identify the target audience for the product: students, parents, teachers or the community.
- 3 Design a suitable package and logo for the product.

- 4 Create the packaging from the best design.
- 5 Brainstorm the best method for selling the product.
- 6 Design a marketing campaign to advertise the product. Your campaign must include **three different types of marketing**, as discussed above. Develop a suitable slogan. Consider social media, school canteen, posters and leaflets.
- 7 Create and release the marketing campaign.

### DISCUSSION

- 1 Who is your target market?
- 2 What is your USP?
- 3 How can you evaluate the effectiveness of the campaign?
- 4 How could you improve your campaign?

## Value-adding

Value-adding is another form of marketing: it involves changing and processing a product further to create a different product. This is usually costlier because farmers need to pay for more processing. However, value-added products sell for higher prices, which can result in excellent profit. Potatoes are one example of an extremely versatile product that can be value-added into many different products such as chips, hot chips and potato scallops. Sometimes value-added products can be made for specific occasions or times of year. For example, in the lead-up to Valentine's Day, sales of chocolates and flower bouquets increase –



Worksheets

Explore other value-added products with the NelsonNet worksheet.

both are examples of value-added products. These are often marketed specifically for occasions such as Valentine's Day, with packaging and labelling designed for the event, adding further value to the product.



## LET'S DISCUSS

- 1 As a class, discuss some value-added products you could make with produce from the school farm.



## LET'S REVIEW

### LOOKING BACK

- 1 What is the difference between supply and demand?
- 2 Explain the factors affecting demand for a product.
- 3 Identify the different methods a farmer can use to market a product.
- 4 Identify the different ways of promoting a product.
- 5 What is value-adding?

### FOR YOU TO DO

- 1 Evaluate the different marketing strategies that can be used to market a product. Use the table below to help your evaluation.

Marketing strategy	Advantages	Disadvantages	Evaluation
Direct selling			
Internet selling			
Contract selling			
Marketing bodies			

- 2 Using the links on NelsonNet, review the 2018 and 2019 lamb campaign videos and posters.
  - a Who do you think the target audience is? Explain why.
  - b What is your personal reaction to the campaign? Would you buy this product? Explain why or why not.
- 3 Which marketing strategy would best suit the following farmers? Justify your decision.
  - a a small market garden in an urban area
  - b a large cattle station
  - c a large hydroponics farm
  - d a small-scale dairy farmer
- 4 Determine the target audience for the following advertisements:
  - a a television advertisement for skimmed milk saying that it has the same properties as sports drinks
  - b a poster describing bananas as the perfect lunchtime treat
  - c a radio jingle singing about the high iron content of pastured eggs.
- 5 Investigate how potatoes can be value-added.
  - a List four value-added potato products.



Video

Australia Day 2019



Video

Australia Day 2018



- **b** Investigate the prices for unwashed potatoes vs washed potatoes. (Hint: check out supermarket websites.)
- c** Draw a marketing chain for unwashed potatoes, washed potatoes and a packet of chips.

### TAKING IT FURTHER

- 1 For a product developed on the school farm, conduct a market survey of staff, students and parents about the consumer preferences for that product.
- 2 Using the results from the survey, develop a market strategy for the product.
- 3 Analyse how an agricultural product grown in your region is promoted; for example, organic milk or saltbush lamb.
- 4 Investigate sales of chrysanthemums, or another floral produce of your choice.
  - a List the ways these can be value-added. (Hint: think out of the box – what products have floral fragrances?)
  - b Design your Mother's Day-inspired, value-added product using chrysanthemums.

## 4.4 Business management

### Records

Record-keeping is essential to ensure a farm is operating efficiently, profitably and meeting legal requirements. Keeping records also enables the farmer to track breeding records, monitor day-to-day planning, analyse the enterprises, participate in quality assurance programs and aid in whole-farm planning for the future.

Meat Livestock Australia, the Department of Primary Industries and other agricultural organisations help farmers to ensure that the appropriate records are kept according to the enterprises on the farm.

### Types of records

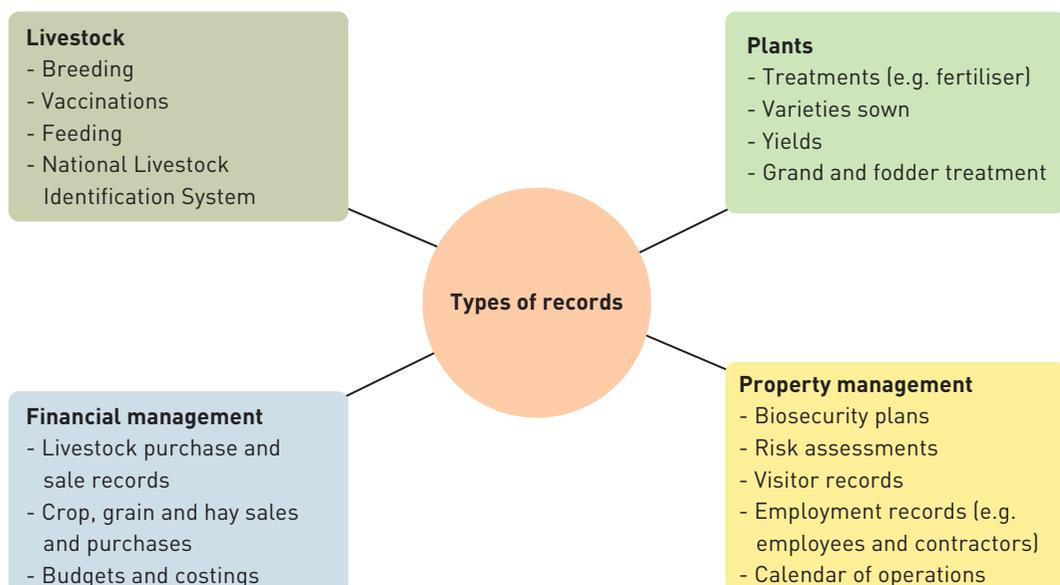


Figure 4.8 Different types of records

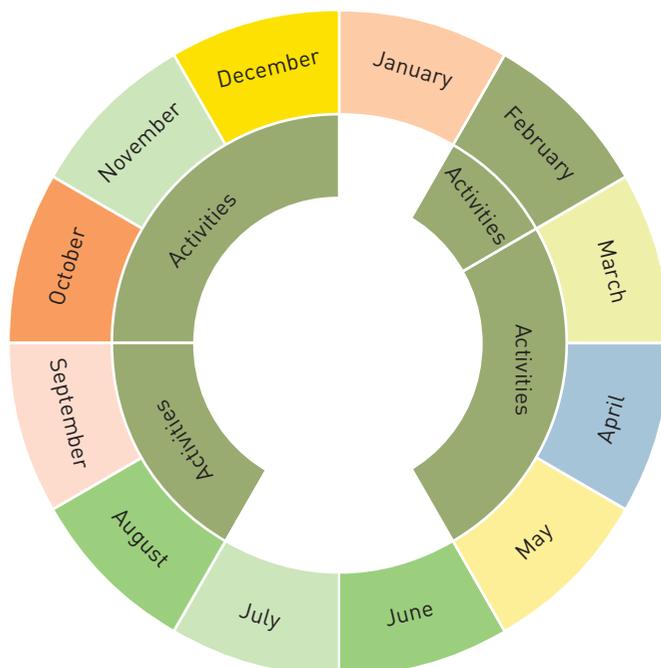
## Calendar of operations

A calendar of operations is a method used to organise the timing of activities throughout the year. It is a management tool that enables farmers to plan, organise and control activities for each enterprise. This also enables farmers to avoid clashes between various key husbandry tasks, such as timing the shearing when the wheat is to be harvested.

A calendar of operations can be drawn in several ways, as shown in Table 4.3 and Figure 4.9.

**Table 4.3** Calendar of operations in table form

	Cropping activities	Livestock activities	Other activities
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			



**Figure 4.9** Calendar of operations in circular form



## LET'S ENGAGE

### CALENDAR OF OPERATIONS

#### PURPOSE

To create a calendar of operations for one or two enterprises on the school farm

#### MATERIALS

- Computer
- Smartphone/smart device
- List of activities
- Download of relevant app if using an app to create

#### METHOD

- 1 Identify the enterprises on the school farm.
- 2 Brainstorm the various activities carried out in a year.
- 3 Identify when these activities need to be carried out.
- 4 Create a calendar of operations using, either the tabular or the

circular format. Draw this on a large piece of butcher's paper and stick on the classroom wall (you could also download an app and create the calendar on your smartphone).

#### DISCUSSION

- 1 Discuss times through the year when activities cannot be carried out. (Hint: think about when you are on school holidays.)
- 2 Identify any possible clashes of activities.
- 3 Display the calendar and monitor the effectiveness of the timing of the activities.
- 4 Draw the table in the other format (tabular or circular). Which way works best for you?

## Technology and management

There are numerous apps that can be used to help a farmer manage the farm, create calendars of operations, monitor finances and track any issues that may arise. The Department of Primary Industries has developed apps to help farmers. Private organisations also supply apps to manage all aspects of the farm. These apps cover weed identification, tracking chemicals, health advice for livestock, whole-farm planning, budget analysis, and monitoring the weather.



WebLink

Research apps available for farmers. Are there any you think could be useful for your school farm?

## Financial records

Financial performance is a way of analysing the effectiveness of the farm. Financial records can be analysed using gross margins, profit and loss statements, and return to capital. Financial records help farmers make decisions on conducting enterprises, and whether to change or modify existing enterprises.

### Financial terms

Table 4.4 shows the different terms used when determining the profitability of an enterprise.

**Table 4.4** Profitability terms

Term	Definition
Profit	The amount obtained when total costs of production are deducted from return generated (income), if a positive number
Loss	The amount obtained when total costs of production are deducted from return generated (income), if a negative number
Capital	Capital is the money used to initially start up a business, such as initial cost of land, machinery, etc.
Fixed costs	The costs that need to be paid irrespective of whether there is production, such as electricity, permanent wages, internet, phones
Variable costs	The costs that are only incurred during the production of an enterprise, such as seeds, fertilisers, fuel

➤ Gross income	The total money – often called net receipts <b>Total product produced × Price</b>
Gross margin	A measure of how a particular enterprise is performing, used to compare different enterprises <b>Total income – Total variable costs</b>
Return to capital	Measures the profit achieved relative to the total assets allocated and used. Over 10% return to capital is considered a good rating. <b>% return to capital = Operating profit/total assets × 100</b>
Whole-farm budget	Measures the profitability of the farm: the total income less the total costs. Whole-farm budgets are simple and easily produced. They are useful tools for planning and analysis of the financial aspect of the farm.

## Gross margins

Gross margins are a measure of how an enterprise is performing. Gross margins use the variable costs and can be used to compare different enterprises or compare similar enterprises within the region. They do not take into account the fixed costs of operating the enterprise.

**Table 4.5** Sample gross margin calculation for merino wethers, 500 sheep

Income			
	Wool kg	Income (cents/kg)	Budget (kg income)
Wool sales	3430 kg	430	\$14 620
	Head	Income (\$/head)	Budget (head × income)
Cull sheep	50	\$22	\$1100
TOTAL INCOME:			\$15720
Variable expenses			
Shearing 500 sheep @ \$135/100		\$675	
Shed labour 2 days @ \$80/day		\$160	
Wool packs 19 packs @ \$7/pack		\$133	
Dipping 500 sheep @ \$0.25/head		\$125	
Selling charges			
Commission 5% of gross proceeds		\$575	
Yard fees		\$0	
Other expenses			
Drench 500 sheep @ \$0.11/head		\$55	
Grain 5 tonne @ \$ 115/tonne		\$575	
VARIABLE COSTS:			\$2298
<b>Gross margin (GM) = Total income – Variable costs =</b>			\$13 422
<b>Gross margin per hectare = GM/250 =</b>			\$53.69
<b>Gross margin per sheep = GM/500 =</b>			\$26.84

When comparing different enterprises there are common units that can be used. When comparing livestock, the following can be used:

- Gross margin per head: the profit per animal
- Gross margin per dry sheep equivalent (DSE)
- Gross margin per hectare: the profit per hectare of land
- Gross margin per litre of milk produced: the profit per litre of milk



Review your knowledge about business with the *Business terminology glossary* worksheet.

For crops we can use the terms:

- Gross margin per hectare: profit per hectare of land
- Gross margin per megalitre of water: profit per megalitre of water used

DSE refers to the amount of feed required for a two-year-old, 45 kg merino sheep to maintain its weight. DSE's allow farmers to compare livestock enterprises. Other animals are given a DSE value related to how much more or less they consume than a dry sheep. For example, a cow suckling her calf would consume the equivalent of 25 dry sheep, so would be given a value of 25 DSEs. In other words, the feed requirements, profit and gross margins of 25 sheep can be compared to those for one lactating cow.

## COMPARING GROSS MARGINS

### AG IN FOCUS

#### Identify

You are a new farmer investigating possible crop enterprises. You are unsure whether to invest in cotton or canola. You need to compare the gross margins of two local enterprises, a cotton and a canola farm, using the gross margin per hectare calculation to help make your decision.

#### Understand

##### The cotton farm

The cotton farm produces 5500 bales of cotton on 500 hectares of land. They sell the cotton at \$480 per bale. Their variable expenses are:

- cultivation: \$124/hectare
- irrigation: \$490/hectare
- seed: \$143/hectare
- fertiliser and other crop protection: \$750/hectare
- picking and ginning harvest costs: \$1000/hectare

##### The canola farm

The canola farm produces 1250 tonnes of canola on 500 hectares of land (producing 2.5 tonnes per hectare). They sell the canola at \$465 per tonne. Their variable expenses are:

- cultivation: \$20.74/hectare
- water: \$490/hectare
- seed/sowing: \$56/hectare
- fertiliser and other crop protection: \$313.91/hectare
- labour costs at harvest: \$135/hectare

#### Discussion

- 1 Using the template in Table 4.5, calculate the gross margin per hectare for the cotton and canola farms.
- 2 Which enterprise would you recommend the farmer invest in?
- 3 What fixed costs will the farmer also incur?



## LET'S REVIEW

### LOOKING BACK

- 1 Describe four different records that a farmer can keep.
- 2 Name two ways to create a calendar of operations.
- 3 What is the difference between a gross margin and a whole-farm budget?
- 4 Identify the variable and fixed costs from the list below.

rates	telephone	cartage
shearing	bank fees	machinery repairs
drenches	seeds	purchase replacement heifers
vaccines	fertilisers	casual labour
permanent wages	electricity	hay contractors

### FOR YOU TO DO

- 1 Investigate the school farm or a local farm and identify the types of records that are being kept in relation to the farming activities.
- 2 Calculate the gross margin using the following information. You can use the template on NelsonNet or Table 4.5 to assist with your calculation.

Income	
50 steers	\$450/head
25 heifers	\$400/head
15 cull cows	\$325/head
Variable costs	
Drench 50 yearlings	\$3/head
Pour on 100 cows	\$1.20/head
Vaccine 50 yearlings	\$0.20/head
100 cows	\$0.20/head
Semen straws	\$50/straw
Ear tags 50	\$3.20/tag
Cartage	\$8/head
Selling costs	\$5/head
AI technician	\$250/day

- 3 What additional information would be needed to calculate the profit and loss of the enterprise and the return to capital of the above example?
- 4 Calculate the return to capital. This measures the profit achieved relative to the total assets are allocated and used.

$$\% \text{ return to capital} = \frac{\text{Operating profit} \times 100}{\text{Total assets}}$$

Land value	\$2 000 000
Livestock and machinery	\$2 500 000
Annual farm income	\$550 000
Annual farm costs	\$280 000

- 5 Use the NelsonNet weblink to develop a calendar of operations for the beef enterprise included in the website.



Scaffold

Gross margin template



Weblink

Beef calendar of operations



**> TAKING IT FURTHER**

- 1 Research apps available to help a farmer manage weeds. Evaluate two different apps and write a report recommending one to be used by your school farm.
  - 2 Investigate how a farmer can use a cash flow budget as part of their management tools.
  - 3 Select an agriculture commodity – list the value-added items that can be created from this commodity, then select one of those value-added products.
    - a Identify the markets.
    - b Create a whole-farm budget for the enterprise.
    - c Develop a marketing strategy: target audience, price, where to advertise and the packaging.
  - 4 Use the NelsonNet weblink to explore an app for managing a sheep flock.
- 



Weblink

Lambing planner

# Let's summarise

## How does multiculturalism influence Australian agricultural production?

Australia is an increasingly multicultural society, which opens up new markets for farmers. In addition to the multicultural markets in Australia, the majority of fresh food produce grown in Australia is exported around the world to countries such as China, Thailand and the United States. Using the examples below, create a mindmap detailing how multiculturalism and export trade influence the production of the products in Australia.

Asian vegetables

Live animal trade

High-quality fish

## How can Australian farmers market their products?

There are a number of ways to advertise and market products in Australia, such as online, television, radio and print. The strategy used is determined by the target market – who the producer is selling to. Evaluate the advantages and disadvantages of each advertising strategy and give an example of a farming enterprise that would use this strategy. Use the table below to help structure your response.

Advertising strategy	Advantages	Disadvantages	Farming enterprise



## CHAPTER 5

Shutterstock.com/Mad Teodor

# Conducting agricultural research

## CHAPTER SUMMARY

Advances in agriculture come about when we identify problems and investigate solutions. Scientific experiments allow us to better understand the world and our effect on it. In this chapter you will be exploring reasons why we conduct agricultural research and learning about how to design valid, reliable experiments. You will apply this knowledge to a variety of real-world farming problems to better understand scientific methodology and the role of research in agriculture.

**What role does research play in agriculture?**

**How can I design a valid and reliable agricultural experiment?**

## 5.1 Why we conduct research

Research uses scientific experiments and other investigations to answer questions, discover facts and build on existing knowledge. In agriculture, we conduct research for a variety of reasons including to:

- increase yields of plant and animal products
- improve the quality of products
- find the most sustainable and effective way to deal with pests and diseases
- create new agricultural products
- improve the welfare of farm animals
- help existing crops and animals adapt to a changing climate.

In this chapter we will examine how scientific method is used to help agricultural scientists find solutions to some of these problems.

### Ethics of research

#### Funding, ownership and conflicts of interest

Research can be funded by a bodies such as the government, industry and private corporations. The CSIRO conducts research and is responsible for a number of significant technological advances including wi-fi, hornless cattle, omega 3-enriched canola, advanced soil mapping and veterinary vaccines.

#### DID YOU KNOW?

Every dollar the government spends on the CSIRO generates, on average, six dollars for the Australian economy.

Rural research development corporations, such as Australian Dairy Farmers, Australian Pork Limited and Australian Wool Innovation, conduct research related to particular areas of agriculture. These bodies are funded partly by farmers in that industry, each of whom pay a levy. These development bodies also receive funding from the federal government.

Large corporations, such as Bayer (who recently purchased Monsanto), Dow and Syngenta, fund a considerable amount of research. Critics of this type of funding are concerned that researchers may feel pressured to skew or alter their methods and findings to benefit the company paying for their work. Corporate funding also raises the ethical dilemma about which research we value and conduct. Rather than agricultural scientists investigating problems affecting farmers or communities, this funding may draw researchers towards problems that are in the corporate interest of the company.



#### LET'S DISCUSS

- 1 Who should pay for agricultural research?
- 2 Should private companies or the public own the findings of agricultural research?

## Research involving animals

All research involving animals must comply with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes. This code applies to all live, non-human **vertebrates** and **cephalopods**.

Animals can only be used in research if they cannot be replaced or substituted with a non-animal model. If animals must be used, researchers must use the minimum number necessary. They must also refine methods to reduce adverse impacts on the animals.

Animals have been used for scientific research in agriculture, veterinary medicine, biology, human medicine and other sciences for many years. They have also been used for product testing and in environmental studies. Many lifesaving surgeries, medicines and devices have relied on animal research. Animals will still be needed in some areas of research in the future.

Alternatives to animal research include:

- **in vitro** testing – ‘organs-on-chips’ contain cells grown to mimic human tissues and organs
- computer modelling – QSARs (quantitative structure–activity relationships) use computer simulations to determine if a substance is likely to be hazardous.

**vertebrate** an animal possessing a spine or vertebral column

**cephalopod** a mollusc, such as a squid, octopus or nautilus

**in vitro** outside a living body; for example, in a test tube or laboratory

## AG IN FOCUS

### CSIRO HORNLESS CATTLE

#### Identify

CSIRO researchers have developed a test to see if Brahman cattle carry a gene for horns.

#### Understand

Horns cause bruising and damage to carcasses during transportation. They also cause injury to farmers during handling. Researchers have discovered an area of DNA in Brahman cattle related to whether or not a particular

animal possesses horns. Cattle without horns are referred to as ‘polled’. Horns are a recessive trait, meaning that some polled animals will have a gene for horns that they can pass on to their offspring. This makes selection of breeding stock very difficult if farmers want to eliminate horns from their herd.

After several trials using scientific methodology, the CSIRO has made this test available for cattle farmers. Farmers can now test their cattle to see if they possess the gene marker. They will then be able to make decisions about whether to use a particular animal for breeding.

#### Discussion

- 1 Explain why horns are a problem for cattle farmers.
- 2 Why has it been difficult for farmers to breed horns out of their Brahman cattle in the past?
- 3 How has agricultural research helped to solve this problem?
- 4 Outline the benefits of this research-based innovation.
- 5 Investigate other CSIRO innovations using the NelsonNet weblink.



**Figure 5.1** Brahman cattle: one polled (hornless) and one horned

iStockphoto.com/R.H. Koenig



Weblink

CSIRO



## LET'S REVIEW

### LOOKING BACK

- 1 Outline some reasons for conducting agricultural research.
- 2 Explain the role of the government, industry bodies and corporations in funding agricultural research.
- 3 What animals are covered by the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes?
- 4 Identify two alternatives to using live animals for research purposes.

### FOR YOU TO DO

- 1 Conduct a class discussion on the ethics of animal research. Debate whether there is an ethical difference between using animals for agricultural research and medical research.
- 2 Investigate the responsibilities of students and teachers working with animals in schools by exploring the Animals in Schools website.

### TAKING IT FURTHER

- 1 Scientific research is published in journals. Search the CSIRO journal database to find three different journals related to agriculture.
  - a Name each journal and describe what area of agriculture it is generally concerned with.
  - b Find one article from each journal, name it and write a brief description of the research.
- 2 Learn more about the ethics of animal research by watching the YouTube video on how animal research saved the life of someone suffering from blue baby syndrome.



Weblink

Animals in Schools



Weblink

CSIRO Journals



Video

Blue baby syndrome

## 5.2 Creating research questions

### Identifying the problem

Agricultural researchers may have a problem brought to them by an industry body, a farmer, the government or a company. Initially, this problem might be very broad. In order for it to be investigated scientifically, the problem must be narrowed down and defined. The first step in doing this is to conduct a literature review.

### Literature reviews

A huge body of research already exists for most areas of agriculture and other human knowledge. New research tests the assumptions and conclusions of this previous knowledge, but also builds on it. A literature review is an investigation of all the relevant previous research to learn about what we already know and what we don't know yet about a subject. Literature reviews sometimes uncover inconsistencies between similar experiments, prompting scientists to design and conduct more experiments in that area.

Once we have learned more about the area we are investigating, we might have some questions to which we cannot find answers. If these questions are testable, we can design experiments to get those answers.

## Writing a testable aim

Research questions need to be scientifically testable. The aim of an experiment is based on this testable question.

**Table 5.1** Formulating aims from testable questions

Testable question	Aim
What is the effect of the concentration of a liquid fertiliser on tomato yield?	To test the effect of liquid fertiliser concentration on the yield of tomatoes
What is the effect of a feed supplement on the methane emissions of grazing cattle?	To test the effect of feed supplement on the methane emissions of grazing cattle
Which breed of sheep produces the most protein in its milk?	To test the effect of sheep breed on protein content in milk

The aim seeks to find the effect of one variable on another. A variable is something that can change, just as the name implies. An aim has two important variables:

- 1 the independent variable – this is the factor being changed or manipulated in the experiment. In the first example above, the independent variable is the concentration of liquid fertiliser.
- 2 the dependent variable – this is the result being measured. It depends on the independent variable. The dependent variable in the first example above is the yield of tomatoes.

For an aim to be testable, the independent variable must be able to be manipulated and the dependent variable able to be measured.



Worksheets

Practise creating research questions with the NelsonNet worksheet.

## Formulating a hypothesis

Once the testable aim has been determined, a prediction or educated guess can be made as to what the experiment might find. This is called the hypothesis. In the first example above, you might hypothesise that increasing the concentration of the fertiliser will increase the yield of tomatoes. The experiment will then be designed to prove or disprove the hypothesis.

### AG IN FOCUS

#### AGRICULTURAL RESEARCH IN CAMBODIA

##### Identify

Associate Professor Russell Bush is a researcher and lecturer in livestock health and production at Sydney University. He applies the knowledge he has gained from his agricultural studies, as well as the skills he honed as a farmer, to help farming communities around the world.

##### Understand

Increasing cattle prices, due to rising consumer demand for beef and dwindling cattle populations, have proved a challenge for Cambodian farmers. Cattle in Cambodia are affected by a number of diseases



**Figure 5.2** Preparing to weigh cattle as part of a research project in Cambodia

Associate Professor Russell Bush



including brucellosis and foot-and-mouth disease. These diseases spread rapidly within and between districts, causing cattle deaths and reduced production. Farmers and their families, including young children, walk to find food for their cattle for hours a day, wasting precious time and preventing children from attending school. Reproduction rates for cattle are also low, putting even more pressure on farmers.

Bush has been working with Cambodian communities, identifying problems and attempting to address them via research. He has found that cattle fed on fodder crops – nutritious plants grown as a pasture – gain 0.8 kg more weight per day than cattle that must walk long distances to find feed.

### Discussion

- 1 Why are cattle prices rising in Cambodia?
- 2 Identify three broad areas of potential research that would help these farmers.
- 3 For one of these areas, decide on a single problem or issue that could be helped with research. Compose a testable question based on this problem.
- 4 Associate Professor Bush has helped to solve a problem with cattle nutrition by conducting research. Identify the independent and dependent variables from this research from the last paragraph of the case study.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the following terms: variable, independent variable, dependent variable and hypothesis.
- 2 How can we determine whether a question is testable?
- 3 Outline the role of a literature review.

### FOR YOU TO DO

- 1 Convert these testable questions into aims and then formulate suitable hypotheses.
  - a What will happen to the sugar content of grapes if we change the pH of the soil in which they are grown?
  - b Can we make meat chickens gain more weight by feeding them extra protein?
  - c Will compost break down more quickly if we add comfrey leaves?
- 2 Identify the independent and dependent variables in each of the following aims.
  - a Aim 1: To test the effect of light intensity on volume of egg production.
  - b Aim 2: To compare the effect of four fertilisers on the growth rate of ryegrass.
  - c Aim 3: To test whether a new variety of oats is more resistant to rust diseases than the traditional variety.
- 3 Brainstorm issues affecting the school farm.
  - a Identify a problem and construct a testable question relating to one of these problems.
  - b Write an aim and hypothesis for this testable question.

### TAKING IT FURTHER

- 1 Investigate real scientific research at Science Journal for Kids. Find one research paper relating to agriculture and write a report.
  - a Outline the problem the research is addressing.
  - b State the aim of the experiment.
  - c Give a brief description of how the research was carried out. You will be learning more about this step in the next section.
  - d What did they find out and how did it help farmers?



Weblink

Science Journal for Kids

## 5.3 Scientific methodology

### Risk assessment



Scaffold

Check out the risk assessment template on NelsonNet.

It is a legal requirement to conduct a risk assessment before conducting experiments in Australian schools. Risks will vary depending on the nature of the experiment but may be related to chemicals, sharp implements, biological hazards, animal handling, and exposure to climatic elements. Risk assessments are living documents, meaning they must be continually updated and modified as new risks emerge during the experiment.

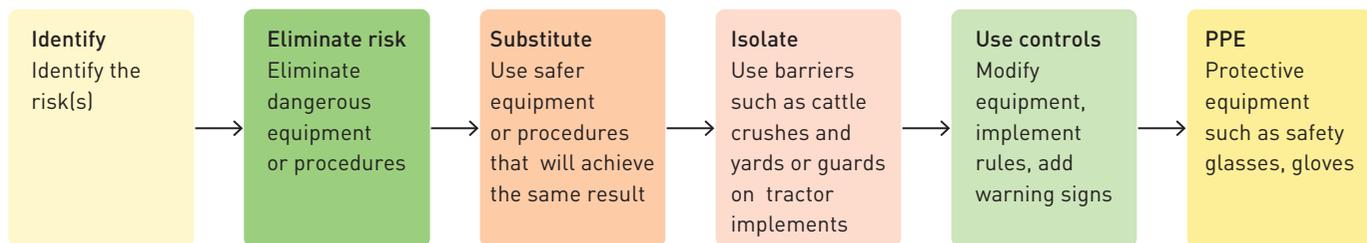


Figure 5.3 How to conduct risk assessments in research

### Designing scientific experiments

Table 5.2 Experimental design template

<b>Aim</b>	Expresses the purpose of the experiment. To test the effect of _____ (independent variable) on _____ (dependent variable).	
<b>Hypothesis</b>	A prediction of what the experiment will find. As the _____ (independent variable) increases/decreases/changes, the _____ (dependent variable) will increase/decrease/change.	
<b>Risk assessment</b>	A living document <ul style="list-style-type: none"> <li>• identify</li> <li>• eliminate</li> <li>• substitute</li> <li>• isolate</li> <li>• controls</li> <li>• PPE</li> </ul>	
<b>Materials</b>	A comprehensive list of all materials needed for the experiment	
<b>Method</b>	A detailed procedure of how to conduct the experiment, with evidence of: <ul style="list-style-type: none"> <li>- standardisation</li> <li>- randomisation</li> <li>- repetition</li> <li>- a control, if necessary</li> </ul>	Diagram:
<b>Results</b>	Data collated, analysed and presented in a table and appropriate graph.	
<b>Discussion</b>	Interpret the results and make recommendations. Identify issues with experimental design and suggest improvements. Identify further questions or experiments which have arisen.	
<b>Conclusion</b>	State whether the hypothesis was correct, incorrect or partially correct.	

## Treatment groups

To test the hypothesis that increasing the concentration of liquid fertiliser leads to an increase in tomato yield, treatment groups need to be set up. These are groups containing test subjects (in this case, tomato plants). Each treatment group receives a particular treatment in the experiment. In Table 5.3, treatment group 1 is receiving 20 g/L of fertiliser, while treatment group 3 is receiving 60 g/L.

**Table 5.3** Treatment groups for an experiment assessing the concentration of liquid fertiliser (g/L)

Control	Treatment group 1	Treatment group 2	Treatment group 3
0	20	40	60

### Using a control

A control is a group that does not receive the treatment. The control group in Table 5.3 receives no fertiliser. This group allows us to compare the treatment groups to a normal untreated (in this case, unfertilised) group. If there is a difference between the results for the control and the treatment groups, the treatment had an effect.

Not all experiments need a control. For example, there would be no need for one if the test was whether Jersey or Holstein cows produced milk with the most butterfat.

### Valid experiments

A valid experiment is a fair test. If a teacher decided to test how much the students in a class had learned about geometry, then gave half of the class extra time in the exam and helped them with the answers, it would not be a fair test. To make a test fair, all the other things that might influence the outcome of the experiment need to be controlled. The method used must also answer the question asked in the aim.

### Standardisation

Standardisation involves controlling all the variables that might affect the dependent variable. The example of a geometry test above is not standardised because some variables, such as the amount of time, are not being controlled.

Table 5.4 identifies some of the variables that can affect tomato yield. To test the effect of fertiliser concentration (the independent variable in the centre of the table), all other variables must be kept constant, or the same.

**Table 5.4** Controlling variables

Amount of sunlight	Volume of water	Water source
Variety of tomato plant	Concentration of fertiliser (independent variable)	Type of soil
Presence of disease and pests	Amount of wind	Size of pot

### Randomisation

Ideally, the test would be conducted on the entire population of the plant or animal in question. This is not possible because populations are very large. Instead, samples are drawn from the population to make treatment groups.

#### DID YOU KNOW?

Using a control is not the same as controlling variables.

Test subjects should be allocated randomly to groups in an experiment. This avoids bias from influencing the results. While this might not seem important in a test involving tomato seeds, it can be very important to ensure the validity of clinical trials for human medicines. If, for example, researchers were able to decide which patients were to receive a potentially life-saving drug in a clinical trial, then they might subconsciously favour particular people, such

as parents of young children. This bias might result in the treatment group being quite different to the control group, making the experiment invalid.

Randomisation also helps to guard against variables that may not have been identified. Figure 5.4 shows the layout of a wheat field trial comparing different crop varieties. Different varieties of wheat have been randomly allocated to a number of plots. In this case, randomisation reduces the chance of problems like unidentified soil compaction in one part of the field influencing the results.



Alamy Stock Photo/Nigel Cattlin

**Figure 5.4** Field trial of new wheat varieties

### Reliable experiments

A reliable experiment is one that has consistent results on repeated testing. If, on repeated testing, inconsistent or varying results are collected, then the experiment is not reliable and the experimental design needs to be re-evaluated.

### Repetition and replication

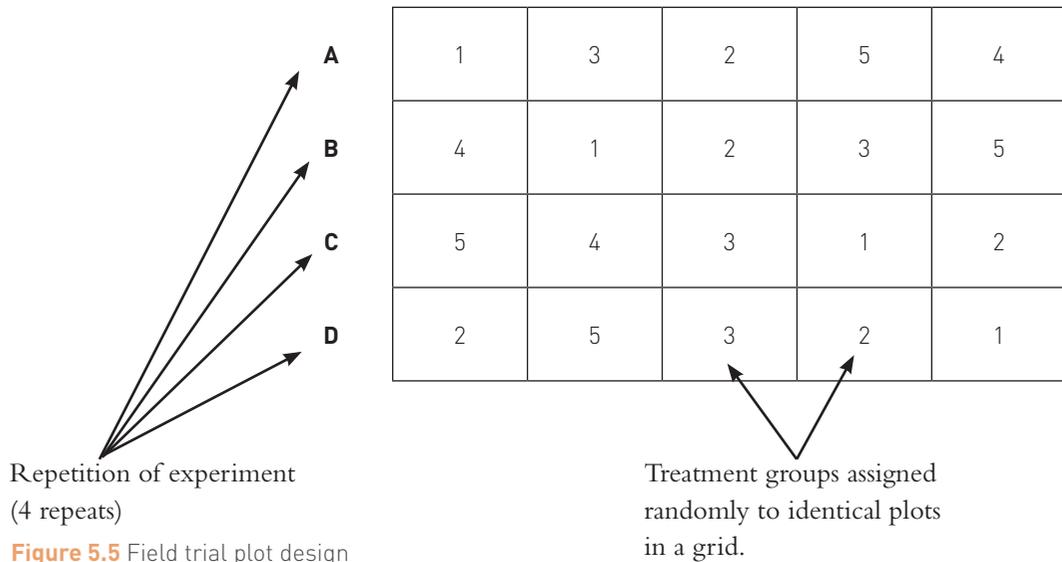
Repetition is when multiple treatment groups and test subjects are included in the experiment. In Figure 5.5, each treatment group (numbered 1 to 5) has multiple test subjects (wheat plants) and is repeated four times (A to D). This reduces the chance of individual variation affecting the results.

Replication involves other researchers using the same procedure and conducting exact copies of the experiment.



Worksheets

Use the *Scientific methodology* worksheet on NelsonNet to practise evaluating experiments.



**Figure 5.5** Field trial plot design



## LET'S ENGAGE

## DESIGNING A FIELD TRIAL

## PURPOSE

To design an experiment using scientific methodology testing the effect of mustard variety on yield

*Note: this experiment can be conducted in pots rather than in the field if space is not available. Use 20 identical pots arranged in a grid.*

## MATERIALS

- Measuring tape
- Cultivation equipment
- Seeds from five different mustard varieties
- Stakes or posts for labelling
- Experimental Design Template

## METHOD

Design a scientific experiment to test which mustard variety has the highest yield. You will need to complete the following steps.

- 1 Use the Experimental Design Template to record details of your methodology.

- 2 Formulate an aim and hypothesis.

- 3 Conduct a risk assessment. Remember, you will be working outdoors with tools.

- 4 Measure out and cultivate a grid area containing 5 x 4 plots of equal size. Consider experimental design in your choice of location.

- 5 Design your experiment, making sure you include standardisation, randomisation and repetition.

You will be collecting results and completing this experiment later in the chapter.

## DISCUSSION

- 1 Identify the independent and dependent variables.

- 2 Outline how you controlled five variables for standardisation.

- 3 Identify one way you used randomisation in this experiment.

- 4 Did this experiment need a control? Why?



Scaffold

Risk assessment template



Scaffold

Experimental design template



## LET'S REVIEW

## LOOKING BACK

- 1 Define the following terms: treatment group, control, standardisation, replication and randomisation.
- 2 Outline what is meant by the term 'living document', and explain why risk assessments are an example of this kind of document.
- 3 Describe the role of a control in an experiment.
- 4 Explain how experiments can be made valid.
- 5 How can you determine if an experiment is reliable?

## FOR YOU TO DO

- 1 Identify four variables that should be controlled in each of the following experiments:
  - a a field trial testing the yields of five new corn varieties
  - b a feed trial examining the impact of fermented mash on the growth rates of chicks.
- 2 Evaluate the scientific methodology of the following experiment.

A researcher is investigating whether a hormone supplement will increase the pregnancy rates in ewes. The researcher gives the supplement to three ewes: a 3-year-old merino, a 12-month-old Border Leicester and a 2-year-old Corriedale. A control group with two merino cross ewes is also set up. The ewes are pasture-fed and hay is put out every morning for them in a large pile. Water is available in a dam and in a trough. After joining the ewes to a ram, the researcher performs ultrasound scans to see if they are pregnant.

## TAKING IT FURTHER

- 1 Design a valid experiment to test the effect of shearing sheep before blowfly season on the incidence of flystrike. (Hint: flystrike involves sheep blowflies laying eggs on moist, dirty sheep skin. The eggs hatch and maggots then eat the wet, damaged flesh.)

# 5.4 Data collection, analysis and presentation

## Types of data

Raw data is collected through observation and measurement. It is then analysed and presented in the results section of an experimental report.

**Table 5.5** Types of data

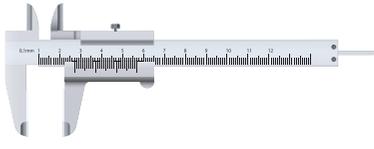
Data Type	Definition	Examples
Raw	Individual measurements and observations taken during the experiment. Raw data is then analysed and processed to find trends and patterns.	<ul style="list-style-type: none"> <li>Individual plant heights</li> <li>Weights of single sheep at a particular point in time</li> <li>Mass of tomatoes off each single plant</li> </ul>
Qualitative	Characteristics and descriptions that cannot be given a numerical value.	Odour, taste, texture, colour
Quantitative	Can be assigned a numerical value and measured objectively.	Temperature, height, mass, circumference
Continuous	Possible values exist between data points.	Time, length, volume, temperature
Discrete	Data with finite values.	Qualitative examples: breed of cow, type of fertiliser Quantitative example: number of apples

## Data collection

### Equipment

The equipment chosen to collect data will depend on what observations and measurements need to be made. Equipment choice will affect the **accuracy** of our measurements. If the live weight scales we are using to weigh cattle with have not been **calibrated**, our results will not be accurate. Interestingly, such results could still be reliable, because each measurement will be incorrect by the same amount.

**Table 5.6** Examples of equipment for measuring results

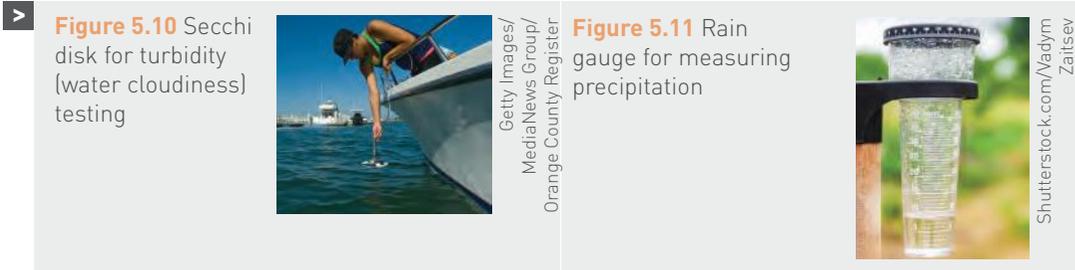
<p><b>Figure 5.6</b> Cattle scales for measuring live weight</p>	 <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Shutterstock.com/fotosaga</p>	<p><b>Figure 5.7</b> Data logger in a greenhouse measuring temperature and humidity</p>	 <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Alamy Stock Photo/Arterra Picture Library</p>
 <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Shutterstock.com/VitaminCo</p>	<p><b>Figure 5.9</b> Calf tape for estimating weight of dairy calves</p>	 <p style="writing-mode: vertical-rl; transform: rotate(180deg);">© The Coburn Company</p>	

**Figure 5.8** Vernier calipers for measuring small distances

**accuracy** how close a measurement is to a true or correct figure

**calibrate** to correct a measuring device by comparing it with a standard to ensure accuracy





**Figure 5.12**  
Evaporation pan for measuring evaporation rate



By Bidgee - Own work, CC BY 3.0, <https://commons.wikimedia.org/w/index.php?curid=3910646>

**Figure 5.13**  
Haematology analyser for measuring substances in blood



Getty Images/  
UniversalImagesGroup

## Data presentation and analysis

### Tables

Tables are a useful way of organising and presenting data. Each table should be self-explanatory and include a title as well as labels and units for all the variables it contains.

Table 5.7 contains raw data, highlighted in yellow, and analysed data, highlighted in blue.

**Table 5.7** Fertiliser concentration and tomato yields

Pot no.	Tomato yield (kg/plant)			
	Control	Treatment group 1 (20 g/L)	Treatment group 2 (40 g/L)	Treatment group 3 (60 g/L)
1	9.2	10.3	13.4	10.2
2	7.3	11.2	12.4	9.3
3	1.3 *	9.5	11.6	9.8
4	11.0	12.6	12.0	7.9
5	7.9	11.5	13.1	9.6
6	9.0	10.8	12.5	9.7
7	9.6	9.7	12.4	11.1
Mean	9.0	10.8	12.5	9.7
Standard deviation	1.3	1.1	0.61	0.97

### Data analysis

Data analysis is carried out to look for differences between treatment group results. If there is a statistically significant difference between treatment groups, we can draw conclusions about the effect of our independent variable on our dependent variable. In other words, data analysis allows us to see if our results support or refute our hypothesis.

### Outliers

The result for pot number 3 in the control group in Table 5.7 has an asterisk (\*) beside it. This data value is an outlier: it is very different to the other values in the group and is most likely due to an error. This plant may have, for example, been attacked by a pest that ate most of the tomatoes. We discount (do not count) obvious outliers in our analysis so that they don't affect our results.

## Measures of central tendency

These calculations are used to describe the centre point of a set of raw data.

The **mean** ( $\bar{x}$ ) is the average value of a set of numbers. It is calculated in the following way:

$$\bar{x} = \frac{\text{Sum of all the values in a data set}}{\text{Number of values in that data set}}$$

or more specifically, for treatment group 1 in Table 5.7:

$$\begin{aligned}\bar{x} &= \frac{10.3 + 11.2 + 9.5 + 12.6 + 11.5 + 10.8 + 9.7}{7} \\ &= 10.8 \text{ kg}\end{aligned}$$

The **mode** is the data value that occurs most commonly. For example, in treatment group 2, 12.4 appears twice whereas all the other numbers appear only once. Therefore, the mode is 12.4 kg.

The **median** is the data value in the middle, when the set is sorted numerically. For treatment group 3 (7.9, 9.3, 9.6, 9.7, 9.8, 10.2, 11.1) the median value is 9.7 kg.

## Measures of variability

These calculations measure the spread or variation of data. Data that is very spread out could indicate an unreliable experiment. Consider the data sets in Table 5.8. Both contain live weights of cattle in trials for different feed supplements. The two groups have the same mean, but the results of animals in treatment group 1 are much less varied.

**Table 5.8** Cattle live weight results

	Weights of individual animals (kg)					Mean	Standard deviation
Treatment group 1	201	199	200	204	196	200	2.92
Treatment group 2	151	200	189	249	211	200	35.6

Standard deviation ( $\sigma$ ) is a measure of data spread. It can give us information on how reliable an experiment is, and can also be used to test whether the results of the experiment are statistically significant. The bigger the number, the larger the spread. The standard deviation of treatment group 2 is much larger than that of treatment group 1, indicating that the results for group 2 are much more spread out (less reliable) than group 1 (more reliable). Standard deviation can be calculated using a mathematical formula, the statistical function on a calculator or on a spreadsheet.

Another measure of spread is the range. This is the difference between the largest and the smallest value in a data set. For example, the cattle in treatment group 1 have a range of  $(204 - 196) = 8$  kg.

## Statistical significance

Several statistical tests can be performed to help us determine if our hypothesis is supported by the results we obtained in an experiment. Many of these, including t-tests, chi-square tests and ANOVA (analysis of variance), involve complex statistical analysis of data. In essence, these tests help us to decide whether any difference we find between our treatment groups is real or just due to chance. Statistically significant differences are those that are likely not due to chance and indicate a real difference between treatment groups.



Worksheets

Use the *Data collection, analysis and presentation* worksheet to review your knowledge about data.

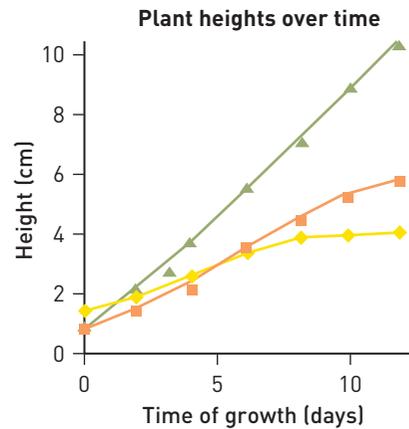
## Graphs

Graphs are useful for showing relationships between variables.

### Line graphs

Line graphs are used for plotting continuous variables, such as time, temperature, mass and volume. The  $x$ -axis should show the independent variable and the  $y$ -axis should show the dependent variable. A line or curve of best fit can be drawn to show the relationship between the independent and dependent variables. It should pass as close to as many data points as possible while following the trend of the all the data points.

Stacked line graphs have more than one line graph drawn on the same axes. These are useful when we want to compare trends between different groups, such as growth rates of chicks on different diets.



**Figure 5.14** A line graph showing plant height over time



Worksheets

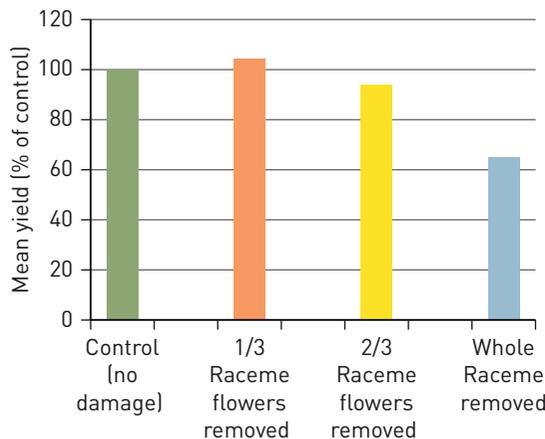
Which graph should you use? Practise with the NelsonNet worksheet

### Bar or column graphs

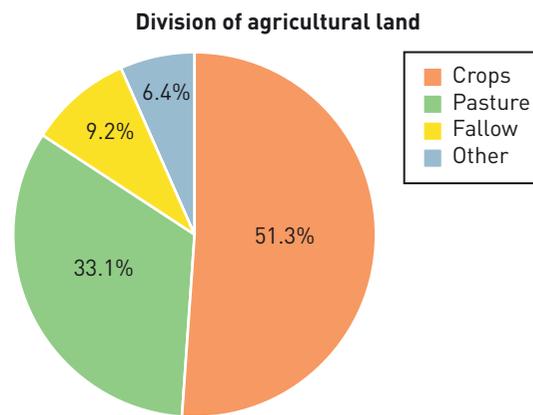
Bar graphs compare discrete variables, such as fertiliser type or breed of cow. Columns are usually presented vertically with the independent variable on the  $x$ -axis.

### Pie charts

Pie charts display discrete variables as portions of a whole group or population.



**Figure 5.15** Bar graph showing production yield



**Figure 5.16** Pie chart showing division of agricultural land



## LET'S ENGAGE

# COLLECTING AND ANALYSING DATA FROM THE MUSTARD TRIAL

## PURPOSE

To collect and analyse data from an experiment. This can be performed early in the growth of the plants, with leaves and stems being collected and weighed. Alternatively, the plants can be allowed to go to seed then the seeds can be collected and weighed.

## MATERIALS

- Quadrats (wire coat hangers bent into a square shape will suffice)
- Scissors or secateurs
- Bags for collection



Alamy Stock Photo/Suzanne Long

**Figure 5.17** A 1 m<sup>2</sup> quadrat being used to randomly select a sample

## METHOD

If you have grown the mustard in a field trial using large plots, there will be too many plants to harvest and collect. Instead, you will need to take a random

sample from each plot. Make a quadrat and use this to take your sample.

- 1 Throw the quadrat into one plot at a time. Make sure it lands so that the inside area is completely filled with mustard plants.
- 2 Harvest the mustard in the quadrat (leaves and stems or seeds) and place in labelled bags. If you have grown mustard in pots, simply harvest all the mustard in each pot.
- 3 Repeat this process with the remaining plots or pots.
- 4 Construct a table to record your results.
- 5 Weigh each bag and complete your table.

## DISCUSSION

- 1 Analyse your data by calculating means and ranges for each treatment group.
- 2 Draw a bar graph with mustard variety on the x-axis and yield (grams) on the y-axis.
- 3 Interpret your results. Which variety had the highest yield? Which one would you recommend to a mustard farmer?

Note: see the review section of 5.5 for instructions on completing your experimental report.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the following terms: raw data, qualitative data, quantitative data, discrete data and continuous data.
- 2 Why do we discount outliers?
- 3 Outline the importance of measures of spread, including standard deviation and range, in analysing data.
- 4 On which axis on a graph should the independent variable be plotted?

### FOR YOU TO DO

- 1 Classify the following data as qualitative, quantitative, continuous or discrete: temperature, pH of soil, concentration of urine, colour, number of eggs produced, rate of photosynthesis, odour, area, presence or absence of horns.



- 2 Identify the most appropriate way(s) to present the following data. Justify your decisions.
- a breakdown of the proportion of minerals, water, air and organic matter in soil
  - raw numerical data in the form of cattle liveweights collected in the field
  - results from an experiment testing the effect of carbon dioxide concentration on plant growth
  - a comparative study on the growth rates of four different breeds of goat
- 3 The following data was collected by a farmer who was testing the effect of a new feed pellet on the growth of sheep.

Pen 1: Hay diet (kg live weight)	Pen 2: Hay + pellet diet (kg live weight)
32, 32.5, 31, 32, 33, 32.5, 33.5, 35, 30, 29.5, 29.5, 30.5, 31, 31, 32.5, 33, 35, 31.5, 36, 29.5, 30, 31, 33.5, 34, 34.5	41, 42, 41, 45, 44, 39, 39.5, 41.5, 46, 50, 41, 42.5, 48, 46, 41.5, 42.5, 43, 43, 46, 45.5, 41.5, 46, 46, 39, 39.5

- For each group, calculate the:
  - mean
  - median
  - mode
  - range
- Draw a bar graph comparing the means for the two groups.
- Based on your analysis of this data, would you recommend these pellets? What other information would be useful before you made your recommendation?

### TAKING IT FURTHER

- Investigate the use of dataloggers in agricultural experiments.
- Design a piece of equipment to measure one natural variable. For example, a rain gauge to measure precipitation

## 5.5 Discussing results and concluding experiments

### Discussion

The discussion of an experiment should include:

- An interpretation of results
 

Did you find a relationship between the independent and dependent variables? Graphs are a useful tool to determine whether such a relationship exists. Can you explain your findings? Most importantly, what do your results mean for the real world? Make recommendations to farmers and other interested parties based on your findings.
- An evaluation of the methodology
 

Evaluate the validity and reliability of your experiment. Were there any issues with your experimental design that affected the outcome?
- Identification of problems and future solutions
 

Discuss issues you had during the experiment and ways you overcame them. Identify solutions to these problems that could improve future experimental designs.
- Further areas of investigation
 

Often, finding the answer to one research question raises many other research questions. A discussion is a good place to identify these questions so future researchers can design experiments and test them.

### Conclusions

A conclusion is a brief statement that points out whether the hypothesis of the experiment was proven to be correct, incorrect or partially correct.

## INDUSTRY IN FOCUS

### AGRICULTURAL RESEARCH SCIENTIST

#### Identify

Agricultural research scientists work with governments, farmers and companies to solve real-world problems in plant and animal production. Research scientists often share their time between working in the laboratory or office and outside on farms and agricultural research facilities. They are responsible for designing and conducting experiments and making recommendations based on their findings.

Agricultural research scientists need to study science at university and undertake further postgraduate study in an area of specialisation.

**Table 5.10** Recent innovations and findings from agricultural research scientists

Innovation	Finding
'Hacking' of photosynthesis	Tobacco plants have been genetically modified to grow 40% faster. Research scientists introduced a gene into tobacco plants that helps detoxify compounds produced during photosynthesis. Scientists are now working on applying this to food crops.
Drought-proofing plants	Australian researchers have found a sensor inside plant cells that tells the cells there is a drought. The plants then make beneficial compounds that help them cope with dry conditions. Damage to plant cells is reduced by turning this sensor on early.
Tackling the European carp problem	Researchers are investigating the use of a herpes virus to kill carp in the Murray–Darling river systems. Carp are an introduced pest species that damage river banks, silt up rivers, and compete with and prey on native fish species.

#### Discussion

- 1 Explain the role of agricultural research scientists.
- 2 Outline the qualifications needed to become a research scientist.
- 3 What kind of personal qualities do you think an agricultural research scientist would need to possess?
- 4 Investigate one of the areas of agricultural research listed above, or one of your own choosing. Summarise the aim of the research and report on the significance of this research to the agricultural sector.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify the four key areas of a discussion.
- 2 What information should a conclusion contain?

### FOR YOU TO DO

- 1 Complete your report for the mustard trial.
  - a Write a discussion and conclusion for this experiment.
  - b Evaluate the validity and reliability of this experiment. How could we make it more valid and reliable?

### TAKING IT FURTHER

- 1 Peer review is a process where other expert scientists in a particular field of knowledge look at new research and evaluate whether it is valid and reliable. Use the digital Peer Review template to review another student's experimental report.



Scaffold

# Let's summarise

## What role does research play in agriculture?

Research is central to innovation and improvement in agriculture. Construct a mind map explaining the key reasons for agricultural research, who funds it and who benefits. Use some or all of the following examples in your mind map. Include more of your own choosing.

Government	Corporations	Climate change
Animal welfare	Economic	Farmers
Research scientists	Environmental research scientists	

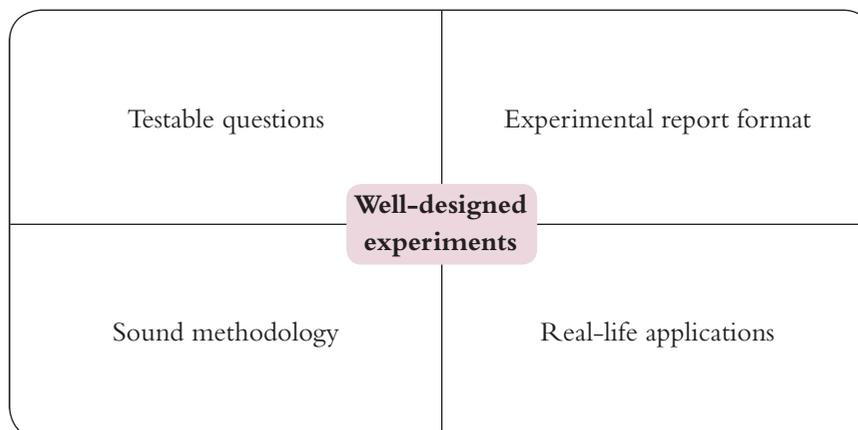


Practice quiz

Complete the chapter review test on NelsonNet to review what you've learnt about conducting agricultural research.

## How can I design a valid and reliable agricultural experiment?

Well-designed experiments need to answer testable questions relating to real-life problems. They need to adhere to the correct reporting format, and they need to be constructed using sound methodology. Review what you have learned in this chapter and copy out and fill in the boxes below with examples of how experiments can achieve these standards.



# Plant enterprises

Section

2



## CHAPTER 6



# Vegetable market gardening

## CHAPTER SUMMARY

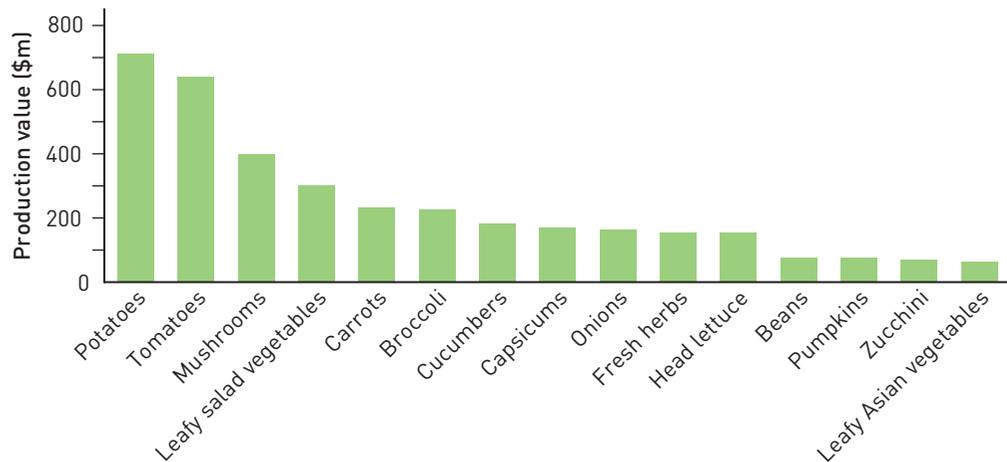
Vegetables are one of the most used products in agriculture. Almost every household will use vegetables in daily life. Vegetables have been farmed for centuries, with Aboriginal peoples digging yam daisies from the ground prior to European settlement. Sustainable vegetable-growing practices, such as crop rotations and clever management of water and soil, enable farmers to grow vegetables efficiently. Investigation of the best growing methods for plants and knowledge of plant management techniques can be used to grow and monitor your own vegetables.

**How can we manage the environment to successfully grow vegetables?**

**How can we sustainably grow vegetables in our own backyards?**

## 6.1 Introduction

There are many ways to define vegetables, but this chapter will look at the edible produce of market gardeners and larger scale vegetable growers, including crops grown for their fruit, leaves, stems, roots and seeds. The vegetable industry contributed \$4.148 billion to the Australian economy in 2018-19. Potatoes are the bestseller with 1.3 million tonnes produced annually, valued at approximately \$745 million. They are closely followed by tomatoes, mushrooms, leafy salad vegetables and carrots. Vegetables are the fourth-highest valued agricultural industry in Australia, after beef, wheat and milk.



Australian Horticulture Statistics Handbook, 2016/17

**Figure 6.1** Most popular vegetables produced in Australia by production value

There are approximately 2300 vegetable farms in Australia. These are a mix of intensive farms (high production in small areas) or extensive farms on large areas of ground. Thirty per cent of these farms are less than 5 hectares. Most of these intensive farms are located close to major towns and cities, but these are under threat from urbanisation as cities and towns continue to expand.

## 6.2 Functions and structures

### Functions

**herbaceous** plants with little or no woody tissue, usually grown in one season

**perennial** a plant that lives for more than two years without needing to be re-sown

Vegetables are plants of which at least one part is used for food. Vegetables come from different parts of a plant, such as the leaves, flowers, roots, seeds, buds, fruit and stem. They are typically classified as **herbaceous** plants that are grown seasonally. Some vegetables are harvested for a second year or can be **perennial**, such as asparagus and warrigal greens.

**Table 6.1** Vegetables are classified according to the part of the plant that is eaten

Part of the vegetable	Examples
root	carrot, beetroot, turnip
stem	celery, asparagus
leaf	lettuce, kale, spinach
bud	Brussels sprouts
seed	corn, sugar snap peas
flower	broccoli, cauliflower, artichoke
fruit of the plant	tomato, capsicum, zucchini, watermelon
bulb	onion, fennel, garlic



## LET'S DISCUSS

- 1 Brainstorm different vegetables that can be eaten (try to think of ones not in the table above).
- 2 Categorise the vegetables according to the part that is eaten.

Vegetables can be classified into other groups as well, including:

- country of origin: for example, Europe – celery, lettuce, asparagus; Asia – Chinese cabbage, bok choy, pak choy
- botanical name and the plant family they belong to, as seen in Table 6.2.

**Table 6.2** Plant families

Family name	Examples
<i>Allium</i>	garlic, onions, leek
<i>Brassica</i>	broccoli, cabbage, cauliflower
<i>Cucurbits</i>	pumpkin, cucumber, gourds
<i>Fabaceae</i>	beans, peas, snow peas
<i>Solanaceae</i>	potatoes, tomatoes, eggplant
<i>Umbelliferae</i>	carrots, celery



The most popular vegetables in Australia are carrots and potatoes, with 93% of Australian households purchasing these vegetables!

# Structure

## Parts of a plant

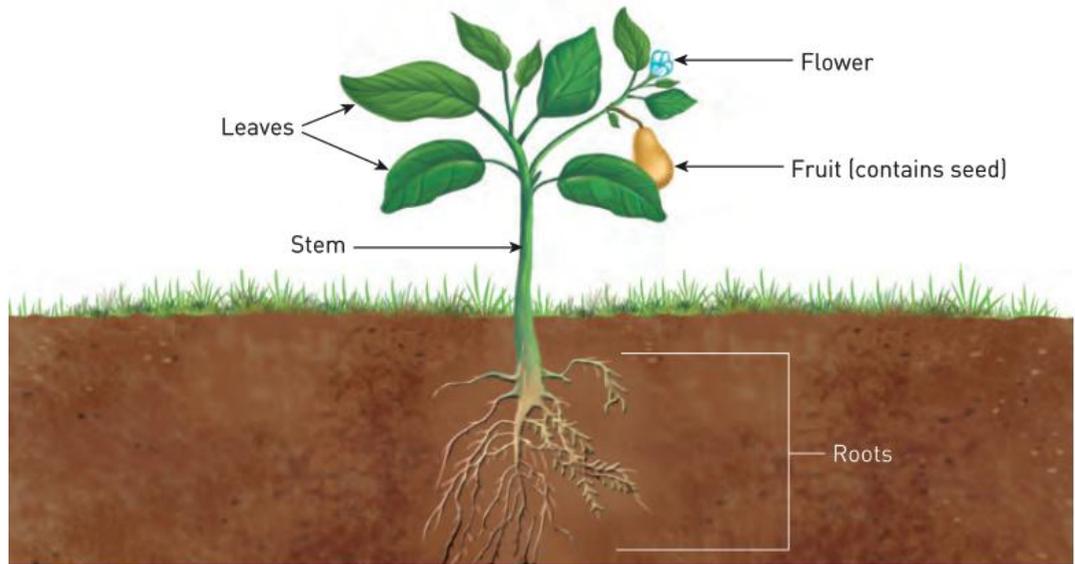


Figure 6.2 Diagram of a typical plant

## The seed

**dicotyledon** plants that, among other traits, have a pair of special leaves called cotyledons that emerge from the seed. These cotyledons contain a food source for the newly emerged seedling.

**monocotyledon** plants that have only one seed leaf and whose seeds contain endosperm to provide nutrients for the seedling

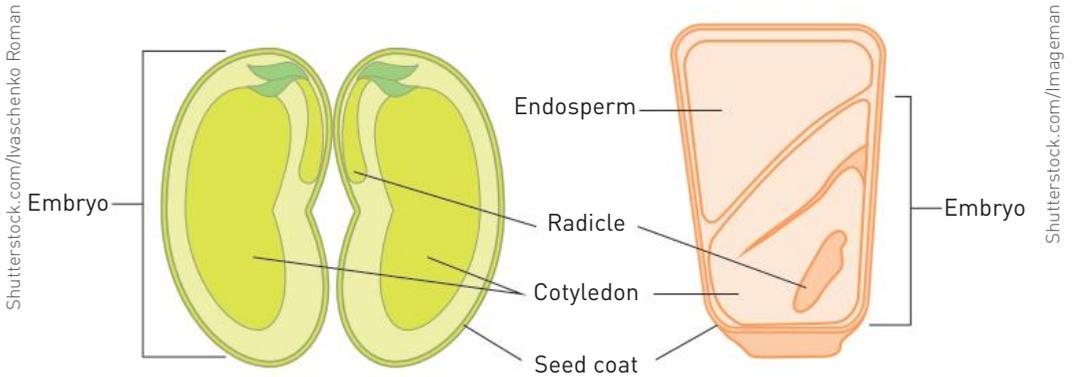


Figure 6.3 Inside of a bean (dicotyledon) and corn (monocotyledon) seed

Table 6.3 Parts of a seed

Term	Definition
Embryo	Initial stage of development for the future plant – a baby plant
Radicle	The first part of a seed to emerge; it becomes the roots of the plant
Cotyledon	The seed leaves; first leaves of the plant
Seed coat	Outside of the seedling, a protective cover
Endosperm	The tissue surrounding a seed embryo, providing it with nutrition

The seed contains the embryo, or baby, of a new plant. It contains a source of nutrition for the embryo and is covered in a protective coating, allowing it to survive until the conditions are right for **germination**. During germination, the seed swells with water and a first root and shoot emerge.



## LET'S ENGAGE

### COMPARING TYPES OF SEED

#### PURPOSE

To identify the difference between a corn seed (monocot) and a bean seed (dicot)

#### MATERIALS

- Bean seeds
- Corn seeds
- Petri dish
- Water
- Scalpel
- Pen and paper

#### RISK ASSESSMENT



Scalpels should be handled with care.

#### METHOD

- 1 Soak the seeds in water for at least a few hours (or overnight).
- 2 When soft, gently dissect the seeds, cutting each in half.
- 3 Draw a sketch of the inside of each seed.
- 4 Label your sketch. Use Table 6.3 and Figure 6.3 to help you identify different parts of your seed.

#### DISCUSSION

- 1 Describe the differences between the cotyledons of the two seeds.
- 2 Was one seed easier to dissect than the other? Can you explain why?
- 3 Identify the region in each seed that provides nutrition to the seed and newly emerged seedling.
- 4 Now germinate some of the seeds, and examine them during the process of germination.
  - a Do shoots or roots emerge first?
  - b Describe differences between the appearance of seed leaves.
  - c What happens to the seed coat in each example?

**germination** the sprouting of a seed to produce a seedling

### The roots

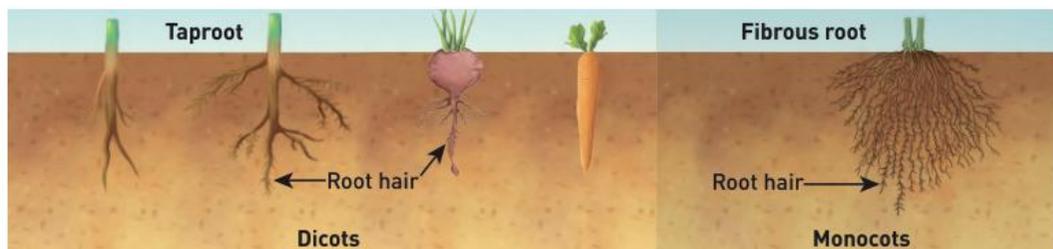


Figure 6.4 Types of roots

**taproot** a main root that descends from the base of the stem on a dicot plant seed as a primary root and produces numerous branches. Taproots often store sugars and starches.

**fibrous roots** multiple roots that come off the base of the stem of a monocot plant seed and branch out in all directions

The roots anchor the plant into the soil, absorb minerals and water, and sometimes store sugars and starches. Water and dissolved nutrients are absorbed through tiny root hairs into the plant roots.

### The stem

The stem holds the leaves and flowers up in the air. The stems also contain the phloem, which transports sugars, and xylem, which transports water and mineral nutrients around the plant.

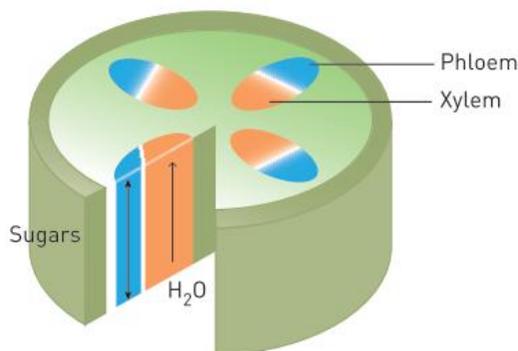


Figure 6.5 The phloem and xylem



### LET'S ENGAGE

## OBSERVING STEMS

### PURPOSE

To identify how water travels up the stem of celery

### MATERIALS

- Few drops of food dye
- Beaker of water
- Fresh stalk of celery

### METHOD

- 1 Place a few drops of food dye in the beaker of water.
- 2 Cut off the bottom of the celery.
- 3 Place the stem into the beaker of water and observe at regular intervals over the next two days.

- 4 As soon as the dye starts to be taken up by the celery, cut a thin cross section from one stem and examine under a microscope. Make a drawing showing the location of the xylem (it will be stained by the food colouring).

### DISCUSSION

- 1 Draw a diagram showing the passage of water up the celery stalk. Make sure to label your diagram.
- 2 How long did it take for food colouring to reach the leaves?
- 3 What environmental or climate factors might affect how much water and nutrients will be transported up stems?

### The leaves

The leaves are the most important part of the plant because photosynthesis occurs there. Photosynthesis is when the plant absorbs carbon dioxide and water and, using the energy from sunlight, produces glucose and oxygen. The leaves contain tiny holes called stomata. Carbon dioxide and oxygen travel through these holes, in and out of the leaves. Water evaporates through the stomata, and this causes more water to be sucked up the xylem, just like drinking through a straw. This process is called transpiration and brings water and dissolved soil nutrients needed for growth and development up into the plant tissue.



Respiration is when the plant uses the glucose produced by photosynthesis and oxygen to supply itself with its energy requirements. Respiration occurs all the time, while photosynthesis only occurs in daytime.

## The flower

Flowers are the sexual reproductive structures of plants. Male sex cells, the pollen, are produced on the anthers. Female sex cells are called ovules and are held inside the ovary. Some plants have flowers with both male and female parts (example, tomatoes). Others possess these separately. For example, pumpkin plants have separate male and female flowers. Other plants, such as avocados, have only male or female flowers.

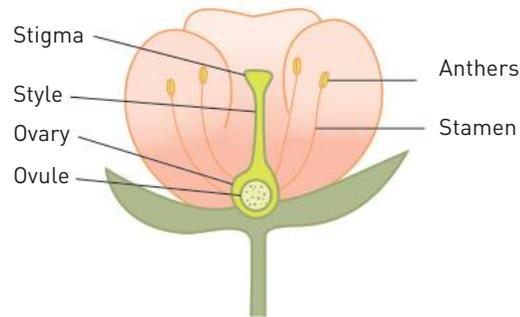


Figure 6.6 Parts of a flower

Plants reproduce sexually through a process of pollination followed by **fertilisation**.

Table 6.4 Parts of a flower

Term	Definition
Stigma	A sticky surface to which pollen attaches during pollination
Style	A thin tube through which the pollen tube moves to reach the ovary
Ovary	Site of the female reproductive cells, or ovule
Ovule	Female reproductive cells (once fertilised will develop into seeds)
Stamen	Holds anthers up
Anthers	Site of pollen production

Pollination involves the transfer of pollen from the anthers to the sticky surface of the stigma. A plant can pollinate itself in a process called self-pollination. One flower can also pollinate a flower from another plant, a process called cross pollination. Pollination can occur via the wind (with plants such as corn), the movement of animals, and, importantly, through the actions of pollinators such as bees.

Once the pollen lands on the stigma, it forms a pollen tube and the male sex cell is transported down the style to the ovary. The fusion of the male pollen cell and the female ovule is called fertilisation and produces an embryo or seed.

**fertilisation** the fusion of male and female sex cells to produce an embryo



Worksheets

Review the functions of different parts of a plant with the NelsonNet worksheet.



## LET'S REVIEW

### LOOKING BACK

- 1 Explain the role of the following plant parts: stem, leaves, roots and flower.
- 2 How does water move through a plant?
- 3 Explain the difference between cross-pollination and self-pollination.
- 4 Group the following vegetables by the part of the plant that is eaten:

Carrots	Jalapeno	Cucumber
Eggplant	Celery	Asparagus
Broccoli	Pak choy	Leek
Onion	Lettuce	Pumpkin





Weblink

Harvest to Home Quickfacts

### FOR YOU TO DO

- 1 Go to a grocery store and list all the different vegetables you can see. Highlight all the Asian-style vegetables in pink and all the European-style vegetables in yellow.
- 2 Make a poster showing all structures in a typical plant.
- 3 Pick a vegetable at Nielsen's Harvest to Home Quickfacts webpage.
  - a Describe how Australians purchased this vegetable in 2018.
  - b Pick another vegetable. Describe how purchasing differs between the two.

### TAKING IT FURTHER

- 1 Investigate the different Asian vegetables that are now being grown in Australia.
- 2 Research the role of bees in the pollination process.
- 3 Investigate plants requiring wind pollination.
  - a List some plants requiring wind pollination.
  - b What type of weather would be best suited for these plants?
  - c Where in Australia might you find these crops?
  - d What factors would farmers have to consider when planting a crop requiring wind pollination?

## 6.3 Production

### Production cycle

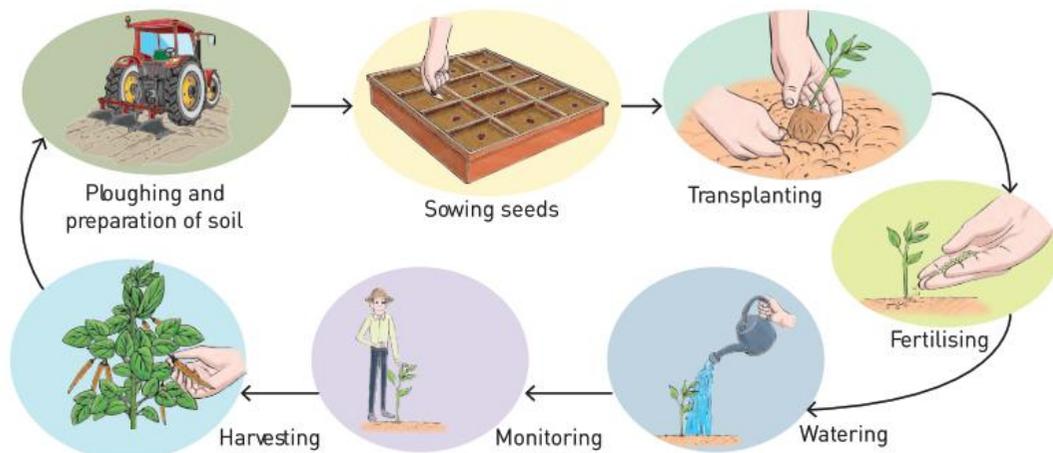


Figure 6.7 Vegetable production cycle

### Soil preparation

Many different tasks need to be completed to prepare the soil before planting. These can include ploughing, soil testing, adding amendments or organic matter to the soil, and weed control.

#### Soil testing

Soil tests are conducted to test chemical and nutrient levels (such as nitrogen and phosphorus) as well as acidity (pH of the soil). Farmers can then add amendments to the soil, such as adding lime to very acidic soils or nitrogen to soils low in nitrogen, to ensure their crop is healthy and productive.



Worksheets

Make sure you know what tools to use and how to use these safely by completing the NelsonNet worksheet before you begin planting.

## Ploughing

Ploughing loosens the soil to allow seeds or seedlings to be planted. This allows them to better absorb the moisture and nutrients from the soil. Ploughing can be done by machines such as a rotary hoe, disc plough or by hand using tools such as a three-pronged cultivator.

## Weed control

Farmers need to watch out for weeds, which are defined as any unwanted plants. Farmers can use ploughing, herbicides or other weed control measures to control weeds before sowing. Weeds outcompete seedlings for water, nutrients and sunlight. They can also harbour pests and diseases. Farmers can control weeds using integrated weed management (IWM) strategies such as those in Table 6.5.

**Table 6.5** IWM strategies

IWM component	Strategies
Cultural	Using correct planting density; choosing vigorous crops
Physical	Removal by hand or machinery
Biological	Using natural pests or predators
Chemical	Using herbicides

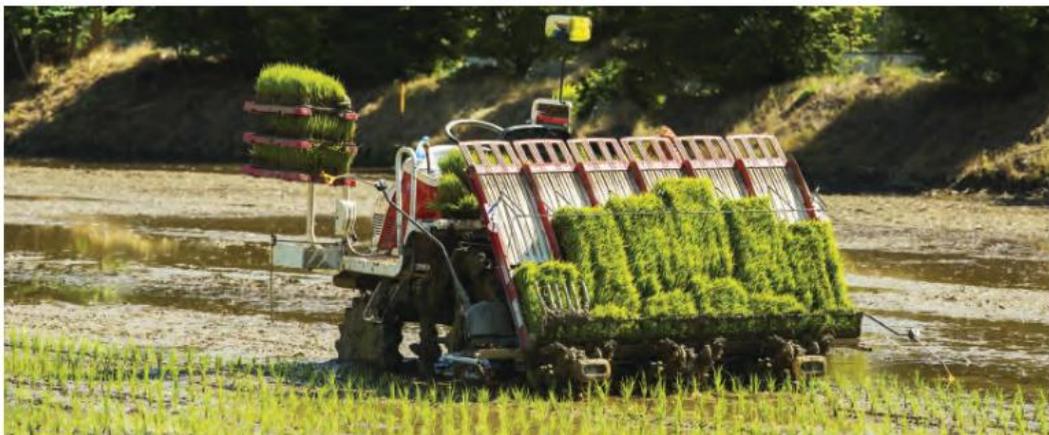
## Seed propagation and sowing

Propagation refers to any form of growing new plants from existing plants. Some vegetable seeds, such as carrots, are best sown directly into the soil in which they will grow. This is called direct sowing. Other vegetable seeds are best sown into seedling trays or punnets and grown in greenhouses, shade houses or polytunnels until they are strong enough to be transplanted.

## Sowing

Careful monitoring of the sowing depth is crucial to ensure successful germination. Too shallow, and the seed will dry out or be eaten by pests, too deep and the plant will not reach the surface. The rule of thumb is to plant the seeds two to three times as deep as they are long. While this generally works, it is always best to follow the sowing guide on the packet. To germinate successfully, seeds need water, warmth and oxygen. No nutrients are needed until the plant reaches the surface and its second leaves emerge.

## Transplanting



**Figure 6.8** A seed transplanting machine



Worksheets

Complete the *Why are weeds so successful?* worksheet to understand more about managing weeds in your local area.

Seed transplanting is planting a seedling into its permanent location. Seedlings propagated in polytunnels, greenhouses or shade houses should be hardened off before transplanting. This involves gradual exposure of the seedlings to the outdoor environment (for example, harsh sunlight or cool nights).

When transplanting it is crucial to allow the plant to have adequate space to grow. Every vegetable requires different **row spacing** and **plant spacing**. A hole or trench is dug in the prepared seedling bed. Fertiliser, compost or other amendments are sometimes added to the hole or mixed into the soil before transplanting. The hole must be watered, then carefully remove the seedling from the tray or punnet, being careful not to disturb the roots and keep as much of the seed raising mix around the roots as possible. The seedling should be carefully placed in the hole, then backfilled up to the base of the stem. Seedlings can suffer from transplant shock. To avoid this (and make sure the seedling has a chance to grow into a productive plant), it should be watered regularly.

**row spacing** the space between the rows

**plant spacing** the space between the growing plants



Use the Gardenate website to help determine row and plant spacing.



How does plant spacing affect yield? To investigate, check out the data scenario on NelsonNet.

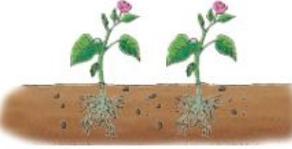
### Fertilising

Fertilising is the act of adding essential nutrients to the soil to aid the growing crop. Fertilisers can be organic (such as animal manures or mushroom compost) or inorganic (such as superphosphate). Inorganic fertilisers such as urea can provide an immediate source of nutrients to the plants (quick-release fertiliser). The exact concentration of nutrients is known, so they can be measured precisely and the exact amount required used. Organic fertilisers, such as animal manures, need to be broken down before plant roots can absorb them; the nutrients are not immediately available to the plants (slow-release fertiliser). While large amounts of organic fertilisers are required, they help soil structure and microbial life.

Fertilising soil can be done by other plants. Crop rotations and using legumes, such as snow peas, mung beans and soybeans, play an important part in maintaining healthy soil. The legumes put nitrogen into the soil, improving the soil quality naturally.

Table 6.6 lists different methods of fertilising your plants.

**Table 6.6** Different methods of fertilising

Fertilising method	Description
Direct placement 	<ul style="list-style-type: none"> <li>• Place at the base of the crop</li> <li>• Direct</li> <li>• Labour intensive</li> <li>• Need to water after fertiliser has been placed</li> </ul>
Broadcast spreader 	<ul style="list-style-type: none"> <li>• Fast placement</li> <li>• Spreads over crops via tractor attachment</li> <li>• Can also have a hand-wheeled version</li> </ul>
Band 	<ul style="list-style-type: none"> <li>• Fertiliser placed in bands next to rows</li> <li>• 2.5 cm over and 2.5 cm down from the seed</li> <li>• Done at same time as sowing/transplanting</li> </ul>
Side dressing 	<ul style="list-style-type: none"> <li>• Similar to band but applied later</li> <li>• Can be placed in circle around plants or alongside</li> <li>• Extra nutrients for plants</li> </ul>

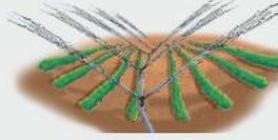


► Foliar spray



- Apply liquid fertiliser direct to leaves
- Good short-term fix for struggling plants
- Should be used alongside soil fertilisers

Irrigation water



- Mix fertiliser with irrigation water
- Supply as per irrigation system used
- Process is called fertigation

Macronutrients are nutrients that plants need in large amounts. Micronutrients or trace elements are nutrients that plants need in small doses.

The three main macronutrients, nitrogen, phosphorous and potassium, are often referred to as NPK. The NPK ratio of a fertiliser tells us how much of these macronutrients is present. Table 6.7 demonstrates why they are the most important nutrients for plant growth and development.

**Table 6.7** Most important nutrients

Nitrogen (N)	Phosphorous (P)	Potassium (K)
Promotes leaf growth	Promotes development of roots, seeds, flowers and fruit	Promotes stem, flowers and fruit growth



## LET'S DISCUSS

- Which of the three major nutrients would be most useful for the following plants?
  - A seedling just transplanted, with a strong stem but weak leaves
  - A newly sown crop of carrots
  - A tomato plant yet to form any flowers
  - A plant with unhealthy, yellowing leaves

## Monitoring

A growing crop needs monitoring for any sign of pest or disease problems. Some crops, such as tomatoes, require **trellising**. Regular weeding is required to reduce the competition and mulch should be added to assist with weed control.

**trellising** supporting growing plants with stakes or wires to grow up

## Irrigation

Irrigation is the process of watering the plants. Plants need to be watered regularly because natural rainfall is not reliable. Water is required for photosynthesis and transpiration, and therefore plant growth. Irrigation systems can be set up for larger areas to enable more efficient and effective watering. Irrigation systems include sprinkler, drip, sub-irrigation and sprayers.

## Harvesting

Harvesting is the picking of the crop when it is ready. Growers inspect the crop and will often pick or harvest the crop before it is ready. This is to ensure the crop will arrive in the best possible condition ready for the consumer to use. Features the growers look for include size, shape, colour, texture, crispness, sweetness and blemishes. Tomatoes are ideally picked before



Worksheets

Use the information gathered in the production cycle section to plan your own vegetable garden with the NelsonNet worksheet.

turning fully red. Broccoli should be picked when the flower buds are still closed. Potatoes are harder to see when ready because they grow underground. However, when the stems and leaves growing above the ground die, the potatoes are ready to harvest.

Harvesting can be done by hand or machine, depending on the specific crop and growing method.



Video

Watch cabbage and carrots being harvested



Video

Watch tomatoes being harvested



Shutterstock.com/Jackson Stock Photography

**Figure 6.9** Carrots being harvested

## DID YOU KNOW?

Carrots were originally white, yellow and purple, but the Dutch selectively bred them to be orange as a tribute to the Dutch royal family.



## LET'S ENGAGE

### FROM SEED TO VEGETABLE

#### PURPOSE

To investigate 'three sisters planting', and successfully grow and monitor a bean, corn and squash crop. Three sisters planting is a type of companion planting: the bean crop is a legume, so provides nitrogen to the soil; corn provides trellising or support for the climbing bean; and squash suppresses weeds.

*Note: these crops like to be direct sown, so make sure you sow in a garden bed or large pots.*

#### MATERIALS

- Garden area or large pots (approx. 50 cm diameter)
- Seed-raising potting mix
- Bean seeds
- Corn seeds
- Squash seeds
- Water can
- Mulch
- Fertiliser
- Paper cups or seedling trays





## RISK ASSESSMENT



Use the risk assessment template on NelsonNet to conduct a risk assessment for growing three vegetables. Consider the risks of working with soil and fertiliser.



Scaffold

Risk assessment template

### METHOD

- 1 If using pots, fill with seed-raising mix. Otherwise, prepare the garden bed and cultivate the soil to form a fine seed bed.
- 2 Prepare three holes for sowing, in a triangle, with 30 cm between each hole.
- 3 In one hole, sow two corn seeds, in the next sow two bean seeds, in the third two squash seeds, according to the packet instructions.
- 4 Mulch the area around the seeds but not over the seeds.
- 5 Water in well.
- 6 Do not water the bean seed again until it emerges; water the others as required until germination.
- 7 Thin out to one of each plant once germinated.
- 8 Monitor your growing crops! Make sure to water and fertilise as required. It will take around 60 days until they are ready to harvest, but this length of time varies between each of the crops.

### DISCUSSION

- 1 Keep a diary on the growing crop. Each week, take a photo and measure height. In your vegetable diary, keep track of key stages noted in the table below.

Part	Corn	Bean	Squash
Days to germination			
Stem			
When the first leaf appears Sketch the first leaf			
When the second leaf appears			
Appearance of the flower(s)			
Fruit – when does the fruit/cob/pod start being produced			
When ready to harvest, pull out the plant and sketch the root system			

- 2 Which were monocots, and which were dicots? (Hint: base your decision on the appearance of the first leaves.)
- 3 Outline the relationships between the plants.
- 4 Describe the differences in reproductive structures (flowers) of each crop.
  - a How many flowers were they on each plant?
  - b Which flowers produced the harvestable crop?
- 5 Explain how the following factors affect production:
  - a temperature when transplanted
  - b frequency of fertiliser use
  - c use of mulch.

## Production systems

There are a variety of methods to grow vegetable crops.

### Garden beds vs greenhouses

The conventional method for growing vegetables is in prepared soil beds, usually exposed to the elements. In contrast, greenhouses are large shed-like structures that can be glass, special plastics or shade cloth. Greenhouses allow plants to be grown all year round in a controlled environment.

### Hydroponics

Hydroponics is the practice of growing vegetables without soil. The vegetables are grown in trays using soil alternatives such as vermiculite, perlite, rockwool or coconut fibre. You can learn about hydroponics in Chapter 15.

### Polytunnels

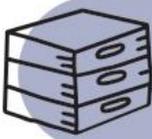
Polytunnels are lightweight greenhouses, either small or large, that use poly pipes to form semicircular hoops which are then covered with builders' film or shade cloth. The tunnels are often used to propagate seeds in seedling trays.

Dreamstime/Eagle



Shutterstock.com/city hunter

**Figure 6.10** Small and large polytunnel vegetable production



## COMPARING SEED PROPAGATION METHODS

### PURPOSE

To compare growing seedlings with or without a polytunnel

### HYPOTHESIS

Do you think seedlings will grow fastest with or without a polytunnel?

### RISK ASSESSMENT



Conduct a risk assessment using the template on NelsonNet.

### MATERIALS

- Polytunnel or polytunnel kit
- Six seedling trays (three for each treatment group)
- Seed-raising mix
- Radish or silverbeet seeds
- Icopole sticks
- Permanent marker
- Suitable area outside to place trays

## LET'S EXPERIMENT



Scaffold

Risk assessment template



Weblink

Polytunnel kit





### METHOD

- 1 Prepare the polytunnel using the instructions on the kit.
- 2 Fill each seedling tray with seed-raising mix.
- 3 Randomly assign 10 seeds to each tray. Ensure you have the same sowing density and sowing depth for each tray.
- 4 Use the icypole sticks to label the trays with the numbers 1 to 6, the date and the location.
- 5 Place three of the trays in the polytunnel. Place the other three trays in a warm, sunny place near the polytunnel. This is your control group.
- 6 Water all trays. Ensure each tray is watered the same amount at the same time each day.

### RESULTS

- 1 Construct a table to record the growth rates of three seedlings randomly selected from each tray. Measure their heights and calculate the average height for that tray. After all trays in a group are measured calculate the average of the group overall.
- 2 Draw a stacked line graph tracking the growth rate for each group over the 15 days (use the 'Average of group' columns to create your graph).

### DISCUSSION

- 1 Interpret your results. Which method produced the fastest growing rate?
- 2 What kinds of climates would be best suited to using polytunnels?
- 3 Were there any other advantages of using polytunnels in your experiment?
- 4 How could you improve this experiment?
- 5 Would you recommend farmers use polytunnels to grow seedlings? Give reasons for your recommendation.

### CONCLUSION

Was your hypothesis correct, incorrect or partially correct?

## Organic farming

Organic farming uses conventional growing methods without artificial fertilisers and chemicals. Organic growers use natural methods to control weeds, pests and diseases.

## Bush food production

Bush foods are any food native to Australia that Aboriginal and Torres Strait Islander peoples gather to eat. These peoples use the environment, creating meals that are rich in protein, fibre, nutrients and sugars. One interesting bush food is the yam daisy. This plant is a root vegetable that was very common before European settlement. You can still find yam daisies in the bush in Victoria and NSW. Yam daisies were dug out with sticks and the roots baked in earth ovens for food. Aboriginal Australians knew to harvest the yam daisies when the plants flowered – yam daisies produce a bright yellow flower, which makes it easy to tell when they are ready to harvest.

The yam daisy is reasonably easy to grow, and seed is available through specialist stockists. It prefers a nice moist soil in full sun and will grow well in pots as long as it is not shaded by other plants or placed in an area with too much shade.

Warrigal green is a popular leafy green vegetable that is native to Australia. It was used in early European settlements as a spinach substitute and is still used and cooked like spinach. While there isn't much evidence that this plant was used by Aboriginal Australians, it was



Worksheets

Find out more about organic farming by completing the *Organic Russian garlic* worksheet on NelsonNet.

used by the Maori in New Zealand and as such is often called New Zealand spinach. The Maori would boil the leaves of the warrigal green with the roots of other plants to reduce the bitterness. This leafy green plant grows well in sunny to shady spots and a range of soils, although it prefers salty soil such as coastlines. The leaves can be harvested as required.

## DID YOU KNOW?

Warrigal greens should be boiled or blanched before eating because they contain a toxin that can be harmful to humans in large quantities – boiling or blanching reduces the levels of this toxin.



Web link

Research how Aboriginal peoples use other vegetables in their meals.



## LET'S DISCUSS

- 1 How do Aboriginal production methods differ from European methods?
- 2 Which method do you think is most sustainable?



## LET'S REVIEW

### LOOKING BACK

- 1 Draw a diagram of the vegetable production cycle.
- 2 Explain how to transplant a seedling.
- 3 What is the difference between organic and inorganic farming?
- 4 Describe the different systems used to grow vegetables.

### FOR YOU TO DO

- 1 Design an experiment to investigate how sowing depth affects germination.
- 2 Research the production systems used in your local area. Can you find a farm that uses each of the following production systems? Garden beds, hydroponics, greenhouses, polytunnels and organic farming.
- 3 Survey parents and teachers about their attitudes towards organic production.
- 4 Research how yam daisies were affected by grazing livestock.

### TAKING IT FURTHER

- 1 Watch the video with Wiruungga Dungiir, an Aboriginal Australian elder, discussing different native plants and how they can be used. Answer the following questions.
  - a Describe the process to grow seedlings from seeds with bark.
  - b What else can the bark be used for?
  - c Research what a food forest is.
  - d Design a plan for a food forest at your school farm.
- 2 Select a vegetable and design a leaflet detailing how to grow the vegetable.
- 3 Evaluate the effect of organic and inorganic fertiliser on the soil.



Video

Food forest  
Abundance Part 1:  
Walk with Morag  
and Wiruungga



Web link

Organic vs inorganic  
fertilisers

## 6.4 Management

### Environmental management

#### Distribution of enterprise

Vegetables are grown in many areas throughout Australia. The use of greenhouses and hydroponics means vegetables can be grown all year round, protecting them from the weather. In 2016–2017 there were 2300 Australian farm businesses growing vegetables. These farms ranged from less than 20 hectares to larger farms planting over 70 hectares.

#### Climate

The sun provides both heat and light for plants. The amount of each guides which vegetables are selected to grow at what time of year and where. Growing guides are useful tools to help the grower select the best vegetable for their region.

Plants require a certain amount of day length to encourage flowering. The length of light period in a day is known as the photoperiod. Some plants, such as chrysanthemums, are short-day flowering plants (winter plants). They require an amount of daylight below a critical length.

Long-day plants, such as spinach or lettuce, require an amount of light above the critical length. A day-neutral plant, such as tomatoes or cucumbers, is not sensitive to the day length. Growing out of season can lead to disappointing results.

As well as day length, temperature also guides when vegetables can be grown. Cool season vegetables, such as brassicas and peas, like to grow in low temperatures of 10–20°C. Warm season vegetables, such as potatoes and tomatoes, grow best in temperatures above 20°C. Intermediate season vegetables, such as root crops and leeks, prefer temperature ranges of 15–25°C.

#### Soils

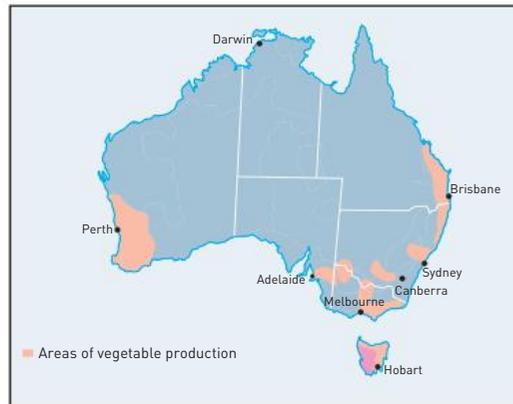
Soils vary from sandy through to loams and clays. The soil type affects how the vegetables will grow because each soil type holds nutrients and water differently. While sandy soils may be easy to cultivate, they do not hold the nutrients that many vegetable crops need. Clay, on the other hand, can harden and crack when dry, causing root crops to grow in odd and stunted shapes. Loam soils hold moisture and nutrients, and are suitable for a wide range of vegetable crops.

Soil pH can affect the growth and yield of vegetable crops. Most vegetables, including tomatoes, onions and cucumbers, prefer slightly acidic soils (pH 6.5–7). Some crops, such as potatoes and eggplant, thrive in more acidic soils of pH 5.25–6.

### Enterprise management

#### Propagation

Propagation is the deliberate production of new plants, either from seed or using techniques such as taking cuttings from an existing plant.



**Figure 6.11** Location of vegetable production in Australia



Web link

You can explore the AusVeg webpage to find out more facts about Australia's vegetable farmers.



Worksheets

Investigate which type of soil is best for growing radishes with the practical worksheet.



Data scenario

Mulch can be used as a layer on top of soil to help retain water. Investigate different types of mulch by examining the NelsonNet data scenario.

## Sexual propagation

Sexual propagation involves growing plants from seeds. Sexual propagation allows for a mixing of genes through cross pollination, producing more genetic diversity. It can be used to create new varieties of plants.

## Asexual propagation

Asexual propagation involves producing new plants from vegetative (non-reproductive) tissues including leaves, stems and roots. The new plants are genetically identical to the parent plant. This is useful when plant growers want to produce large harvests of identical crops.

**Table 6.8** Types of propagation

Sexual propagation	Asexual propagation
<ul style="list-style-type: none"> <li>• Pollination</li> <li>• Fertilisation of ovules to produce seeds</li> </ul>	<ul style="list-style-type: none"> <li>• Layering</li> <li>• Grafting fruit trees</li> <li>• Cuttings</li> <li>• Tubers</li> </ul>



LET'S ENGAGE

## ASEXUAL PROPAGATION

### PURPOSE

To develop an understanding of asexual reproduction by taking a cutting from a rosemary plant

### MATERIALS

- Scissors or secateurs
- Rosemary plant
- Pots
- Gloves
- Propagation potting mix
- Hormone rooting powder or liquid
- Icy pole sticks
- Pen



Secateurs and scissors should be handled with care.

### METHOD

- 1 Start with a healthy piece of rosemary plant – cut a piece of plant that is new growth of the plant.



Science Photo Library/Phamie/Noisrin

**Figure 6.12** Rosemary growths

- 2 Fill a pot with the propagating potting mix.
- 3 Prepare the cutting by removing the lower leaves and any large leaves.
- 4 Dip the base of the cutting into the hormonal rooting powder or liquid.
- 5 Use a dibbler or chopstick to make a hole in the potting mix and place in the cutting.
- 6 Water the cutting.
- 7 Write on the icy pole stick the date and plant type, and place in the pot.
- 8 Make a little mini greenhouse, using wire and a plastic bag. Put the wires into the pot then place the plastic bag over the pot to provide a moist environment.
- 9 Monitor the growing plant.
- 10 When ready, plant the cutting into the garden.

### DISCUSSION

- 1 Define the term 'asexual reproduction'.
- 2 Why is your new rosemary cutting considered asexual reproduction?
- 3 Discuss the benefits and detriments of creating new rosemary using asexual reproduction.
- 4 Research another type of asexual reproduction, such as grafting or layering.

## Record keeping and financial management

### Gross margins

Gross margin analysis can be used to compare different enterprises and determine which one will be most profitable (see Chapter 4 for more information).

**Table 6.9** Example of a gross margin calculation

Income		
100 pumpkins	@ \$5.00/pumpkin	
Total income (A)		\$500
Variable costs		
Seedlings x 25	\$2.50/seedling	\$62.50
Fertilisers 1 bag x 25 kg	\$75/bag	\$75.00
Vegetable dust x 3 containers	@ \$7.95	\$23.85
Snail bait x 2 packets	@ \$6.99	\$13.98
Mulch x 5 bags	@ \$16.50	\$82.50
Total variable costs (B)		\$257.33
Gross margin (A – B)		<b>\$242.67</b>
Gross margin/pumpkin		<b>\$2.42</b>



### LET'S ENGAGE

#### PROFIT ANALYSIS

##### PURPOSE

To calculate how much it costs to grow a vegetable crop

##### MATERIALS

- Computer
- Gross margin template
- Calculator

##### METHOD

- 1 Research and record all the costs involved in establishing and growing a vegetable crop on the school farm.
- 2 Identify all the variable costs.
- 3 Decide on a price to sell the crop.

- 4 Estimate the possible income. Predict how much crop will actually grow to get a budget.
- 5 Once harvested, calculate the gross margin.

##### DISCUSSION

- 1 Identify any issues that might affect on your predicted income.
- 2 Calculate the gross margin using the template on NelsonNet.
- 3 Compare the predicted income with the actual income. Did you accurately predict your income?



Template

Gross margin template



## LET'S REVIEW

### LOOKING BACK

- 1 Where are the main vegetable growing areas in Australia?
- 2 How does the sun affect vegetable farming?
- 3 Define sexual propagation and asexual propagation.
- 4 Explain how soil type affects vegetable production.
- 5 Outline the difference between a fixed and variable cost.

### FOR YOU TO DO

- 1 Create a poster showing which vegetables grow best in Australia. Using a map of Australia, label where different vegetables would grow best.
- 2 Using the Gardenate website, identify four vegetables that can be grown in your region. Explain why these vegetables work in your region.
- 3 Investigate why potatoes are grown from certified seed potatoes rather than old potatoes or just seeds.
- 4 Design a weed control plan for your school farm. Plan to use each of the four methods of control.
- 5 Investigate the variable costs in growing the vegetable crop at school. Outline how these costs can be reduced.
- 6 Compare the gross margin for lettuce and tomatoes on the Department of Primary Industries website. Which vegetable would you recommend planting?

### TAKING IT FURTHER

- 1 Investigate the importance of organic matter in the soil. Design an experiment to test the effect of organic matter on vegetable growth.
- 2 Research two weeds that are a problem in your region and discuss the impact of these weeds on the environment and in vegetable production.
- 3 Propagate strawberries from runners. You can watch the YouTube video on NelsonNet to help you.
- 4 Referring to Chapter 4, create a calendar of operations for a vegetable crop.



WebLink

Gardenate



WebLink

DPI Agriculture budgets



WebLink

How to propagate strawberries

## 6.5 Pests and diseases

### Pests



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Dreamstime.com/Paul Reeves

**Figure 6.13** Pests that affect vegetable production: snails (left) and cabbage white butterflies (right)

Snails are a common pest that attack vegetables, seedlings, leaves and the fruit of the plant. Other pests can include sucking insects, curl grubs and aphids. All these pests attack the growing crop and result in damaged vegetables and sometimes death, reducing the number of vegetables harvested and the overall yield.

The cabbage white butterfly is a white butterfly with distinct black spots on the wings. The butterfly lays eggs on the leaves of predominantly *Brassica* plants such as broccoli, cabbage and cauliflower. The eggs hatch into green larvae, which then burrow into the leaves and the head-forming section of the plant.

## INDUSTRY IN FOCUS

### ENTOMOLOGIST

#### Identify

An entomologist is a scientist who specialises in the study of insects. Some entomologists work in pest control and are responsible for breeding biological controls that can be used in vegetable production. They also breed the food sources for the biological control insects. The entomologist visits the farms that use biological control insects to ensure they are carrying out the job effectively. They also monitor the pest problems on the properties, identifying the pests and making recommendations for the most suitable IPM control methods.

#### Discussion

- 1 Define the following terms: entomologist, biological control and IPM.
- 2 What would be some of the issues facing an entomologist when breeding the biological control?
- 3 What type of skills and knowledge would you need to be an entomologist?
- 4 How would the work of an entomologist affect farmers?

## Diseases

Diseases include microorganisms such as bacteria, viruses and fungi that can attack vegetables.

Powdery mildew is a common fungus that attacks a large variety of vegetables. This disease usually occurs when conditions are warm, dry and cloudy. It causes a white mould layer, starting as spots and gradually spreading to cover the plant.

Leaf roll virus in potatoes is carried by aphids and causes the leaves to roll upwards. The virus infects the growing tuber, stunting its growth. It remains in the soil and can be a source of infection for subsequent crops.

## Control methods

Integrated pest management uses a combination of methods and ensures chemicals are only used when necessary.

### Cultural practices

These strategies include ensuring increased hygiene of machinery and tools to minimise disease spread, using crop rotations, purchasing certified seeds and seedlings from reputable suppliers, ensuring correct plant spacing and trap cropping to attract the pests to another crop.

Companion planting is the practice of selecting plants that complement each other to naturally control pests and diseases and provide protection. Some plants, such as garlic and onions, give off a strong smell that can confuse insects and prevent them from finding other crops.

Trap crops can also be used to aid natural controls of insect problems. The trap crop is grown nearby or surrounding the main crop to attract the insects away from the main crop. The trap crop can then be monitored to identify whether the insect infestation is developing into a problem and then be treated, which avoids spraying chemicals on the main crop.

## Genetic

Growers must choose their breed of plant carefully. They can use genetically modified plants that have been engineered to be pest-resistant, or plants that have been altered to be resistant to chemicals. This means growers can spray chemicals without damaging their main crop.

## Biological

Natural predators can be used to control pests or pathogens. These can be purchased from suppliers. The benefit is that the biological control agent will die out after they attack the pest they have been released to control. Examples include aphidius (parasitoid of aphids) and cucumeris (predatory mite of thrips). *Bacillus thuringiensis* (Bt) is a bacterium toxic to some insects. It has been developed into an insecticide, targeting insect larvae.



Web link

Research other biocontrol agents for vegetable farmers.

## Chemical

Chemicals should be used strategically and only when necessary. See Chapter 3 Farm Resources and Technology for more information on how to safely use chemicals to control pests.



## LET'S REVIEW

### LOOKING BACK

- 1 Name three pests and three diseases that can affect vegetable production.
- 2 Describe an example of each of the control methods that can be used to control pests and diseases.
- 3 What is the difference between companion planting and trap crops?

### FOR YOU TO DO

- 1 Research one pest and one disease that can affect the vegetables you are growing at school.
- 2 Go out to your school farm and search your vegetables for signs of pests or diseases. Research any symptoms or signs you find – can you identify the pest or disease?
- 3 Design an IPM program for your school farm.

### TAKING IT FURTHER

- 1 Research exotic pests and diseases and the impact on the Australian vegetable industry if these reached Australia. Examples could be the carrot rust fly or bacterial ring rot.
- 2 Find out possible biological controls for a pest problem in your region.

## 6.6 Social and ethical issues

### Urbanisation



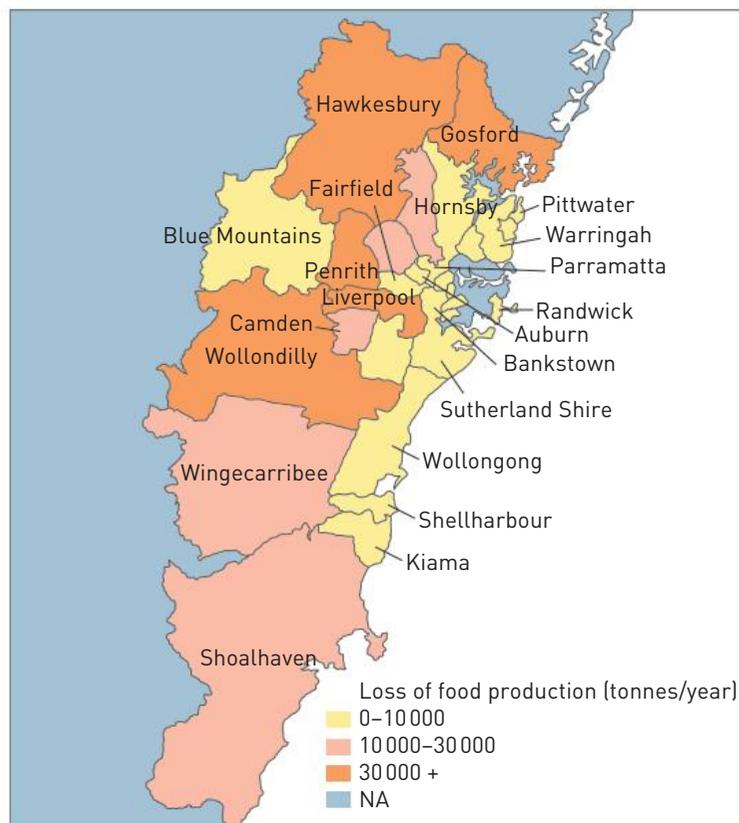
#### LET'S DISCUSS

- 1 Should land around cities be protected from development, even if it means people have to live in high-density housing rather than have their own backyards?
- 2 Would you like to live near a farm? What issues might affect urban neighbours of farms?

Urbanisation is the biggest threat to the vegetable production in the Sydney Basin. The Sydney Basin currently produces enough food to feed 20% of Sydney's population. This vegetable production occurs in the **peri-urban** areas within the Sydney basin. Currently this is under threat with the development and expansion of Sydney into these peri-urban areas.

Urbanisation is due to the increase in population, with the land required for development of houses and infrastructure. This expansion occurs into the rural areas close to the towns and cities. The concern is that if the growth and expansion of Sydney continues in the current unrestrained way, then Sydney agriculture is gravely threatened. Current estimates predict that 60% of the agricultural land in the Sydney Basin will be lost by 2031, including 92% of the current vegetable production in the area.

**peri-urban** areas that are the dynamic interface between cities and rural areas



**Figure 6.14** Estimated 2031 urban sprawl and potential loss of agriculture land



Worksheets

Investigate the *Sydney Food Futures* plan for the Sydney Basin in the NelsonNet case study worksheet.



## LET'S DISCUSS

- 1 Identify urban effects on agriculture around your town or city. Are there areas which used to be farmland but are now parts of towns?
- 2 Brainstorm solutions to the threat of urbanisation on Australia's vegetable production.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the terms: urbanisation, peri-urban and intensive vegetable production.
- 2 Describe two intensive vegetable production systems.
- 3 Explain current predictions of the effect of urbanisation on the Sydney Basin.

### FOR YOU TO DO

- 1 Design a leaflet for Sydney Food Futures, exposing the dangers of urbanisation and affect it will have on the Sydney Basin.
- 2 Research the use of genetically modified corn.

### TAKING IT FURTHER

- 1 Propose a solution to the current threat of urbanisation. Prepare a report detailing the problem and how it could be solved.

## 6.7 Sustainability

### Sustainable methods and practices

#### No-dig gardens

No-dig gardens are a simple and effective way to create an edible garden that uses organic materials to form the garden bed. The garden can be placed on cement, lawn or clay pans. The garden is made up layers of straw, lucerne, dried leaves, manure and newspaper as a base. The mix is similar to making compost.



Figure 6.15 A no-dig garden

## Crop rotations

Crop rotations assist to break the disease cycle and help replenish the nutrients in the soil. Some vegetables such as tomatoes and potatoes are heavy feeders, taking the nutrients from the soil. Legumes such as snow peas and beans help put nutrients back in the soils

**Table 6.10** Sample crop rotation program

	Summer	Autumn	Winter	Spring
Garden bed 1	Legume (Beans)	Heavy feeder (Broccoli)	Light feeder (Lettuce)	Green manure
Garden bed 2	Heavy feeder (Tomatoes)	Light feeder (carrots)	Green manure	Legume (snow peas)

## Sustainable technology

### Soil moisture sensors

Soil moisture sensors monitor the moisture in the soils to the depth that the sensor is planted, and can be linked via computer to irrigation systems to automatically deliver water when the moisture falls below the designated setting on the device. This system encourages sustainable water usage by only watering when the plants require watering.

### ‘Hacking’ photosynthesis

Photosynthesis is the process by which plants turn sunlight, water and carbon dioxide into energy. This energy is used to help the plants grow. Sometimes in the photosynthesis process, a plant might accidentally absorb oxygen instead of carbon dioxide. This results in the production of a toxic compound, and the plant then has to expend energy getting rid of it. A team of scientists has genetically modified tobacco plants to dispose of the toxin more quickly, which mean the plants have more energy left to focus on growing. This has resulted in the modified tobacco plants growing 40% bigger than the unmodified ones. By growing bigger plants more quickly, enough food could be produced to feed the growing population.

## Sustainable decision-making

### AG IN FOCUS

#### GREEN MANURE

##### Identify

Green manure crop rotations can be used to create better soil for farmers growing vegetables. Green manure crops are crops such as grasses or legumes that are ploughed or worked back into the soil before they seed or flower.

##### Understand

Australian farmers face many soil issues because they often grow European crops that aren't suited to Australian soil or climate. They therefore use a high level of nutrients and cause greater levels of erosion. One solution is to use a green manure crop rotation. Green manure crops add nutrients and organic matter back into the soil and improve soil structure. While these are a low-cost seed, by scheduling a green manure crop farmers are not making any income as they are not producing anything. However, in the long term, their future crops will benefit from the increased nutrients and improved soil

structure. Farmers must weigh the costs of losing income for several months versus the benefits to future crops and the environment.

### Discussion

- 1 What is a green manure crop rotation?
- 2 How does green manure benefit soils?
- 3 Evaluate the short- and long-term impacts of a green manure crop rotation. Make a recommendation to farmers.



## LET'S REVIEW

### LOOKING BACK

- 1 Define 'sustainability'.
- 2 Why is sustainability vital in vegetable production?
- 3 Describe two technologies which are improving the sustainability of vegetable production.

### FOR YOU TO DO

- 1 Research environmental problems on your school farm or in your region. (Hint: think about any extreme weather events that have happened recently.) Pick one, and research two different technologies your school farm could use to help manage this environmental problem.
- 2 Investigate how AUSVEG encourages farmers to implement sustainable practices.
- 3 Visit the Sydney Food Futures website. Using the interactive map, select a scenario to view what potentially can occur in the Sydney Basin due to urbanisation. Debate the concerns about using the vegetable production areas to develop and create more homes.
- 4 Research how algae-based fertilisers can be used by vegetable producers. Conduct a class discussion on the sustainability and profitability of using these fertilisers.

### TAKING IT FURTHER

- 1 Investigate permaculture and the role it plays in sustainable food production.
- 2 As a class, debate the topic: 'Whose responsibility is it to ensure the sustainability of vegetable production systems?'



WebLink

EnviroVeg



WebLink

Sydney Food Futures



WebLink

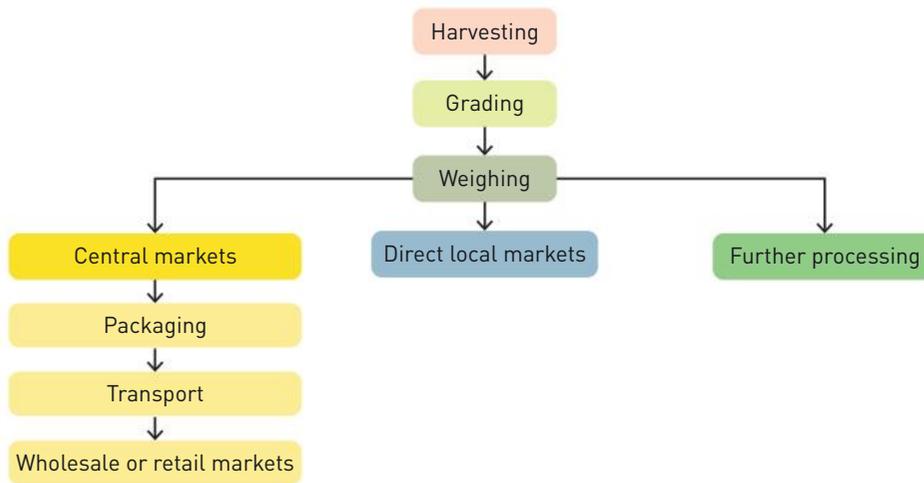
Are algae-based fertilisers a more sustainable option?

## 6.8 Marketing

### The market

Australia's produce has two distinct markets: domestic and export. To help farmers meet buyer needs (and therefore ensure that supply meets demand), there are specifications in place to guide them.

## Domestic markets



**Figure 6.16** Marketing chain for vegetables showing three main destinations

Most of the vegetables produced in Australia (50–60%) are sold through central markets in the major cities. These central markets set the market price for the vegetable industry. Over 15 000 growers supply to businesses operating within the central market system.

There is a growing trend for local producers to sell at local produce markets, allowing consumers to buy direct from the growers. Growers are electing to establish themselves at these local markets because they can ensure a fresh product for the consumer, more direct payment methods and a connection with the consumer.



On average, Australians eat 160 kg of vegetables in a year.

The diversifying of Australia’s population and recent increases in immigration from countries in Asia has driven up demand for Asian vegetables such as pak choy, bok choy and Chinese cabbage. These have grown in popularity because they are versatile and easy-to-prepare and can be used in a variety of recipes. You can find out more about the demand for Asian vegetables in the case study in Chapter 4.



Find out more about the success of Asian vegetables in Australia by completing the *Marketing bok choy* worksheet.

## Export markets

Australia exports 190 000 tonnes of vegetables each year. Table 6.11 shows the top five markets and vegetable commodities for Australian exports.

**Table 6.11** Top export vegetables and markets

Top 5 markets				Top 5 commodities			
Volume (tonnes)		Value (\$ millions)		Volume (tonnes)		Value (\$ millions)	
UAE	39 400	Singapore	\$45.3	Carrots	111 500	Carrots	\$91
Singapore	29 900	UAE	\$35.9	Potatoes	38 000	Asparagus	\$31
South Korea	21 200	Japan	\$34.2	Onions	25 800	Potatoes	\$30
Malaysia	21 000	Malaysia	\$20.7	Cauliflower and broccoli	7 700	Onions	\$18
Japan	16 100	Hong Kong	\$15.7	Asparagus	6 100	Cauliflower and broccoli	\$17

Source: Ausveg website, 2018

## Market specifications

Market specifications are the guidelines that farmers can use to ensure they meet the requirements of the buyers. They identify the criteria the buyer is seeking in the product. These specifications cover the general appearance criteria, major defects, minor defects, and consignment criteria. FreshSpecs was created after a response from industry that there was a need to produce a uniform set of standards for fresh produce.



WebLink

FreshSpecs

LET'S ENGAGE

### JUNIOR JUDGING VEGETABLES

#### PURPOSE

To develop skills in assessing the quality of fruit and vegetables using market specifications

#### MATERIALS

- Four samples of four different fruit or vegetables
- Market specifications (from the FreshSpecs website)
- Junior judging sheet

#### METHOD

- 1 Select a fruit or vegetable. Set up four plates with four samples of the selected fruit or vegetable on each plate.
- 2 Using the specifications, assess the quality of each plate.
- 3 Record the placings in the chart below.

	1	2	3	4
Placings				
Comments				

#### DISCUSSION

- 1 Discuss how your fruit or vegetables were placed.
- 2 Did the fruit or vegetables meet market specifications?
- 3 What impact would it have on the grower if the produce doesn't meet market specifications?
- 4 What management techniques could you implement to make sure your fruit or vegetables meet market specifications?

## AG IN FOCUS

### WONKY VEGETABLES



Alamy Stock Photo/Jim West



Alamy Stock Photo/Simon Littlejohn

**Figure 6.17** Tonnes of tomatoes go to waste in Queensland.

### Identify

A recent study showed up to 87% of tomatoes from a farm in Queensland were rejected by suppliers because they were wonky.

### Understand

In a world with an ever-increasing population, farmers are striving to farm more produce on smaller land areas. However, large amounts of waste product limit supply. Researchers looked at a farm in Queensland that supplied to markets in Brisbane and Bundaberg. Across the entire supply chain, up to 87% of the tomatoes were rejected for being an odd shape, too big or too small.

This is a problem across many countries including Australia, the UK and United States. In the UK, a study found that almost all celery produced was discarded before even leaving the farm. Meanwhile Americans throw away as much food as they eat.

The problem is thought to be caused in part by the stringent standards mainstream supermarkets place on farmers, although the supermarkets claim this comes from consumer preferences for perfect fruit and vegetables. Some supermarkets are trialling 'wonky veg' products, such as the Odd Bunch range at Woolworths, to reduce food waste. However, until there are more clear demands from sustainably minded consumers, it is likely that huge amounts of food and produce will continue to be wasted.

### Discussion

- 1 What did the Queensland study reveal?
- 2 Describe the findings from studies in the UK and the United States.
- 3 Conduct your own survey with parents and teachers around their perception of 'wonky veg'. Do you agree with the statement from mainstream suppliers that consumer preferences are the cause of wonky vegetable food wastage?

## Marketing strategies

### Central market system and contracts

Growers transport vegetables to central markets and supply the produce to wholesalers who operate at each of these markets. Another common scenario is that growers have contracts with supermarkets, restaurants and fast-food companies. To supply under contract, the grower needs to ensure the product meets the company's specifications and ensure consistent supply.

### Direct selling

Farmers can sell direct to the consumers through a variety of methods such as on-farm sales, roadside stalls, farmers markets and 'pick your own' schemes. Selling direct to consumers gives the opportunity for the growers to interact with the consumer and gain direct feedback. Direct selling can also give growers the possibility of achieving higher returns.

### Advertising and promotion

In Australia there is very little advertising and promotion for eating vegetables. Campaigns tend to come from nutrition organisations, such the 'Try for 5' campaign from Nutrition Australia, which aims to get Australian's eating five serves of vegetables a day.

**DID YOU KNOW?**

Only 1% of the total annual dollars spent on food advertising is on promoting vegetables.



Nutrition Australia

Figure 6.18 Try for 5 campaign



## LET'S DISCUSS

- 1 Why do you think fruit and vegetables are not advertised?

### Value-adding

Growers can value-add to vegetables by freezing, canning, freeze-drying and pre-cutting them. While the value-adding market for vegetables is growing, there are still perceptions that pre-cut or canned vegetables are more processed and therefore less healthy than the fresh alternatives.

## AG IN FOCUS

### KIKAI FOODS

#### Identify

Kikai Foods is a Kenyan company founded by Caroline Mbogo. Mbogo recently participated in the Climate LaunchPad competition with her value-added fruit and vegetable products.

## Understand

Kikai Foods create value-added snack foods made from the waste of fruit and vegetable production. They solar-dry fruit and vegetables to create snack foods. Solar-drying uses the sun to naturally dry products, making it a sustainable alternative to drying machinery. The produce they use would normally be waste product from the Kenyan agricultural chain. About half of Kenya's potential fruit and vegetable exports are rejected before being exported due to the harsh specifications required by Western markets. By creating a product from this waste food, Kikai Foods also provides income to local farmers whose produce might otherwise be rejected from export.

## Discussion

- 1 How do Kikai Foods value-add?
- 2 Describe the sustainable methods of production used to create the snack foods.
- 3 Brainstorm fruit and vegetables you could create dried snacks from.
- 4 Try solar-drying! Cut up some fruit or vegetables into thin slices and leave them on a tray to dry out in the sun. Once dried, taste your product. What fruits and vegetables taste best in dried form?
- 5 Design packaging for your new value-added dried fruit or vegetable product. Remember, you used a sustainable method of production, so try to think of sustainable ways of packaging your product.



## LET'S REVIEW

### LOOKING BACK

- 1 What are central markets?
- 2 List the top five export vegetable markets by value.
- 3 What are market specifications?
- 4 Define three types of marketing strategy.

### FOR YOU TO DO

- 1 Check out the specifications for vegetables growing in your school farm. Describe what the perfect vegetable should look like.
- 2 Draw the marketing chain for frozen vegetables. You can use Figure 6.16, the simple vegetable marketing chain, to help you.
- 3 Create a marketing campaign to advertise your school vegetables. You could create a video advertisement, a poster or a leaflet. Refer to Chapter 4 to assist you.
- 4 Design a label and packaging for the vegetable that you are growing.
- 5 Go to a local market and talk to one of the farmers selling produce. How do they market their produce?

### TAKING IT FURTHER

- 1 Evaluate the advertising for one of the following products: cauliflower rice, vegetable noodles (e.g. zoodles), salad bowls or ugly vegetables.
- 2 Conduct a survey of the school community on the quality of the vegetables grown on the school farm. Analyse the results and make relevant modifications to improve the production and sale of the vegetable crop.

# Let's summarise



Practice quiz

Complete the chapter review test on NelsonNet to review what you've learnt about vegetable market gardening.

## How can we manage the environment to successfully grow vegetables?

Different vegetables require different environments to grow most successfully. In Australia, where the climate and soil is often not suited to introduced European crops, farmers must carefully manage the environment to grow produce that meets market specifications. Use the words in the table below to discuss the different ways a farmer can control the environment to ensure the best crop.

Greenhouse	Polytunnel	Day length
Garden bed	Soil type	Location
Hydroponics	Soil pH	Fertilising

## How can we sustainably grow vegetables in our own backyards?

Vegetable farmers use many methods and technologies to ensure they are creating a sustainable enterprise. With reference to the below practices, create a mindmap showing how we can use these practices in our own backyards.

No-dig gardens	Crop rotations	Organic farming
Wonky vegetable waste	Weed control	Companion planting



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# Wheat

## CHAPTER SUMMARY

Wheat is one of the most important crops grown in Australia. It is grown mainly for the export market to make products such as bread, pasta and noodles. Some wheat is grown for livestock feed and can be used as pasture for grazing, which is then harvested for grain. Many aspects of the environment must be managed to ensure a high-quality grain yield. There is much demand for wheat worldwide and the challenge for growers will be to sustainably grow a crop in a constantly changing climate.

**How significant is wheat to Australia and the world?**

**How will farmers manage to grow enough wheat to feed a rapidly expanding population within increasing environmental constraints?**

## 7.1 Introduction

Wheat originated in the Middle East and is one of the oldest agricultural crops ever grown. It is one of Australia's most valuable crops and its biggest grain crop. Wheat is classed as a cereal or grain crop in the family *Poaceae*. It contains a significant amount of starch that is utilised for energy. It is a staple of most modern diets around the world.

Wheat is grown around Australia with the main production areas in Western Australia, New South Wales, Queensland, South Australia and Victoria, and 71% of production exported. Wheat is classified according to protein content and grain size. This determines wheat quality, which then determines its end use.



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Figure 7.1 A field of wheat

## 7.2 Functions and structures

### Uses of wheat

Wheat is an edible grain that is used for both human and livestock consumption. Wheat has been a human staple for thousands of years and is one of the first crops of early agriculture. It has evolved to provide a variety of uses for markets all over the world and is used commercially in the following ways.

- 1 *Food production* – wheat is a versatile grain that is milled to provide flour for a number of food products and its unique properties have seen wheat dough used across the globe in products such as:
  - breads and tortillas
  - baked goods such as cakes, pastries and biscuits
  - breakfast cereals
  - dumplings
  - pasta and noodles.



**Figure 7.2** Food products made from wheat

- 2 *Livestock feed* – wheat grain can be used as livestock feed as a substitute for other cereals such as oats and corn. When wheat cannot meet the protein requirements for food production, it is classed as feed wheat and sold as such, but still remains a valuable source of protein for livestock. Wheat in its **vegetative state** can provide valuable winter forage for livestock in mixed farming enterprises.
- 3 *Alcohol and bioethanol production* – wheat can be fermented and distilled to create alcohol. The resulting alcohol is neutral in colour and flavour and is used to make spirits such as vodka. Wheat alcohol also has cosmetic and pharmaceutical applications, acting as a preservative, antiseptic and disinfectant. Wheat alcohol can also be used in the production of bioethanol for fuel, a market that is growing rapidly with wheat becoming a major biofuel crop.

### DID YOU KNOW?

The protein content of wheat grain can vary from 8% to 15%.

**vegetative state** the growth stage of a plant where leaves and stems are produced, before the onset of flowering and seeding

## Wheat plant structure

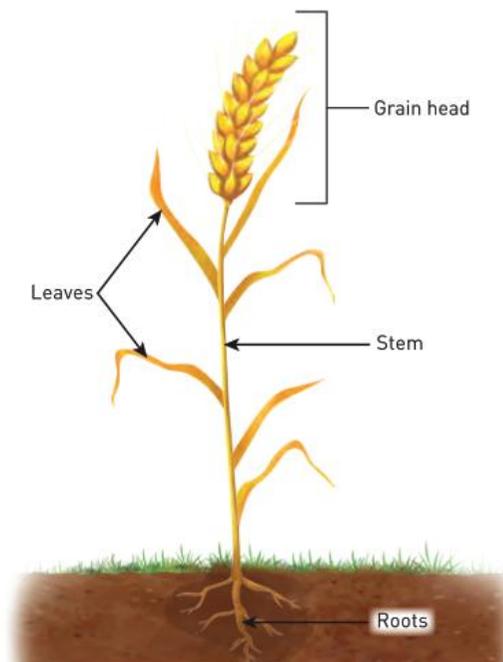
Wheat is an annual plant, classed in the family of grasses. Like other grasses, wheat grows from a crown base that produces multiple lateral stems called tillers. Tillers provide the wheat plant with leaves for photosynthesis and eventually form an **inflorescence** from which the grain develops.

### The wheat plant

When the first wheat leaf begins to grow, it emerges surrounded by a protective sheath called a coleoptile, which protects it as it pushes through the surface of the soil. The coleoptile is extremely important because it influences the growth and development of the wheat plant, its length determining how well the plant establishes.

### Wheat flowering

The reproductive stage of the wheat plant is when the flower develops after it emerges from a stem, a process called heading. The wheat flower is self-pollinating and the flowerhead, or inflorescence, is made up of a cluster of flowers called spikelets. After the flowers are pollinated, the grain begins to ripen and mature.



**Figure 7.3** The structure of a wheat plant

**inflorescence** a flower head that consists of individual flowers arranged in cluster

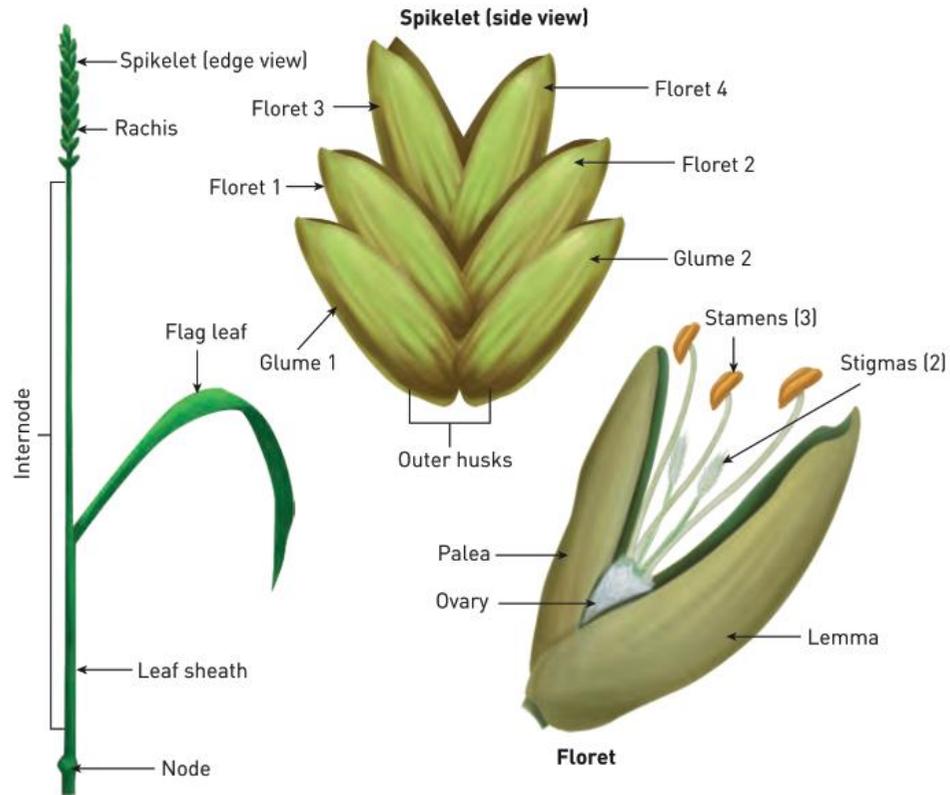


Figure 7.4 The wheat flower

### The wheat grain



Worksheets

Review your knowledge about the structure of a wheat plant and grain with the worksheet on NelsonNet.

The wheat seed is classified as a grain or kernel and is the fruit of the wheat plant. Wheat grains consist of approximately 70% carbohydrate, of which 97% is starch. A wheat grain is made up of the parts shown in Table 7.1.

Table 7.1 Parts of a wheat grain

<b>Seed coat</b>	Outer protective coating of seed, generally removed during the milling process
<b>Endosperm</b>	Tissue that provides the seed with the energy required for germination. It makes up a large proportion of the grain and stores starch and protein.
<b>Aleurone</b>	Protein layer that surrounds the endosperm. It secretes enzymes that break down starch in the endosperm.
<b>Embryo</b>	Contains all the main structures of the plant and is the germinating part of the seed

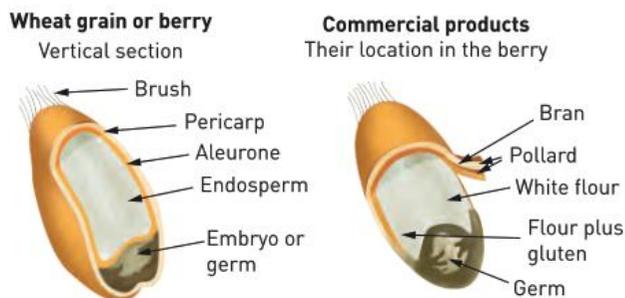


Figure 7.5 The wheat grain

## Red vs white grains

Wheat grains are classified by their colour. While most wheat grown for the commercial market in Australia is white grained, red grains are commonly seen in wheats grown for livestock feed. In the northern hemisphere, red-grained varieties are grown more extensively and are used in wholemeal or ‘whole wheat’ products.

### DID YOU KNOW?

Poultry farmers favour red-grained wheat to feed their chickens because it results in a lovely golden yolk without the use of feed additives to achieve the same colour.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify and list products made from wheat.
- 2 Outline the functions of the main structures of the wheat plant.
- 3 Explain the importance of the coleoptile.
- 4 List the parts of a wheat grain. What commercial products are made from each part?
- 5 Outline the differences between red and white wheat grains.

### FOR YOU TO DO

- 1 Explain how the structure of the wheat inflorescence indicates that it is wind pollinated.
- 2 Draw a series of diagrams that indicate the germination, vegetative and reproductive stages of the wheat plant. Describe the growth and development in each stage.

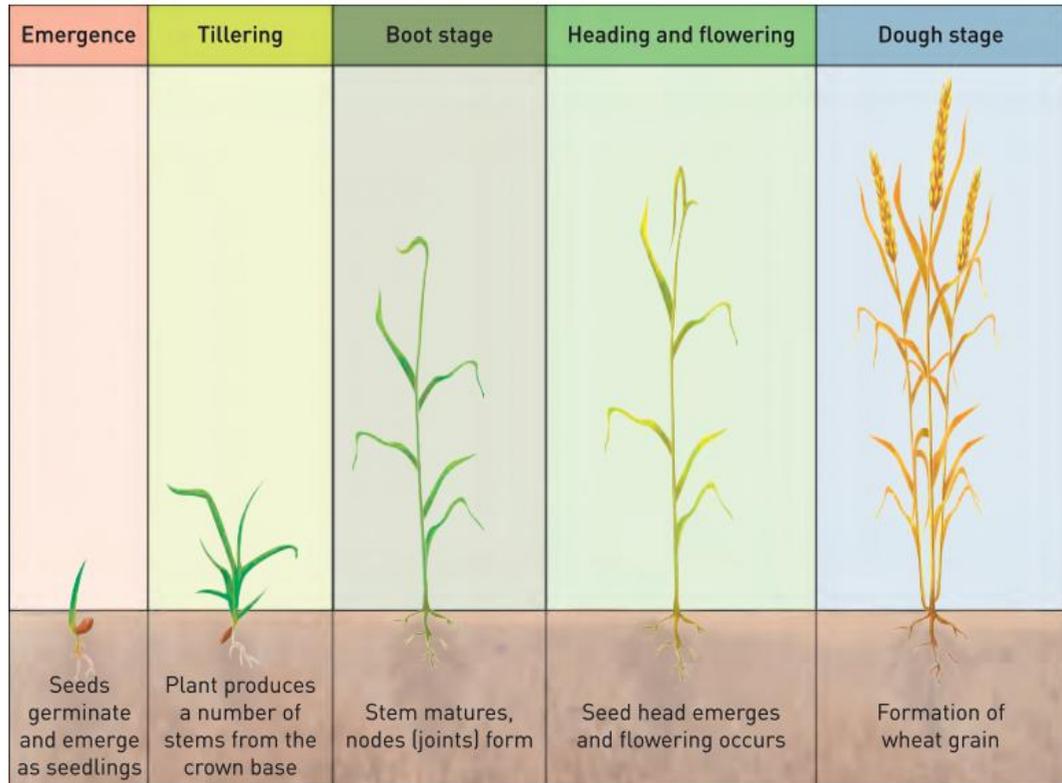
### TAKING IT FURTHER

- 1 Research the milling process. Draw a flow diagram that explains the process.
- 2 What are the by-products of flour milling and how are they value-added to create other products?
- 3 Investigate the nutritional differences between white bread and wholemeal bread. Relate these differences back to the physical characteristics of the grain.

## 7.3 Production

### Production cycle

Wheat is an annual plant, which means its entire lifecycle from germination to reproduction is completed in one growing season. The flowering time of wheat is due to either photoperiod (daylength) or vernalisation (temperature). Spring varieties, the most common wheat sown in Australia, rely on photoperiod to flower, while winter varieties need cold temperatures to flower. The growth stages of wheat shown in Figure 7.6 are determined by temperature and daylength.



**Figure 7.6** The growth stages of wheat

## Production systems

To ensure high wheat yields, a grower must implement appropriate production systems.

- 1 *Dryland wheat farming* – the traditional method of growing wheat. It relies on the natural rainfall patterns of the area and is dependent on appropriate variety selection.
- 2 *Irrigated wheat* – can be grown under irrigated systems. While regular systems rely on rainfall to meet the crop's water requirements, irrigation can provide essential moisture, particularly during flowering. This has a direct impact on disease control and yields.
- 3 *Mixed farming system* – can provide valuable winter forage for livestock. Winter varieties can be sown early and grazed by livestock throughout the winter. The livestock are taken off before flowering to preserve crop yields. This method has proved effective in high rainfall areas where sheep production dominates.

## AG IN FOCUS

### WINTER WHEATS

#### Identify

Dual purpose wheats can provide multiple benefits for farmers.

#### Understand

Unlike spring wheats, winter wheats can provide valuable grazing pasture during winter and still maintain the ability to produce a high grain yield in summer. Winter wheats require cold temperatures before they can flower, called vernalisation. This allows the plant to be grazed by livestock in the months prior to flowering. The crop provides

valuable pasture during the winter months and can be sown earlier, capitalising on late summer rainfall to ensure adequate moisture at sowing for germination.

Winter wheats were developed in the late 1970s by Professor Jim Davidson who pioneered the breeding of winter wheats. His aim was to provide farmers in the high rainfall areas of Australia, which were generally limited to grazing enterprises, access to the benefits of growing a high-value crop. As a result significant grazing land, particularly in Victoria, shifted to become valuable cropping areas. Winter wheats were originally bred without **awns** that made them more palatable to livestock. Initially the breeding program focused on wheats adapted to the waterlogged conditions experienced in the high-rainfall areas that were not suited to cropping.



**Figure 7.7** Winter wheats have no awns to make them easier for livestock to eat.

Today, winter wheats remain a valuable resource in mixed farming areas and breeding has focused on disease-resistant, high-yielding white grain varieties. These give farmers the opportunity to sow early when conditions are ideal. This ensures that flowering occurs late enough to avoid frost, but early enough to avoid heat stress, all while maximising vegetative growth for grazing prior to harvesting the grain.

## Discussion

- 1 Describe the key features of a winter wheat breed.
- 2 What are the advantages and disadvantages of a grazing–cropping rotation on the farm environment?
- 3 Farming can be a high-risk business. Is diversification worth the additional inputs required by the farmer? Why or why not?
- 4 An effective pasture is one that has an appropriate mix of plant species for biodiversity and livestock nutrition. What are the implications of livestock grazing on single type of pasture?

## Aboriginal production systems

Aboriginal peoples were the first to successfully grow, manage, harvest and process grain crops, with evidence extending back approximately 40 000 years. Native millet (*Panicum decompositum*), a perennial grass species, was grown across Australia in areas known as the Aboriginal grain belt (Figure 7.8). This grain belt covers a larger area than the current wheat belt and spanned across Australia.

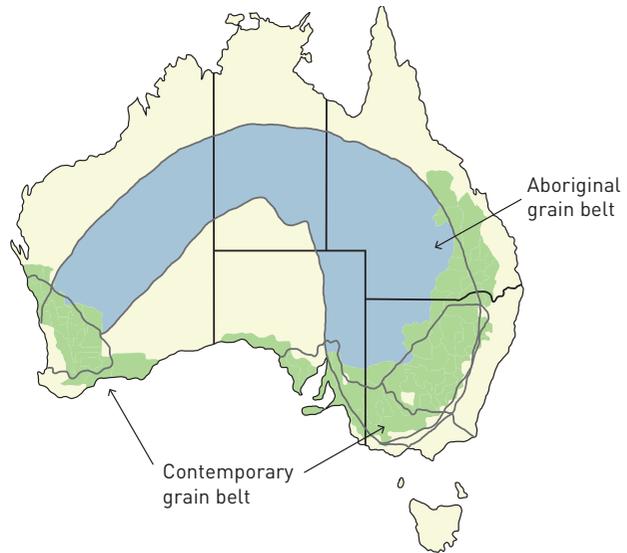


Worksheets

How do Aboriginal production systems compare to other modern systems? Use the *Production systems* worksheet to compare.

Aboriginal Australians used fire as a management tool, burning in autumn to early winter, just as the millet seed was sprouting, because the smoke encouraged the germination of the native millet. Perennial native grasses such as native millet can be used to stabilise areas and act as weed and disease breaks when used in rotation with wheat.

Aboriginal grain growers were known as Panera and sowed seed by hand casting. The crop was planted over large areas to insure against adverse seasons. At maturity, the grain was harvested by pulling or stripping the heads with stone knives. It was then dried and stored in skin bags or milled by mortar and pestle to make flour for bread.



**Figure 7.8** The Aboriginal grain belt compared to present-day wheat-growing areas



Video

See how farmers are encouraging pasture growth by using fire as a management tool for perennial native grasses.



Video

Bruce Pascoe



## LET'S DISCUSS

- 1 What are the benefits of growing a perennial grain crop as opposed to an annual grain crop?
- 2 If a grain crop such as native millet can be grown over a wider range of environmental conditions, as indicated by the Aboriginal grain belt, what would be the implications of an increase in grain production areas, both locally and globally?

## AG IN FOCUS

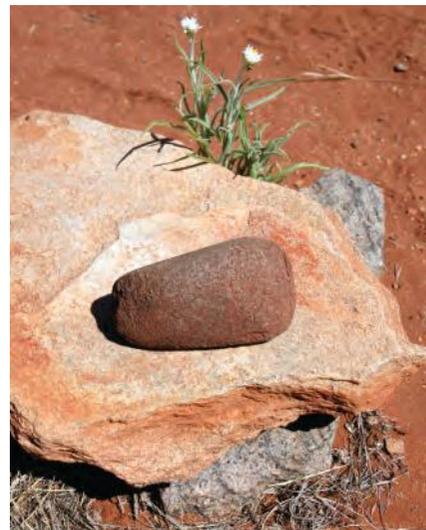
### THE WORLD'S FIRST BREAD

#### Identify

Aboriginal Australian communities are fostering the use of native grass species in modern baking.

#### Understand

Native millet can be milled to create a nutritious flour for breadmaking, as was once used by Aboriginal communities before colonisation. With increasing demand for natural products and ingredients, bread made from native millet would satisfy a growing consumer market. The environmental implications of this would be significant due to the nature of the species



Alamy Stock Photo/Susanna Bennett

**Figure 7.9** Grinding stones used by Aboriginal Australians to grind the seed of native millet to make bread



used. Native millet is a perennial species that, once established, requires minimal cultivation and no additional fertilisers or pesticides. Perennial species improve soil structure and tend to establish vigorous deep root systems that draw nutrients and water to the upper levels of soil. The establishment of commercial production of native millet could have huge benefits for the sustainability of the local environment.

## Discussion

- 1 What are some management issues that could be encountered when growing a perennial crop?
- 2 What are the risks involved in establishing a new product for consumers?
- 3 Find out more information regarding bush tucker foods. How large is the market for native ingredients?
- 4 Select an Aboriginal food ingredient to investigate. How is the ingredient used?
- 5 Design a value-added product based on native millet as an Aboriginal food ingredient to market to consumers.



## LET'S ENGAGE

### ANNUAL VS PERENNIAL GRAIN CROPS

#### PURPOSE

To compare the management of an introduced annual crop vs a native perennial grain crop

#### MATERIALS

- Large pots – you can grow as many plants as you like; five to ten plants of each species are recommended. If space allows, you may choose to grow each species in rows in your garden plot.
- Soil/all-purpose potting mix
- Ruler
- Winter wheat seeds and native millet seeds. Seeds can be purchased from a number of websites found on NelsonNet.
- Watering can
- All-purpose granular fertiliser, such as Osmocote
- Camera

#### RISK ASSESSMENT

Using the template found on NelsonNet, complete a risk assessment based on the following hazards:



- potting mix
- fertiliser
- slips, trips and falls

Identify any additional hazards in your area and make sure you list them in your risk assessment.

#### METHOD

- 1 Fill all the pots with soil or potting mix to the top of the pot and level with a ruler.
- 2 Sow two to three seeds per pot at a depth of 10 mm (you will thin out seedlings after germination to ensure only one plant per pot remains). If sowing in rows, sprinkle the seeds evenly into the rows.
- 3 Water the pots with a watering can until the soil is wet but do not flood the pot. If sowing into the ground, ensure the water does not pool at the surface.
- 4 Place the pots in a sunny position and monitor every couple of days.
- 5 When all seeds have germinated and reached 10–15 cm in height, thin the seedlings until only one plant per pot remains.
- 6 Monitor the plants, growth and take photographs every two to three days, or daily if you prefer. You may even set up a time-lapse camera to monitor the plants, growth and development. Day 0 will be the day you sowed the seeds. Ideally you should grow the plants for the length of each species growing season.
- 7 When the wheat plants are at the tillering stage, an all-purpose fertiliser can be applied to support growth. This is not needed for the native millet.



Weblink

Native Seeds



Weblink

Richmond Driver Seeds



Weblink

Seed World



Template

Risk assessment template



### DISCUSSION

- 1 Compare the vegetative stages of both crops and describe any differences in their growth stages.
- 2 How did your management techniques differ for each crop?
- 3 What are the advantages of a perennial crop in a mixed farming enterprise?
- 4 Winter wheats are grazed during the winter months, while native millet can provide feed for livestock into the dry season. Design a calendar of operations that maximises the grazing potential of both species in a mixed farming enterprise while producing effective yields for both species. The calendar should show a two-year cycle.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify two factors that influence the flowering of wheat.
- 2 Identify and describe two production systems used to grow wheat.
- 3 Contrast the location of the Aboriginal grain belt and the contemporary wheat belt in Figure 7.8.

### FOR YOU TO DO

- 1 Compare and contrast the different wheat production systems in terms of management, environmental issues and productivity.
- 2 Compare and contrast the modern wheat production systems with the Aboriginal grain production system.
- 3 Construct a flowchart demonstrating the steps in native millet production by the Panera.

### TAKING IT FURTHER

- 1 Create a calendar of operations for an enterprise that crops wheat and canola while also grazing sheep.
- 2 Farmers must select appropriate varieties for their environmental conditions and market requirements. Research different wheat varieties and select three that would be suited to your location. Justify the reasons for the selection in terms of purpose and suitability.

## 7.4 Management



Data scenario

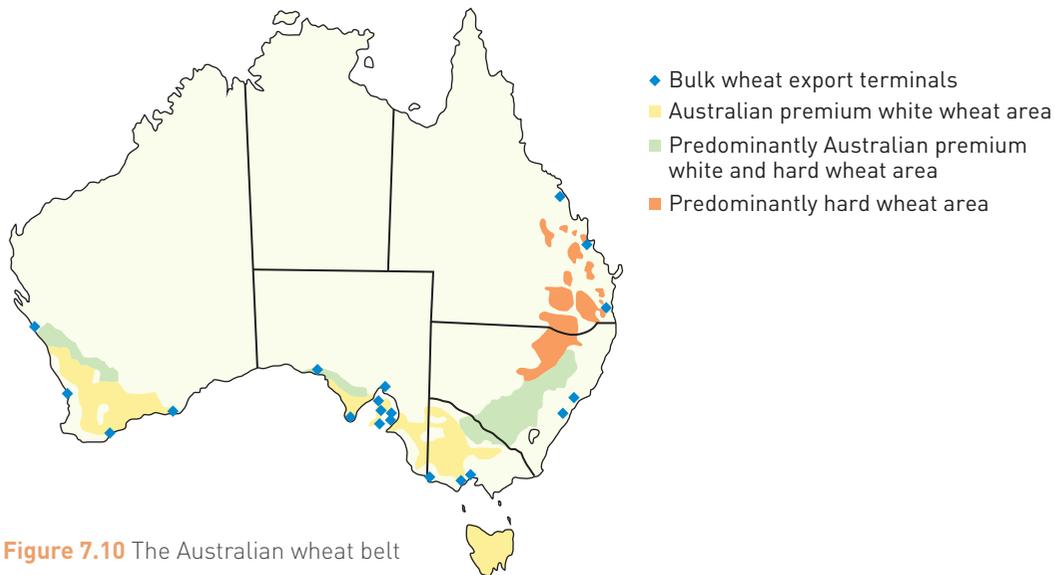
Wheat production can be delayed due to high temperatures and dry conditions during autumn and winter. Investigate the effect of heat stress on wheat grain yields with the NelsonNet data scenario.

### Environmental management

To grow a high-yielding wheat crop, the environment must be appropriately managed to ensure that conditions are ideal for germination, growth and harvest of the wheat.

#### Climate and distribution

Wheat can be grown in a range of different climates, but the main wheat growing areas of Australia occur in what is known as the Australian wheat belt.



**Figure 7.10** The Australian wheat belt

Wheat growing areas are expanding due to the availability of new **varieties**, including dual-purpose varieties that are suited to high-rainfall environments. These dual-purpose varieties can be used in mixed farming enterprises and where wheat is used as a rotation crop.

## Soil

Wheat is adapted to a wide range of soil types and grows best on well-drained soils because it does not tolerate waterlogged conditions. **Waterlogging** causes reduced root growth and can encourage root diseases. However, crop growth and development rely heavily on adequate soil moisture and it is vital that there is adequate soil moisture at all growth stages of the plant. Soil moisture directly affects germination by influencing the speed of germination.

## Enterprise management

### Variety selection

High-yielding wheat production is largely dependent on selecting the most appropriate wheat varieties for specific locations. Varieties must be selected to ensure that flowering does not occur at times when frost is likely, leading to major crop losses. Temperature is also key when selecting a variety because it directly affects the length of the coleoptile – too cold or too warm temperatures tend to shorten coleoptile length, affecting seedling establishment. Varieties are generally selected for:

- local environment – must be adapted to local conditions
- grain quality – determined by target market, for example, wheat for bread as opposed to feed wheat
- disease resistance
- sowing time – must be appropriate for region
- resistance to **lodging** and **shattering**
- tolerance to soil acidity
- frost tolerance
- performance in low moisture conditions.

Drones are a valuable tool for use in cropping enterprises. Drones are used in wheat breeding programs to gather field data to enable more accurate variety selection. Drones have sensors that can detect temperature, light, moisture and other weather and climate information, and can sense other information about the physical characteristics of the wheat.

**variety** plants that have different genetics but are still the same species

**waterlogging** a condition where the soil is saturated with water, depriving plant roots of oxygen



Worksheets

Before planting, it is important to measure your soil water-holding capacity to ensure optimum plant growth. Test your soil water-holding capacity with the practical worksheet on NelsonNet.



Worksheets

Find wheat varieties for different locations around Australia with the *Wheat variety selection* worksheet on NelsonNet.

**lodging** when crops bend low in the stem, causing the plant to fall to the ground

**shattering** when wheat seeds are easily detached and fall out of the wheat head

Drones are being used more extensively by farmers to monitor and manage their crops. Drones can be used to detect pest or disease infestations before they become a problem and can be used for spot spraying to deal with issues before they affect a significant portion of the crop.

Drones can also be used to:

- detect areas where there are water shortages
- monitor grain development for ideal harvest timing
- monitor weed growth as wheat seedlings are establishing
- detect areas of soil nutrient deficiencies.

Remote sensing technology such as drones greatly decrease labour and save a farmer valuable time, money and resources.



Shutterstock.com/Artie Medvedev

**Figure 7.11** Drones can monitor wheat crops to determine ideal conditions for harvesting.

## INDUSTRY IN FOCUS

### WHEAT BREEDER

#### Identify

Farmers must select the most appropriate wheat varieties to suit their farms and their needs, as well as fulfilling consumer and market requirements. Wheat and other plant breeders are the scientists behind these plant varieties. They have backgrounds in chemistry, biology, agriculture, genetics and technology.

Plant breeders use their skills and knowledge to:

- evaluate breeds to suit farmers needs
- improve the quality and performance of crops
- develop varieties to meet market requirements and consumer demands.

Wheat breeders work with farmers to develop breeds that are resistant to pests and disease, and tolerant of environmental issues such as heat, drought and waterlogging. They delve into the genetic pool to discover the genes responsible for taste and workability, particularly when it comes to wheats that are used to make bread and noodles. There are career opportunities for plant breeders in government organisations such as the CSIRO and universities. The University of Sydney is home to the Plant Breeding Institute, which supports a vast range of breeding programs from crops to nursery plants. There are also private companies, such as Australian Grain Technologies, that work towards the same goal of providing farmers with the most suitable crop for their needs.

#### Discussion

- 1 Identify three to five skills and attributes required to be a wheat breeder.
- 2 Identify three problems faced by wheat growers. List three characteristics of wheat that could be developed to solve some of these problems.
- 3 Research the career pathway to become a wheat breeder. How does an interest in agriculture assist in determining a pathway to this career?



Grain Central

**Figure 7.12** World-renowned wheat breeder, Richard Trethowan with his wheat plants

## Sowing

Wheat is generally sown from April until mid-July, depending on the variety.

Early sowing can accelerate the establishment of the plant, with a larger root system better able to cope with low moisture conditions. However, early sowing can also increase the plant's susceptibility to some diseases. Crops that are sown too early are also at risk of frost damage as they tend to flower late in winter.

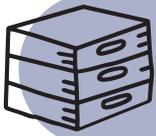
Late sowing is not generally recommended because it can increase the occurrence and severity of disease. Late sowing of crops can also prevent the crop from reaching its potential yield as hot and dry conditions when flowering and grain filling occur can be stressful for the plant.

Seeds can be direct drilled, but disc seeding can provide more effective seed to soil contact, depending on the soil type.



Data scenario

Investigate the effect of using fertiliser on wheat yields with the data scenario on NelsonNet.



### LET'S EXPERIMENT

## DOES SOWING DENSITY AFFECT WHEAT GROWTH?

### PURPOSE

To observe the effects of planting density on wheat seedling growth

### HYPOTHESIS

What effect do you think sowing density will have on the growth of wheat? Write a suitable hypothesis for this experiment.

### RISK ASSESSMENT



Using the template found on NelsonNet, complete a risk assessment based on the hazards of potting mix and slips, trips and falls.

Identify any additional hazards in your area and make sure you list them in your risk assessment.



Template

Risk assessment template

### MATERIALS

- 15 large pots (ideally 20–30 L size)
- All-purpose potting mix
- Ruler
- Pencil
- Wheat seeds
- Watering can

### METHOD

- 1 Fill the pots with potting mix to surface of pot and ensure that the potting mix is level with the edge of the pot.
- 2 Using the ruler, measure 25 mm and mark this level on the pencil. This will be your sowing depth and will ensure planting consistency.
- 3 Separate the pots into three groups of five pots. For each group, label each pot 1 to 5.
- 4 Sow each pot with the number of seeds as indicated in the table below. Ensure that all the seeds are planted to the same depth and are evenly spaced. You can measure the spacing with a ruler for accuracy. Repeat for all replicates. Once all seeds have germinated, plants can be thinned out to the number of plants required per pot.





Pot number	Seeds sown per pot	No of plants per required per pot
1	3	1
2	6	3
3	10	6
4	18	12
5	24	18

- Carefully water all of the pots and place in a warm, sunny location. You will need to rotate the pots regularly to ensure they are not kept in the same location.
- Depending on temperature, the pots will need to be monitored daily to ensure they are kept moist.

### RESULTS

- Monitor the plants for a period of 6–8 weeks and then record in a table:
  - number of tillers
  - plant height
  - observations such as appearance of plant, colour of leaves, etc.
- Calculate the mean number of tillers and height for each condition (plant density).
- Using the tabulated results, construct a graph of the following:
  - number of tillers vs plant density
  - plant height vs plant density.

### DISCUSSION

- Interpret your results. Was there a relationship between planting density and number of tillers or height?
- Predict what would happen if the experiment was conducted over a longer period of time.
- What are the implications of a low sowing density versus a high sowing density on a plants ability to compete with weeds?
- Design another experiment to test the effects of plant density on growth. Consider any improvements or additions that could be made to the experiment to make it more valid.

### CONCLUSION

From the results you obtained, was your hypothesis correct, incorrect or partially correct?

## Weed management

Weed management is vital to the health of the crop and weed control should commence before sowing. Several strategies are available to growers to manage weeds in wheat, including:

- clearing pastures or previous crop rotations
- chemical fallowing, where herbicides are applied and the area left fallow
- no tilling, allowing stubble to prevent weed growth.

When crops are planted at an ideal density, they can have a positive effect on weed growth as a healthy and vigorous crop competes well with weeds, suppressing their growth and seed production.

## Harvesting

Wheat is harvested from September through to December when the grain has dried to a moisture content below 20%. Wheat harvesting must be done at a specific time to ensure the crop maintains yield and quality because a delayed harvest can drastically reduce both. A late



Weblink

Weed management

harvest can also increase the risk of fungal disease setting into the crop and the heads becoming **shot and sprung**. A combine harvester harvests the crop by cutting it, separating the seeds from the seed heads and cleaning the grain. This process has advanced further with combine harvester technology able to:

- record yield data, which can then be wirelessly transferred to database systems
- automatically adjust harvest height and levelling
- use satellite-based guidance and automatic steering
- use automatic settings that can be programmed to avoid blockages
- monitor all aspects of the process using cameras linked to an interactive display inside the cabin.

The future of combine harvesters lies in the ability to use sensor and satellite technology to enable autonomous harvesting at night.

## Records and financial management

For a wheat grower to maintain financial stability and security, they must maintain the profitability of their enterprise.

**shot and sprung** when grain seeds germinate within the wheat head

### AG IN FOCUS

## MEASURING FARM PERFORMANCE WITH GROSS MARGINS

### Identify

A wheat farmer would like to measure the effectiveness of different crop rotations on the yields of successive wheat crops.

### Understand

The income and variable costs are listed below:

Crop rotation	Cereal	Canola	Pulse
Gross income	\$848	\$1007	\$1100

Variable costs	Cereal crop rotation	Canola crop rotation	Pulse crop rotation
Sowing	\$58.40	\$58.40	\$58.40
Fertiliser	\$210.54	\$210.54	\$175.54
Herbicide	\$60.43	\$17.06	\$17.06
Fungicide	\$17.06	\$17.06	\$17.06
Contract-harvesting	\$56.40	\$63.60	\$66.00
Levies	\$8.65	\$10.27	\$11.22
Crop insurance	\$17.38	\$20.64	\$22.55
Total variable costs			

### Discussion

- 1 Calculate the total variable costs.
- 2 Calculate the gross margin for each crop rotation using the formula below and record your results in a table similar to the one below.

$$\text{Gross margin} = \text{Gross income} - \text{Variable costs}$$



Crop rotation	Cereal	Canola	Pulse
Gross margin			

3 Which crop rotation resulted in the highest gross margin?

4 How might a farmer use this information to determine future management practices?



## LET'S ENGAGE



Web link

Thinkable



Web link

Ten farming apps you should download



Web link

Farm Table software and apps



Web link

NVT online apps

## SMART APPS FOR SMART FARMERS

### PURPOSE

To design an app to assist growers to manage their crop. Smart devices and apps have revolutionised the way growers can manage and monitor their crops. Information is conveniently available at the swipe of a finger, at any place or time.

### MATERIALS

- app building application or software. Examples can be found on NelsonNet.

### METHOD

- 1 Define the problem or issue that the app will assist you with. For example, climate and weather information to assist in planning crops.
- 2 Plan your app. What will the app be designed to do? What will be included in the app? How will a grower use the app?
- 3 Collect information. Research the problem and gather data and pictures.
- 4 Map out features of your app and how you would like the app to operate. For example, is it an interactive app? Will it be used for identification, planning or storing data?
- 5 Build your app. Ensure you get feedback as to how your app operates. You could test and rate other students' apps within your class.

### DISCUSSION

- 1 How will apps assist growers to work smarter not harder?
- 2 Research apps available for agriculture. What apps are available for farmers to monitor their production?
- 3 A software development company has heard about your app. They would like to meet with you to discuss purchasing it. Create a sales presentation to help sell the app. You need to explain to the development company:
  - why your app is beneficial to growers
  - who would use the app? Is it for large or small enterprises or for a hobby farm?
  - how would your app benefit the wider farming community? Would it assist with sustainability? Would it create employment?

Present your sales pitch to the class. Have members of the class judge each one and vote for their favourite.



## LET'S REVIEW

### LOOKING BACK

- 1 When is the most appropriate time to apply fertiliser?
- 2 Explain why sowing time is critical to management of a wheat crop.
- 3 Describe three factors to be considered when choosing a wheat variety.



- ▶ 4 Explain why the Australian wheat belt is a suitable area for growing wheat.
- 5 Identify three uses of drones in wheat production. How do drones assist farmers to manage their wheat crop?

### FOR YOU TO DO

- 1 Find out how a farmer can manage acidic soils. What can be done prior to sowing wheat?
- 2 Identify the machinery required to manage a wheat crop from sowing to harvest.
- 3 Research the regulations involving the use of drones. What limitations exist for a farmer wishing to use a drone on their property?

### TAKING IT FURTHER

- 1 Identify a weed that affects wheat production and design an integrated approach to controlling the weed.
- 2 Research apps available to farmers to assist them manage their wheat crop. Download one and try it out. How easy and effective is it to use? Write a review of the app.
- 3 Discuss the implications of the use of an automated combine harvester to operate at night.

## 7.5 Pests and diseases

### Pests

*Cutworms* attack at the vegetative stage of growth. Larvae damage wheat seedlings by eating young leaves. Adult cutworms chew plants at ground level and cause the plant to lodge. Control is achieved through spot spraying with pesticide while ensuring that the natural enemies of cutworms, such as ground beetles, tachinid flies, braconid wasps, are not affected. Cutworms thrive in weeds, so controlling weeds a few weeks before sowing wheat can prevent an attack.

*Armyworms* are the caterpillar stage of certain moths. They feed on leaves, destroying seedlings and damaging the leaves of older plants, just before the grain ripens and matures. Their natural enemies include parasitic flies and wasps, and they are susceptible to fungal diseases. They can be sprayed in spring when they are at their greatest risk to the crop.

*Helicoverpa* moths feed on the exposed tops of developing grains. They have a strong resistance to insecticides, so care must be taken to ensure insecticides are rotated and natural enemies such as predatory bugs, beetles and parasitoid insects are protected and encouraged. *Helicoverpa* can also be controlled by a viral pathogen and a bacterial toxin (Bt), whose genes have been used in resistant plants.



**Figure 7.13** Cutworms damage wheat plants in the leafy stage.

© State of Western Australia  
(Department of Primary Industries and  
Regional Development, WA)



Worksheets

Research IPM strategies to help control wheat pests with the *Management of wheat pests* worksheet.



**Figure 7.14** Barley yellow dwarf virus-affected wheat.

Alamy Stock Photo/Nigel Cattlin

*Aphids and mites* pierce and suck on leaves and are also vectors for diseases such as barley yellow dwarf virus (BYDV). These are controlled by foliar insecticides and planting resistant varieties.

## Diseases

Most of the diseases that affect wheat are fungal diseases. They present as coloured spores or a powdery coating and can affect leaves, roots or the grain heads. The main diseases that affect wheat are:

- *crown rot* – the most damaging of all the diseases. It survives in wheat stubble from one season to the next.
- *rusts* – the different types are stripe rust, stem rust and leaf rust. Rust spores can only survive on living green tissues of the plant.
- *bunts and smuts* – affect wheat heads and prevent grain development
- *viruses* – include wheat streak mosaic virus and BYDV. These diseases are transmitted by aphids and mites, so controlling those can prevent infection.



**Figure 7.15** a) Wheat smut b) Wheat leaf rust

Diseases in wheat can be minimised and controlled by:

- applying seed treatments before sowing
- growing resistant varieties
- managing stubble where disease can lay dormant
- foliar sprays and insecticides to control diseases vectors
- crop rotations to allow for disease breaks
- managing weeds that may harbor disease.



## LET'S REVIEW

### LOOKING BACK

- 1 How can pest damage be minimised in a wheat crop?
- 2 Explain why it is important that a broad-spectrum insecticide is not used on a wheat crop.
- 3 Describe one pest and one disease that attack wheat crops.

### FOR YOU TO DO

- 1 Draw a diagram of a wheat plant. Indicate on the diagram where pests are likely to attack and identify the pest.



- 2 Identify situations and conditions that encourage disease outbreaks. What management strategies can a farmer put in place to minimise disease outbreaks?
- 3 Design a leaflet for wheat farmers detailing how to spot, prevent and control one type of pest.

### TAKING IT FURTHER

- 1 Design an integrated disease management plan for controlling rust in wheat.
- 2 Pests can also attack grains after harvest. Identify the pests that affect grains in storage and explain how they can be managed to prevent grain losses.

## 7.6 Social and ethical issues

Commercial agricultural practices are often placed under the scrutiny of the wider community. Because wheat is the main staple of the diet around the globe, major wheat exporting countries such as Australia are becoming increasingly responsible for feeding the world. There are many issues that growers must be attuned to, including:

- changing consumer trends with consumers moving away from traditional wheat varieties towards ancient grains and gluten-free products
- increasing demand for organic, chemical-free wheat
- commercially driven food products resulting in less profits and bargaining power for farmers.



### LET'S DISCUSS

- 1 Growing organic wheat necessitates the use of increased cropping land to cover losses from the inability to use chemicals to control pests and disease. What are the social impacts of this on the broader farming community?

Farmers must continue to grow and supply a global market while mitigating the pressures of the increased costs of mechanisation, fuel, fertilisers and pesticides. They must also consider the impact of an increase in cropping area on land and water resources. Soil degradation and fertility issues should also be managed in addition to the effects of the loss of biodiversity.



## LET'S ENGAGE

### WILL THE FUTURE OF WHEAT LIE IN ITS HISTORY?

#### PURPOSE

Are ancient grains a more nutritious option to modern wheat? Current nutrition guidelines recommend that people consume four to six serves of grain foods per day, but only two-thirds of this is being consumed as wholegrains. Consumers are becoming increasingly aware of their health and are preferring products that contain natural ingredients. Ancient grains such as einkorn, spelt and khorasan are varieties of wheat that are the precursors of modern wheat species. These varieties are becoming popular with consumers due to their increased fibre and nutrition compared with modern wheat species. They can easily provide wholegrains to the diet. These varieties each carry their own set of genes that can be used to increase the gene pool of current wheat species, encouraging the development of species that are high yielding, high quality and with the benefit of increased nutrition. Take on the challenge of researching and promoting ancient grains by first gaining an insight into consumer preferences by conducting market research.

#### MATERIALS

- Computer or smart device with access to internet

#### METHOD

- 1 Design a survey to establish current consumer preferences to grain products. Find out how much consumers value:
  - nutrition
  - health
  - value for money
  - convenience.
- 2 Survey as many people as you can. Collate the information to determine what consumer preferences in your community are.

- 3 Research ancient grains and their uses. Look at their uses and establish whether they would be a good substitute for modern wheat in products.
- 4 Select one ancient grain and research its nutritional value. How does this compare with traditional white wheat grain. Use this information to create an advertisement to promote an ancient grain to consumers.

#### DISCUSSION

- 1 What limitations are there on the use of ancient grains in modern food products?
- 2 If a product becomes desirable to consumers, then farmers will grow it to meet demand. Evaluate the process of:
  - a a farmer diversifying and growing an additional crop
  - b a farmer changing production to a completely different crop.
- 3 Conduct a cost-benefit analysis of one of the processes indicated in Question 2.
- 4 Research the markets available for ancient grains? Are they sustainable?
- 5 It is recommended that people increase the amount of wholegrains in their diet, but it can be a struggle for parents to replace white bread, a favourite of children, with whole grain varieties. Wonder White bread is promoted as 'high-fibre bread in disguise'. View the television commercial and analyse the promotional campaign for this product. Would this type of campaign work for a product made with ancient grains? Why or why not?



WebLink

Wonder White Bread commercial



## LET'S REVIEW

### LOOKING BACK

- 1 Identify two consumer trends affecting wheat production in Australia.
- 2 Outline some of the impacts of wheat farming on the Australian environment.
- 3 Explain why wheat farmers are facing increased costs whilst trying to feed a growing population.

### FOR YOU TO DO

- 1 Could Australia change to completely organic wheat production? Make a list of pros and cons and discuss the issue with your class.
- 2 Approximately 70% of Australian wheat is exported and the price farmers receive can vary widely. How would unpredictable wheat prices affect Australian farmers and rural communities?

### TAKING IT FURTHER

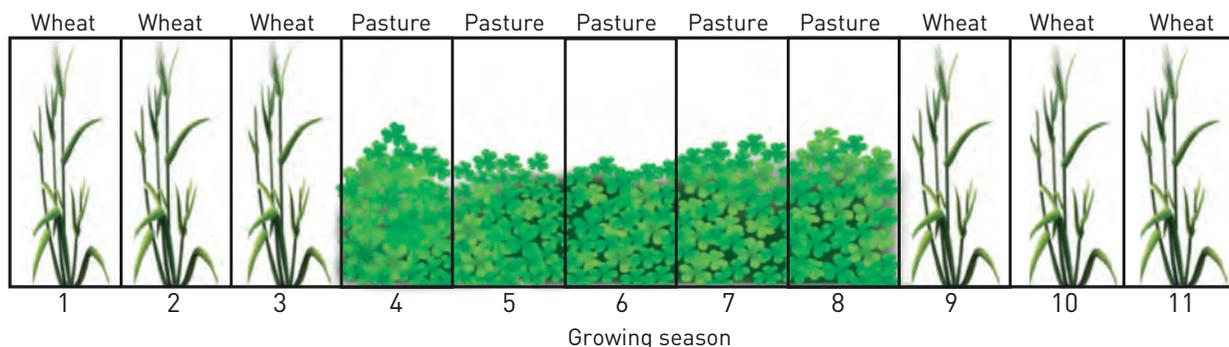
- 1 Investigate which alternative grains are available at your local supermarket.
  - a Compare the price of these grains and flour to wheat products.
  - b Determine the country of origin of each grain.
  - c Research the history and significance of one of these grains to the society from which it first came.

## 7.7 Sustainability

### Sustainable methods and practices

Traditional wheat cropping practices have heavily reduced the amount of soil organic matter over time. This has resulted in declining soil fertility and reduced water use efficiency. These can be alleviated by increasing inputs of organic matter through the application of manures and recycled organic matter and by implementing the following practices.

- 1 *Crop rotations* – it is not ideal to plant wheat crops successively. Growing a different crop in between wheat seasons provides disease and weed breaks. Legume crops and pastures can be used in rotation with wheat as they can provide valuable nitrogen in the soil. This practice is called *ley farming*. Other rotation crops such as canola can be an effective disease break because their taproots help to loosen the soil. These rotations result in reduced pesticide, herbicide and fertiliser applications and the costs associated with these.



**Figure 7.16** Pasture ley farming for improved wheat production

- 2 *Conservation tillage* – this method involves sowing wheat into the residue of the previous crop. This means little or no cultivation is employed, resulting in less compaction and increased moisture retention, which are ideal for wheat growth. Stubble left from the previous crop can stabilise the soil and has the benefit of adding humus to the soil, providing the crop with additional nutrients.

## AG IN FOCUS

### COULD SEWERAGE BE THE SOLUTION TO SOIL SUSTAINABILITY?

#### Identify

Agriash is a by-product of the sewage treatment process that improves the soil.

#### Understand

Agriash is a product made from treated solid sewerage waste. It is heat-treated to over 650 °C and is completely sterile. It is used as a soil conditioner, fertiliser and soil acidity neutraliser. It is an excellent source of phosphorus and ideal for use on acidic soils.

Anecdotal evidence from farmers using Agriash found it to be more effective at encouraging native pasture growth through successive seasons, indicating that it could be highly effective in a pasture rotation with wheat. It is currently being produced in the Australian Capital Territory and should become increasingly sought after as a highly sustainable source of agricultural fertiliser.

#### Discussion

- 1 Many developing countries use human waste as fertiliser but there are health issues associated with this. How does Agriash differ?
- 2 What are the benefits of using a recycled waste product for commercial crop production?
- 3 Create a flow diagram for a) commercial phosphorus fertiliser production and b) Agriash production. Compare each process and find out which has the biggest impact on the carbon footprint of commercial wheat production.



WebLink

Agriash

## Sustainable technology

### Geographical information systems

Geographical information systems (GIS) can be used by farms to collect data and link it to specific geographical locations using global positioning system (GPS) technology. It is a way of giving context to data. For example, GIS can analyse soil data from individual paddocks and map it against farming practices to help farmers make informed decisions regarding crop selection and management practices. Farmers can use seasonal information to determine long-term strategies for their farm by estimating future crop yields and pinpointing problem areas such as susceptibility to soil erosion. The use of such technologies can reduce costs and increase production, all while maintaining the integrity of the environment. GIS and GPS technologies can also be integrated with traditional farming practices and machinery through tramline farming. GIS systems can be used to develop a tramline farming system that creates permanent wheel tracks, minimising soil compaction areas.

## Sustainable decision-making

Sustainable practices and technology have a number of benefits. In the short term, costs can be reduced and farmer incomes stabilised. Maintaining the integrity of the environment and reducing land degradation results in long-term security for a farmer through increased yields. The development of sustainable wheat varieties can have a global impact: genes transcend boundaries and a variety adapted to a specific climate can be used throughout the globe where similar climates and stressors exist.

### AG IN FOCUS

#### DECLINING WHEAT YIELDS DUE TO CLIMATE CHANGE

##### Identify

Rising temperatures and lower rainfall are predicted to significantly reduce wheat yields.

##### Understand

Climate change has resulted in lower annual rainfall and increasing temperatures across the country. This has affected the management and production of wheat crops, not only in Australia but worldwide. In recent years, exceptionally warm and dry conditions during autumn and winter have adversely affected production by delaying the start of the growing season, accelerating development times and reducing the flowering period of the wheat. Short-term effects will initially be seen in the livestock feed market with a predicted rise in grain prices eventually affecting meat prices. Further predictions of climate variability and extreme weather events could further affect wheat and other crop production resulting in uncertainty when it comes to global food security.

##### Discussion

- 1 In terms of the wheat production cycle, what would be the effect of the following weather events:
  - a unseasonal rain at harvest time
  - b a sudden increase in temperature followed by a sudden decrease in temperature
  - c warm and wet conditions during winter.
- 2 How can farmers alter their management practices to safeguard against the effects of climate change on their wheat production?
- 3 How important is agricultural research in terms of maintaining global food security?
- 4 Design an experiment to test the effect of different temperatures on the growth of wheat plants. You could obtain seeds of different wheat varieties to see if their germination and growth is affected by temperature.
- 5 Using the link found on NelsonNet, research different wheat varieties and their growing seasons. Create a resource that maps out which varieties would be best suited for a specific location to be used by farmers determining which variety to plant.



Weblink

Plant breeders  
pre-empt climate  
effects



## LET'S REVIEW

### LOOKING BACK

- 1 How have traditional farming practices affected the quality of the soil?
- 2 Outline the farming practices that can improve a wheat farm's sustainability.
- 3 How does ley farming improve nutrient availability in the soil?
- 4 What sustainable technology is available to farmers to help them in their decision making?

### FOR YOU TO DO

- 1 Research conservation tillage and conventional tillage methods used by wheat growers. Compare the two methods and list the advantages and disadvantages of each method.
- 2 Explain how the use of GIS and GPS technologies can improve the sustainability of a soil.
- 3 Compare the effects of short-term sustainable practices to the long-term effects of sustainable technology.

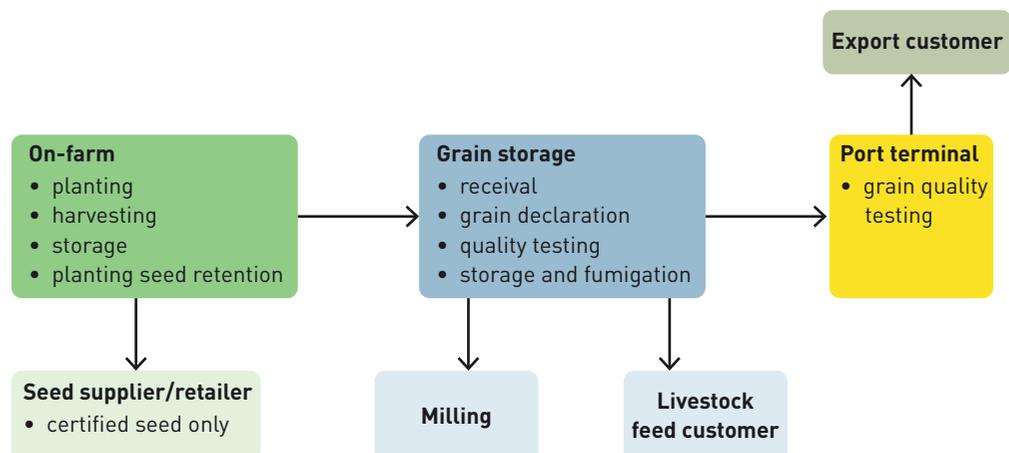
### TAKING IT FURTHER

- 1 Perennial grains such as native millet can improve the sustainability of an area. Research the production cycle of native millet and provide a case for the breeding of perennial wheat.
- 2 Evaluate the use of conservation tillage in a wheat production system with regard to environmental sustainability.

## 7.8 Marketing

### The market

Approximately 70% of wheat grown in Australia is exported overseas, mainly to the Middle East and Asia. Australia accounts for a relatively small proportion of the export market at just under 12%, while European countries are responsible for over half of the international wheat export market. Wheat grown in Western Australia is a high-quality milling grain that is produced specifically for export, while 40% of wheat grown in the eastern states is for local consumers and livestock feed.



**Figure 7.16** The marketing chain of wheat

## Consumer trends

While pasta and noodles have been a staple food in many countries, noodles are set to overtake the market with the increasing popularity of instant noodles. In an age where the workforce is rapidly increasing and populations have restricted time and resources, people are turning towards convenient food options. Owing to the variety, versatility and ease of preparation of instant noodles, the market is expected to dramatically increase. Another increasing trend is the shift to gluten-free products with a rise in the diagnosis of coeliac and other auto-immune diseases in developed countries.



### LET'S DISCUSS

- 1 How will an increase in gluten-free diets affect the Australian wheat industry?

### DID YOU KNOW?

Over 100 billion servings of instant noodles made from wheat are consumed each year globally.

## AG IN FOCUS

### TURNING OFF GENES CAN MAKE WHEAT EASIER TO DIGEST

#### Identify

With the discovery of the wheat genome sequence, genes that relate to coeliac disease, gluten intolerance and allergies can be isolated and potentially deactivated.

#### Understand

Scientists have discovered and mapped the genetic code in wheat. This means that genes for individual traits can be mapped, specifically identifying genes for traits such as disease resistance and frost tolerance. Going beyond yield improvement, genes can be traced to individual characteristics such as digestibility. This would potentially allow genes to be regulated, or turned on or off. The development of a wheat variety that could overcome health issues such as coeliac disease would expand the market for wheat and increase demand for wheat products worldwide.

#### Discussion

- 1 How would the knowledge of a complete gene sequence for wheat speed up the development of new varieties?
- 2 If the demand for wheat rapidly grew in a short amount of time, what would be the implications for global wheat production?
- 3 Public perception of genetically modified crops is often negative. Conduct a debate to argue whether genetic manipulation of wheat is justified if it benefits the health of the wider community.



Weblink

Read more about how scientists managed to crack the genetic code of wheat.

## Market specifications

Wheat quality is determined by its protein content. Protein content then determines the end use of the wheat. The price received for wheat depends on its market classification. Wheat is classified using the following criteria.

- *Australian Prime Hard* (minimum 13% protein) is the top-quality milling wheat. It is used to make high-protein, high-volume breads. It is also used for the production of superior quality Chinese-style yellow noodles and Japanese ramen.
- *Australian Durum* (minimum 13% protein) produces coarse semolina rather than flour when it is milled, and thus is ideal for making pasta.
- *Australian Hard* (minimum 11.5% protein) is used to produce white bread products including flat breads, pan breads and steamed breads.
- *Australian Premium White* (minimum 10.5% protein) is used to make a wide range of products including Hokkien-style noodles and flat breads.
- *Australian Standard White* has no minimum protein content. It is a versatile medium- to low-protein wheat used for general baked goods such as biscuits and cakes.
- *Feed Wheats* have the lowest protein levels and are not suitable for milling.

## Marketing strategies

Wheat growers can store grain on their farms and then sell the grain directly to flour mills and livestock feed wholesalers. Farmers can also sell their grain through grain trading companies or by contract with organisations such as the Australian Wheat Board. The majority of Australia's wheat production is exported overseas to Asia and the Middle East. Wheat prices are determined by the overseas market and is dependent on the quality of the wheat. Wheat prices can rise in response to seasonal conditions that cause a reduction in global production, resulting in Australian wheat being sold for a higher price.



Worksheets

Identify which products require which specifications with the *Wheat market specifications* worksheet.

### AG IN FOCUS

#### VALUE-ADDED WHEAT THAT GOES BEYOND THE BREAD-AND-BUTTER PLATE

##### Identify

A flour milling plant in Nowra makes gluten, starch and alcohol from wheat for a multitude of uses.

##### Understand

While the majority of wheat produced goes to produce flour for baked goods, a flour mill on the south coast of New South Wales produces gluten and starch that is used to make a variety of products such as furniture glue, hand sanitiser and confectionery. With over 6000 wheat growers supplying the factory with wheat, it is the world's biggest starch plant. Because wheat is classified for market according to its protein content, which can be determined by growing conditions, the factory provides a use for wheat that has been adversely affected by unexpected climatic conditions, giving growers the opportunity to sell damaged wheat at a premium price. The factory also recycles its water for irrigation and utilises carbon dioxide produced in another factory that produces carbonated drinks, further adding to the sustainability of the enterprise.

## Discussion

- 1 Research other ways in which wheat can be value added and identify three different products.
- 2 What are the benefits of value-added products for:
  - a the farmer
  - b the manufacturer
  - c the consumer.
- 3 Design a marketing campaign for a value-added wheat product. You should use two different forms of advertising in your campaign (review Chapter 4 to assist you).



## LET'S REVIEW

### LOOKING BACK

- 1 What characteristic determines the quality of wheat?
- 2 How does the market specification determine the price farmers get for their wheat?
- 3 What is the effect of a major overseas drought on the export price of wheat in Australia?

### FOR YOU TO DO

- 1 Explain how consumer food preferences influence wheat variety selection by farmers.
- 2 Classify the market specifications for wheat by putting them in a table reflecting protein content and end products.
- 3 Explain why it may be more effective for a farmer to sell their grain through a grain company rather than directly to a flour mill.
- 4 Design your own value-added instant-meal wheat product. You could also design your own packaging for your product. Remember, it needs to stand out on a shelf!

### TAKING IT FURTHER

- 1 Research the market for Asian noodles versus the market for Italian pasta. Which is the biggest export market for Australian wheat? Evaluate the production of each type of wheat in terms of:
  - a profitability
  - b sustainability.
- 2 Create a marketing chain for the production of starch.

# Let's summarise

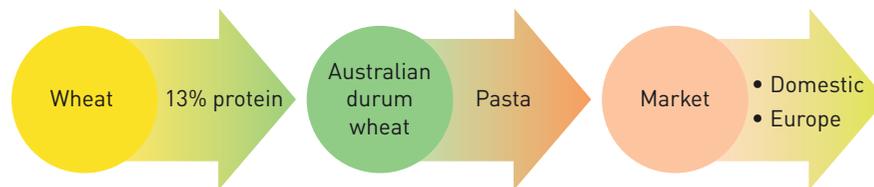


Practice quiz

Complete the chapter review test on NelsonNet to review what you've learnt about wheat production.

## How significant is wheat to Australia and the world?

Wheat has been a staple of the human diet for thousands of years. It is grown across the globe to provide flour to make products such as bread and noodles, which make up a large proportion of the average modern diet. Farmers can grow wheat to provide food for local communities or for the global export market. It is also grown to feed livestock for commercial livestock enterprises, which is another way wheat contributes to feeding a global population. Create a flow diagram that indicates the uses of wheat, the classifications that determine its use and market. An example is shown below.



**Figure 7.17** Example flow chart indicating wheat use

## How will farmers manage to grow enough wheat to feed a rapidly expanding population within increasing environmental constraints?

Farmers select wheat varieties that are best suited to their environment and production system. Farmers must employ appropriate management strategies to ensure that conditions are favourable for wheat growth and development. Timing of sowing and harvesting are critical and must be carried out to coincide with climatic variability and constraints. Pests and disease must also be managed to ensure they do not affect production. Farmers can use technology to assist them in every aspect of production to ensure high yields are achieved without compromising quality and sustainability.

Create a mind map that explains all aspects of production and management of a wheat crop to ensure a high-yielding, high-quality crop is achieved.



# Cotton

## CHAPTER SUMMARY

Cotton is a fibre *and* a food source. The Australian cotton industry has become a world leader for sustainable cotton production and, in the last decade, has improved water production and considerably reduced chemical use through research and technological advances. Many advances in irrigation and harvesting technology have increased production and improved profits for cotton farmers around the world.

**How is cotton used as both a food and a fibre?**

**How is cotton produced from seedbed preparation to marketing?**

**What practices do the cotton industry use to produce high-quality products while ensuring they are environmentally sustainable?**

**How does genetically modified cotton affect production in Australia?**

# 8.1 Introduction

**cotton** a soft white fibrous substance that surrounds the seeds of the cotton plant

**Cotton** is the most widely produced natural fibre and the most used textile fibre in the world, making up about 31% of the textile market. Cotton fibres come from leafy green shrubs and can be used for making clothing and fabrics; cottonseed oil for cooking, margarine and soaps; or as a high-protein stock feed. The remains of the plant itself after harvest can be used as garden mulch.

The world produces around 25 million tonnes of cotton each year, and China is the world's largest producer, consumer and importer of cotton. Australia has over 1400 cotton-growing farms located primarily in Queensland and New South Wales and produces approximately 3 million **bales** annually. Of this production, Australia exports nearly \$2 billion of cotton each year.

**bale** a bundle of cotton fibre, tightly compressed and secured with twine

# 8.2 Functions and structures

## Functions

### Cotton as a fibre

**textiles** a type of cloth or woven fabric

The fibres harvested from a cotton plant have a unique structure that makes them versatile, absorbent and breathable. This makes it an ideal material from which to produce **textiles**. The natural fibre is one of the easiest to dye because of its natural whiteness and high absorbency. It can be woven or knitted into fabrics including flannel, velvet and chambray. Cotton is used to make clothing such as underwear, jeans and shirts, but is also used in other products such as coffee filters, fishing nets, tents and book binding.



**Figure 8.1** Products derived from cotton

## Other uses of cotton

Apart from using cotton lint in textile production, almost all parts of the plant are used in one form of production or another.

**Table 8.1** Products made from cotton plants

Cottonseed	Cottonseed oil	Linters
Cottonseed meal – high protein stock feed for sheep and cattle and fertiliser	soap	bandages
Cottonseed hulls – livestock feed, packaging materials	margarine	bank notes (US paper money)
	cosmetics	cotton buds
	pharmaceuticals	cotton balls
	rubber	x-rays
	plastics	

**linters** short cotton fibres that stick to seeds after a first ginning



Worksheets

Aboriginal and Torres Strait Islander peoples used other materials to produce textiles. Explore these different fibres with the NelsonNet worksheet.

### DID YOU KNOW?

One 227 kg bale of cotton lint can produce 1200 T-shirts.



## LET'S DISCUSS

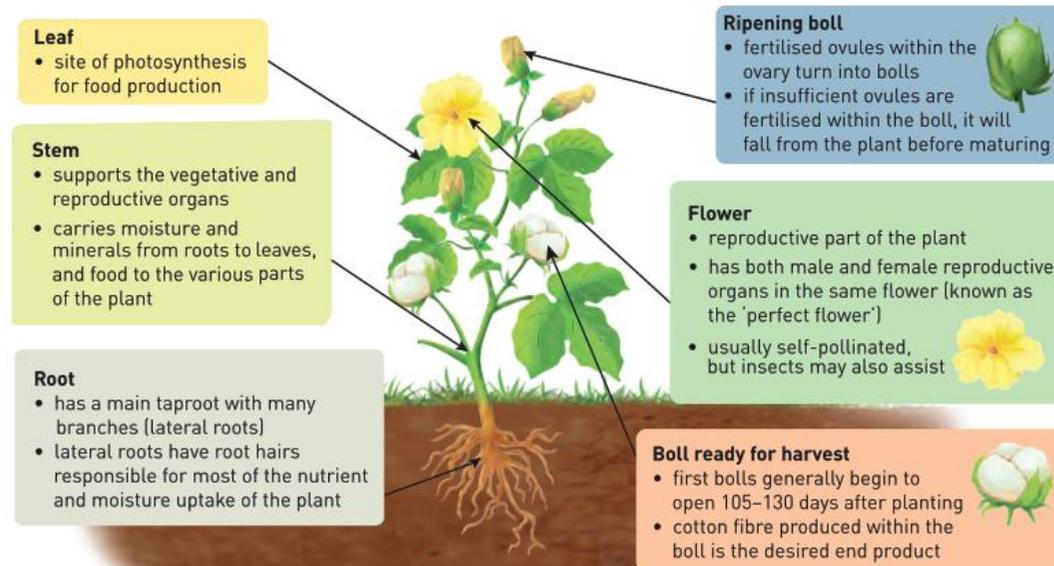
- 1 What other products do you know that are made from cotton?

## Structure of the cotton plant

The cotton plant is a large-leaved **perennial** shrub that belongs to the *Malvaceae* family of plants. As a commercial enterprise it is produced as an **annual** crop, sown and harvested each year. The plant reaches around 1.6 metres in height with a taproot that can reach 1.8 metres deep.

**perennial** a plant that lives for more than two years without needing to be re-sown

**annual** a plant that completes its lifecycle within one growing season



**Figure 8.2** Structures and functions of a cotton plant

## DID YOU KNOW?

There are 43 species of cotton in the world and some cotton grows on trees.



### LET'S ENGAGE

## DETERMINING DIFFERENT PARTS OF THE COTTON PLANT

### PURPOSE

To germinate and grow cotton plants in pots to identify the different parts and discuss the lifecycle

### MATERIALS

- 5 pots
- Potting mix
- 10 cotton seeds
- Greenhouse or suitable warm space (cotton requires warm temperatures for growth)
- Water

### RISK ASSESSMENT



- Open potting mix carefully in a well-ventilated area.
- Wash hands thoroughly after working with potting mix.

### METHOD

- 1 Fill all pots with potting mix.
- 2 Plant two seeds into each pot according to packet instructions.
- 3 Place pots outside in a warm area or inside a greenhouse.
- 4 Water as required.

### DISCUSSION

- 1 Draw and label a diagram, to scale, of the cotton plants:
  - a one day after germination
  - b one week after germination.
- 2 Remove one cotton plant and measure the length of the root and the length of the longest leaf:
  - a one day after germination
  - b one week after germination.
- 3 Describe the differences between the root length and leaf length at both stages.

## The cotton fibre

**cellulose** an insoluble substance that is the main part of plant cell walls

Cotton is a natural, soft staple fibre that is made up of almost pure **cellulose** with a thin coating of wax and is thin and hollow like straw. The arrangement of the cellulose in cotton gives rise to its unique properties: strength, durability and absorbency.

Cotton fibres develop from tiny cells located on the outside surface of the seeds. The seedcoat firmly anchors one end while the fibre stretches out, growing each day. Maximum length will be reached within 15 to 25 days after fertilisation.

Cotton is grouped into short, medium and long lengths and it is the length that determines the quality of the cotton. The longer the length, the higher the quality. Fibre length is largely controlled by genetics, but is also partly due to the environment. Lack of moisture and nutrients cause reduction in fibre length.

When fibres stop growing in length, they begin to fill with cellulose, determining fibre strength and maturity.

## DID YOU KNOW?

Cotton can absorb up to 27 times its own weight in water.



## LET'S REVIEW

### LOOKING BACK

- 1 Apart from cotton fibre, identify other usable raw products that can be harvested from cotton crops.
- 2 Identify five processed products made from cotton plants.
- 3 Draw and label a typical cotton plant.
- 4 Describe the characteristics of cotton fibre that make it a popular textile.
- 5 Sketch a diagram to demonstrate how cotton fibres grow on the cotton seed.

### FOR YOU TO DO

- 1 List all the clothing you are wearing. Look at the labels and record the percentage of cotton and other materials that they contain. Calculate the average percentage of cotton you are wearing.
- 2 Examine cotton fibres under the microscope. Draw diagrams of what you observe at different magnifications.
- 3 Design and conduct a survey to determine the influence that cotton has on the choice of clothing purchased. For example, on a scale of 1 to 10, how important is it that the clothing you purchase is made of or has cotton in it? Is there an item of clothing you buy that you prefer to be cotton such as underclothes?

### TAKING IT FURTHER

- 1 Research and create a mind map of all the products you can find that are made from cotton. Classify them according to the raw cotton product used to make them [e.g. seed, oil, linters].
- 2 Collect as many products as you can find that are made of cotton and build a cotton products wall/stand/board showing the percentage of cotton in each. Organise them into ascending order of percentage of cotton used in each.
- 3 Research one other fibre used in textile production and list the similarities and differences in a table. Explain the advantages and disadvantages of using cotton compared with the other fibre.

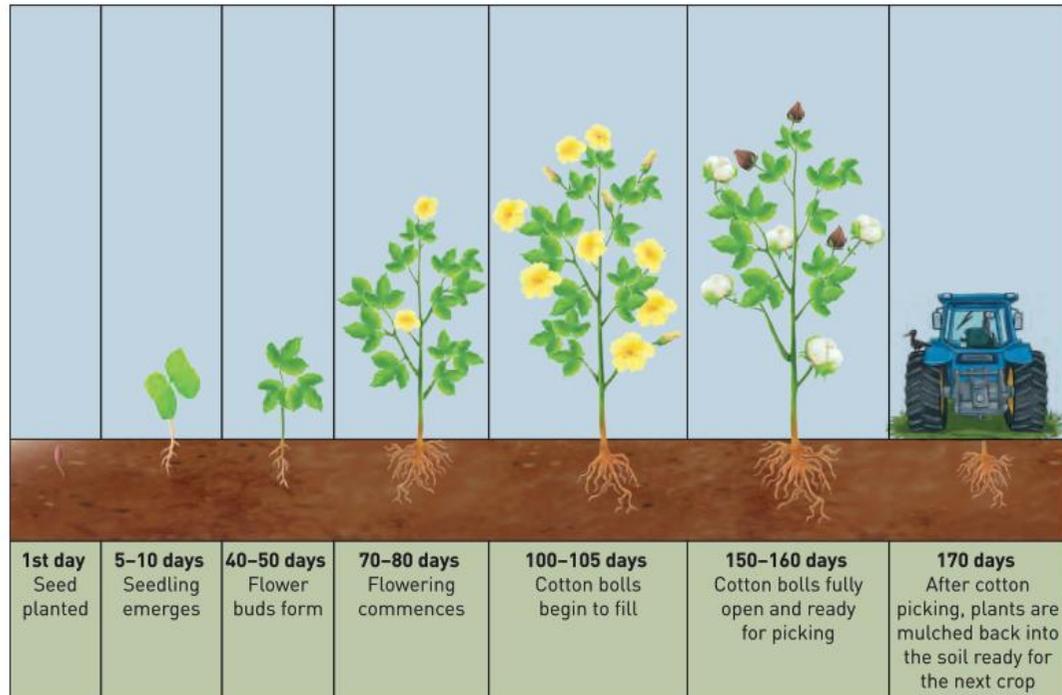
## 8.3 Production

### Cycle

The cotton growing season in Australia lasts for around six months, beginning in September/October and harvesting in March/April. Cotton prefers long, hot and low humidity summers for growth and it usually takes 150–180 days from planting until the cotton is ready for harvest. Flower buds (or ‘**squares**’ as they are called) develop several weeks after the plants germinate. Creamy white flowers develop about three to four weeks later and only remain open for pollination and fertilisation for 24 hours. After fertilisation, the flowers drop and leave ripening seed pods that become fruit, or cotton bolls. Cotton fibres form on the seeds, which are protected within the bolls. It takes around 25 days for a cotton boll to mature, and several weeks later it bursts open to reveal the fluffy white cotton **lint**.

**squares** developing cotton fruit

**lint** the raw fibre from the cotton plant that is pressed into bales at the cotton gin



**Figure 8.3** Growth stages of the cotton plant

## Systems

Cotton can be grown extensively in both dryland (reliant on rainfall) or irrigated regions (requiring supplemented water supply). Irrigated cotton accounts for the majority of cotton production in Australia (around 90%), while dryland cotton currently makes up the remainder. Cotton crops will grow and develop quicker with high average temperatures and a high amount of direct sunlight during the growing season. The hotter and longer the growing season, the higher the cotton yield.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify when cotton planting in Australia usually takes place. Explain why.
- 2 Identify how long it takes for cotton bolls to develop and open.
- 3 When does harvesting take place in Australia? Explain why.
- 4 Identify the two main types of cotton production systems in Australia. Compare the similarities and differences between them.

### FOR YOU TO DO

- 1 Develop a timeline to scale that represents the 180 days it takes from planting to harvesting cotton. Include significant events during the growing process.
- 2 Discuss as a class the advantages and disadvantages of dryland verses irrigated cotton farms.

### TAKING IT FURTHER

- 1 Investigate why a legume crop such as faba beans would be included in a crop rotation for cotton. Evaluate the use of this type of crop rotation for cotton growers.
- 2 Take an excursion to a dryland or irrigated cotton farm and talk to the farmer about why they have chosen that particular type of system. Alternatively, watch the NelsonNet weblink to answer this question.



## 8.4 Management

### Environmental management

#### Distribution of enterprises

Australia has around 900 cotton producers on 1250 farms in both Queensland and NSW. These farms produce approximately 3% of the global total of cotton production. Sixty-two per cent of the cotton crops are grown in NSW and 38% in Queensland. The majority of the farms are irrigated cotton and are mostly located along stretches of large rivers such as the Macintyre River on the Queensland and NSW border, the Barwon and Darling rivers in western NSW and the Lachlan and Murrumbidgee rivers in southern NSW.



Video

Find out how cotton is being introduced to northern Australia by watching the *Landline* episode.



#### LET'S DISCUSS

- 1 How close to your local area are the nearest cotton farms? Are they irrigated or dryland?

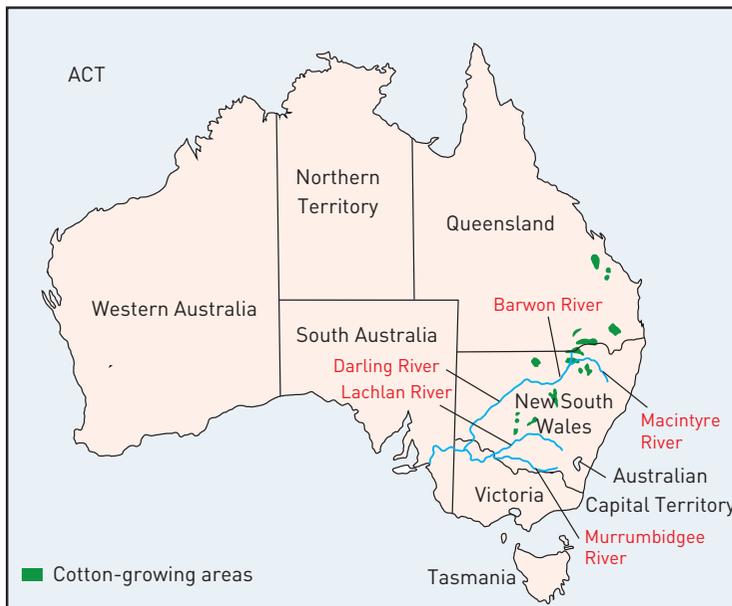


Figure 8.4 Cotton-producing regions of Australia

#### Climate

Cotton's ideal climate consists of warm sunny days with maximum temperatures around 27–32 °C and overnight minimums of 16–20 °C because it is a temperature-sensitive crop. When temperatures exceed these parameters, additional stress is placed on the plant. Temperatures below 11 °C induce 'cold shock' and temperatures above 36 °C induce 'hot shock' that causes the plant to shut down or slow physiological processes. Yield can also be affected by low solar radiation (cloudy days) for extended periods, limited water supplies and high humidity levels, with the cotton plant preferring low humidity.

## Soils

The most important soil characteristics for cotton production are moisture and water-holding capacity. However, cotton has a poor tolerance for waterlogging. Therefore, good porosity for adequate drainage is also necessary. Alluvial soils, black earths and grey and brown clays are preferred by producers and cotton crops can often be found on flood plains next to rivers. Poor soil structure from excessive tillage or traffic (compaction) can restrict water entry and root penetration, causing a restriction of nutrient uptake access to available soil moisture. The optimum pH range for cotton plants is 5.5–7.0.

Cotton needs nutrients from the soil such as nitrogen, phosphorus, potassium, sulphur and zinc. Nitrogen is the most important of these nutrients for cotton plants. Good cotton producers will test the fertility of the soil before production to determine if there is enough nitrogen stored in the soil and work out if fertiliser application is required.



Data scenario

Can you predict how the level of nitrogen in the soil will affect cotton yield and quality?

Investigate the effects of nitrogen on the production of cotton with the data scenario on NelsonNet.



LET'S ENGAGE

### TESTING NITROGEN LEVELS IN THE SOIL BEFORE PLANTING

#### PURPOSE

To test the nitrogen levels in your soil. This activity requires an on-farm test kit; generally an NPK test kit would be used. Results will determine if nitrogen levels are low, medium or high. Because nitrogen is an essential nutrient in cotton production, assume a high level reading is preferred.

#### MATERIALS

- Hand trowel
- 3 soil samples to mix together
- Plastic sheeting
- NPK soil test kit
- Distilled water
- Stopwatch or timer

#### METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Use a clean hand trowel to loosen soil and collect three small samples at a desired location, between 15 and 20 cm below the surface.

- 3 Mix the samples together to get an average sample.
- 4 Spread the sample out on a sheet of plastic to dry out overnight and remove any large stones, leaves, sticks etc.
- 5 Follow the test kit instructions to test for nitrogen levels in the soil.

#### DISCUSSION

- 1 Analyse the results from the soil test. Does this soil contain adequate nitrogen for planting cotton?
- 2 Research the effects of nitrogen deficiency in cotton and other plants. List the signs of limited nitrogen in plants and the causes of nitrogen deficiency in soils.
- 3 Formulate a plan for a farmer with nitrogen-deficient soil to undertake before planting their cotton crop.



Template

Risk assessment template

## Enterprise management

### Seedbed preparation

Good seedbed preparation is required to ensure the root zone is well drained after rain and irrigation as cotton plants are not productive in waterlogged soils. Soil moisture levels are checked, and the area is pre-watered if necessary. Many cotton producers now leave their previous seasons cotton stubble standing in the field between crops. This can be mulched back into the soil to replace nutrients when the fields are levelled and graded.



Data scenario

Salinity is another important characteristic to test for when preparing the seedbed. Use the data scenario on NelsonNet to investigate how salinity affects cotton production.

## Planting

When soil temperatures reach 12–14 °C consistently (dryland cotton prefers soil temperatures of 18 °C), cotton seed is ready to be planted. Planting is done with mechanical planters that can cover as many as 10–24 rows at a time. As the planter moves over the soil it digs a small furrow in each row and drops the seeds in. The seeds are covered over with soil. After five to ten days the seeds will emerge and begin the growing cycle.

## Growing

It takes around four months of growing for cotton bolls to develop, ripen and split open. During this time, producers need to protect their crops from pests and diseases and irrigated farms need to irrigate at regular intervals.

## Weed management

Weeds can be a problem in cotton production and require management throughout the season. They reduce the quality and yield of cotton by:

- competing for light, water and nutrients
- harbouring pests and diseases that affect the cotton plant
- contaminating the harvested lint by increasing the vegetable matter.

Weed management can take a variety of forms, depending on the weed present.

**Table 8.2** Weed management methods

Management method	Example
Physical	Good seedbed preparation can limit the seed bank in the soil.
Chemical	Use a pre-emergence herbicide before planting or use a herbicide during the growth stage without contacting the cotton plant, only the weeds.
Genetic	Genetically modified cotton that is herbicide-resistant can be sprayed with herbicides and not be damaged.

## Harvesting

Harvesting takes place around March/April once most of the cotton bolls have opened and fully matured. There are two basic types of cotton harvesting machines: strippers and pickers. Stripper machines are designed to strip cotton bolls from the stalk. Consequently, both the open and closed bolls, along with many of the leaves and stems, are removed. This excess material is removed during processing at the gin. Picker machines (also known as spindle-type



**Figure 8.5** Mechanical planting of cotton seed



**Figure 8.6** Cotton squares

Alamy Stock Photo/Design Pics Inc



Worksheets

As cotton is a temperature-sensitive crop, soil temperatures at planting are important. Practice measuring soil temperature before planting with the NelsonNet practical activity worksheet.



Video

Research other factors that should be considered prior to planting.



Data scenario

Explore how farmers can use Normalised Difference Vegetation Index imagery via satellites to monitor the health of their cotton crop.



Worksheets



Video

Watch how a baler picker works.



Worksheets



Video

Watch how a baler picker works.



Worksheets



Video

Watch how a baler picker works.

harvesters) are equipped with barbed spindles that detach bolls from the stalk. They remove the cotton from open bolls and leave the bur remaining on the plant. There are pros and cons to both machines, with debris a major problem for stripper machines that require proper cleaning and maintenance, and picker machines often requiring spindle replacement because they break with constant harvesting.

Advances in harvesting technology include machines that are ‘all-in-one’ pickers and module makers. These machines can pick cotton and produce round bales, or modules, on-board and operate without the need to stop and unload. The cotton crop is then loaded onto trucks and transported from the farm to **cotton gins**.

**cotton gin** a machine that quickly and easily separates cotton fibres from their seeds



Practise harvesting and ginning cotton the old-fashioned way with the worksheet on NelsonNet.



Review the steps of the cotton production cycle from seed to fabric with the *Production cycle of cotton* worksheet.



Watch the process of cotton growing from paddock to product



Siphon irrigation on farm



Automated smart siphon system in action

## DID YOU KNOW?

Cotton needs to be harvested dry, or discolouration may occur and cause the quality to be reduced.

### Off-season activities

Harvested cotton is sent to the gin where it is ginned in highly automated machines that clean the plant stems, leaves and seeds from the lint. Some seeds are saved for the next season's crop, some are crushed and turned into oil. The lint is tightly pressed into bales and transported to factories where machines spin it into thread and woven cloths. Bales are finally classed and graded for marketing.

During the off-season some farmers rotate their crops to grow other grains and cereals such as wheat and corn. This helps minimise pests and diseases as well as maintain healthy structure, nutrition and moisture levels. Some producers may choose to graze livestock over winter.

### Irrigation systems for irrigated cotton crops

#### Siphon (furrow) irrigation

The Australian cotton industry primarily uses siphon irrigation, which consists of a pipe that is laid over the bank of an open ditch with one end submerged in water in the ditch and the other end leading to the furrows between the cotton rows. Water flows into the submerged pipe end and is siphoned over the bank and into the furrow. Around 60-70% of the applied water is used by the crop, with the remaining water recycled as run-off.

Due to the labour intensity and water loss of this system, there have been many advances to improve efficiency. Smart-siphons and automated irrigation with small pipes through the banks allow precisely targeted irrigation and reduce waterlogging and plant stress.

#### Bankless channel

This system was designed as an alternative to the labour-intensive siphon system. In this system, a paddock is split into bays that are watered at a high flow rate with all furrows in a bay irrigated at once. There is no need for siphons in this system because it relies on overflowing the head

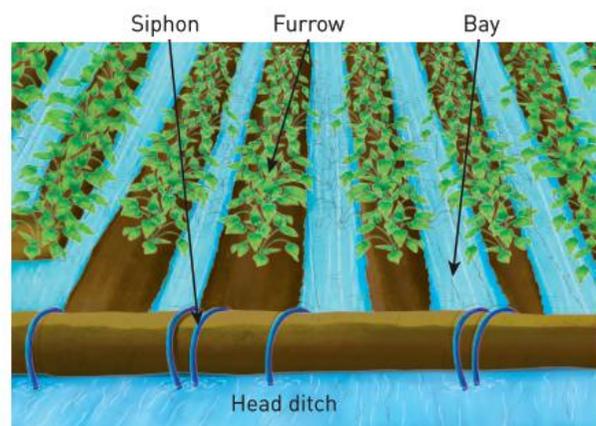


Figure 8.7 Siphon irrigation

ditch into a paddock with the **gradient** of the land running in the opposite direction. Excess water will then drain back into the head ditch and onto the next bay. This system reduces labour and can be managed by one person with limited maintenance, but it is not suited to all paddocks.

**gradient** incline or slope of the land

### Overhead irrigation (central pivots and lateral moves)

Central pivot systems are self-propelled sprinkler systems that feature a main pipeline supported by a row of wheeled towers. The towers are driven by electric or hydraulic motors mounted on them. Water is pumped into the pipeline, which has sprinkler nozzles attached or suspended from it and rotates about a fixed point or the pivot. A large circular area is irrigated as a result.

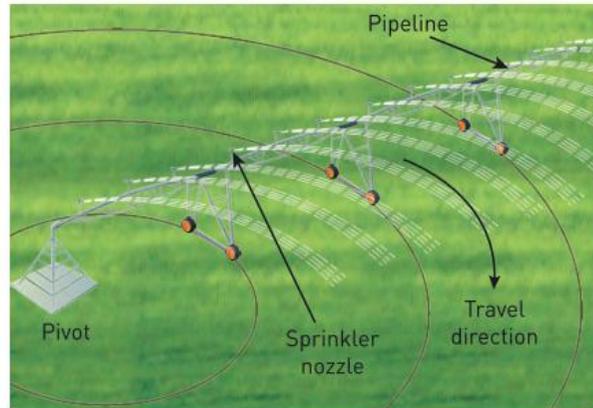


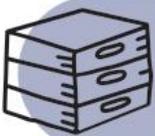
Figure 8.8 Central pivot irrigation

These systems do not require furrows or ditches, which reduces labour required for land preparation. Well-designed overhead irrigation systems can distribute water more evenly than surface irrigation and maximises the water placed at the root zone of the plant. There are higher energy and capital costs.

### Sub-surface drip irrigation

This system applies water below the soil surface through **emitters** in a pressurised irrigation system. It uses buried tubes or tapes that are laid permanently into the paddock and release water at a low pressure and low volume. Being sub-surface, there is less water loss through evaporation, making it water-efficient. With recent developments in technologies and materials for these systems, producers can achieve irrigation efficiencies as high as 90–100%.

**emitters** small holes that discharge water from pipes



## LET'S EXPERIMENT

### SOIL TEMPERATURE EFFECT ON COTTON GERMINATION

#### PURPOSE

To examine the effects of soil temperature on cotton seed germination

#### HYPOTHESIS

What effect do you think temperature (independent variable) will have on germination (dependent variable)?

#### RISK ASSESSMENT



- Open potting mix carefully in well ventilated area.
- Wash hands thoroughly after working with potting mix.

#### MATERIALS

- 15 small seedling pots (short, rectangular pots are recommended)
- Seed-raising potting mix
- Black plastic film (optional)
- Cotton seeds
- Soil thermometer (ensure the soil temperatures are different and adjust as required)





### METHOD

- 1 Fill all pots with the same amount of potting mix
- 2 Place five pots in a warm environment (natural), five pots in a cooler environment and five pots in a hot environment (adding black plastic film over soil can trap heat and increase the soil temperature). Try to keep all other variables as similar as possible.
- 3 Leave for 48 hours to adjust the soil temperatures.
- 4 Plant three seeds into each pot and water equally.
- 5 Water pots every second day, or as needed.
- 6 Record germination results.

### RESULTS

- 1 Construct a table and record how many seedlings germinated in each environment for 12 days.

### DISCUSSION

- 1 Which environment had the greatest germination success rate? Support your answer by displaying the data in a bar graph.
- 2 Explain your results with reference to soil temperature.
- 3 How does soil temperature affect time of sowing for cotton crops?
- 4 With reference to your local area's climate, evaluate its suitability to grow cotton.

### CONCLUSION

Was the hypothesis stated correct, incorrect or partially correct? Why?



Australian cotton bales weigh 227 kg (500 pounds).

## Records and financial management

### AG IN FOCUS

#### COMPARING GROSS MARGINS FROM DRYLAND AND IRRIGATED COTTON CROPS

##### Identify

Gross margins provide a simple method for comparing the performance of enterprises that have similar requirements for capital and labour. A gross margin refers to the total income derived from an enterprise minus the variable costs incurred.

##### Understand

Below is an example budget comparing furrow-irrigated cotton and dryland cotton.



**Table 8.3** Furrow-irrigated cotton

Income	
Bales/ha	10
Cotton lint	\$460
Cotton seed	\$70
<i>Total for cotton lint</i>	<i>\$4600</i>
<i>Total for cotton seed</i>	<i>\$700</i>
<b>Total gross income</b>	<b>\$5300</b>
Variable costs	
Farming: pre-planting	\$120
Nutrition	\$450
Planting	\$150
Irrigation (9.0 ML)	\$560
Crop protection	\$750
Picking, cartage, ginning	\$1100
<b>Total variable costs (\$/ha)</b>	<b>\$3030</b>

$$\begin{aligned} \text{Gross margin} &= \text{Income} - \text{Variable costs } \$/\text{ha} \\ &= \$2270 \end{aligned}$$

**Table 8.4** Dryland cotton

Income	
Bales/ha	3.5
Cotton lint	\$460
Cotton seed	\$70
<i>Total for cotton lint</i>	<i>\$1610</i>
<i>Total for cotton seed</i>	<i>\$245</i>
<b>Total gross income</b>	<b>\$1855</b>
Variable costs	
Nutrition	\$110
Planting	\$170
Crop protection	\$350
Picking, cartage, ginning	\$600
<b>Total variable costs (\$/ha)</b>	<b>\$1230</b>

$$\begin{aligned} \text{Gross margin} &= \text{Income} - \text{Variable costs } \$/\text{ha} \\ &= \$625 \end{aligned}$$

## Discussion

- 1 What is the equation used to calculate gross margins?
- 2 State which farm is more profitable per hectare.
- 3 Compare and contrast the variable costs between the two types of farms.
- 4 If the example dryland cotton farm had 20 hectares of cotton planted, and the irrigated farm had 12 hectares, what would be the total income for each farm? Which farm is more profitable? Explain why.
- 5 Calculate the gross margin for Emma's Dryland Cotton Farm below (use the same prices per bale as the example farms).  
Total bales per hectare = 12

Variable costs	
Nutrition	\$40
Planting	\$80
Crop protection	\$350
Picking, cartage, ginning	\$550



## LETS REVIEW

### LOOKING BACK

- 1 List three ways weeds can affect the yield and quality of cotton and outline weed control techniques that are available to a cotton farmer.
- 2 Identify the main source of irrigation water for cotton crops.
- 3 Compare the different types of irrigation available for irrigation cotton.
- 4 Compare the differences and similarities between traditional siphon irrigation and smart siphon automated irrigation. Evaluate which is more profitable and explain why.
- 5 List the types of records kept by cotton farmers.
- 5 What is a gross margin? Describe how farmers use them to assist with financial management.
- 6 Explain the role of soil testing in determining fertiliser use.
- 7 Name the two different types of cotton harvesters used today and explain how they harvest the cotton.

### FOR YOU TO DO

- 1 Develop a yearly management calendar for a cotton crop, irrigated or dryland.
- 2 Draw a map of Australia showing the main cotton producing regions. Construct a key to show irrigated regions and dryland regions.
- 3 Create a poster that shows the recommended environmental conditions that suit cotton. Include soil characteristics, climate and water.
- 4 Collect copyright-free images of cotton harvesters as they have evolved from the first invention to the modern day. Use these to create a timeline with dates and features included.

### TAKING IT FURTHER

- 1 Research and describe two types of record-keeping technologies that cotton farmers use.
- 2 Research solar diesel-hybrid bore-pump technology in irrigation management and create a short report detailing how it works and how it can improve efficiency and profits on the farm.



Video

Watch a video about the solar diesel hybrid bore pump technology.

## 8.5 Pests and diseases

### Pests

Cotton crops can experience loss of yield and quality through damage caused by pests. Common cotton pests include *Helicoverpa* spp., green mirid, two-spotted mites, cotton aphids, silverleaf whitefly, false wireworms and thrips.



Alamy Stock Photo/Nigel Cattlin

Figure 8.9 *Helicoverpa* spp.



Alamy Stock Photo/Denis Crawford

Figure 8.10 Green mirid

Controlling pests in cotton crops takes a lot of time and labour. Producers seek assistance from agronomists in developing integrated pest management programs. These programs use an approach that relies on preventing and controlling pests through understanding their life cycles and monitoring population levels. The type of action taken will depend on the pest present and its population level.

Table 8.5 Pest management methods used in *Helicoverpa* control

Management method	Example
Cultural	Cultivating paddocks after harvest can disrupt the pupae stage of the <i>Helicoverpa</i> by damaging them, sealing their emergence tunnels and trapping any emerging moths.
Genetic	<i>Bacillus thuringiensis</i> (commonly known as Bt) is genetically modified, insect-resistant cotton that produces toxins that kill <i>Helicoverpa</i> larvae when they feed on the cotton plant.
Biological	Use of beneficial insects to control pests at different life stages, including damsel bugs that are predatory against <i>Helicoverpa</i> at the egg and pupae stages.

### DID YOU KNOW?

There are over 100 known pest species of cotton plants, making crop protection a crucial part of a cotton producer's workload.



Worksheets

Explore the lifecycle of the cotton bollworm and see how it affects cotton production with the NelsonNet worksheet.



Worksheets

Observe damage caused by insects with the practical worksheet on NelsonNet. Remember, some insects are harmful to humans, so only collect specimens under teacher supervision.



## LET'S DISCUSS

- 1 What sort of damage can insects cause to crops and plants in both the short and long term?

## Diseases

Common cotton plant diseases include fusarium wilt, bacterial blight, *Rhizoctonia*, black root rot and boll rots. Disease causes loss of yield and quality is reduced. Producers should use a range of disease management strategies, such as rotating crops, planting disease-resistant varieties, ensuring farm biosecurity and providing plants with essential nutrients for healthy growth.

In addition, controlling pest insects is important for cotton. Cotton bunchy top is transmitted via aphids that feed on infected plants then pass the disease on to healthy ones.



**Figure 8.11** Bacterial blight

Shutterstock.com/Cheng Wei



**Figure 8.12** *Rhizoctonia* in seedlings

Alamy Stock Photo/Nigel Cattlin



## LET'S DISCUSS

Biosecurity is an important issue in farm management.

- 1 What biosecurity measures have you seen or heard about locally and across Australia?
- 2 What are these measures aimed at controlling or preventing?



## LET'S REVIEW

### LOOKING BACK

- 1 List three pests and three diseases that affect cotton production.
- 2 Describe how *Helicoverpa* numbers can be reduced when the cotton crop is not growing.
- 3 Describe how beneficial organisms can be encouraged in the cotton crop.

- 4 Explain why an IPM program would be desirable for cotton growing.
- 5 Explain how crop rotation helps control disease.

### FOR YOU TO DO

- 1 Create a poster showing the major pests and diseases of cotton and the parts of the plant they affect.
- 2 Design an IPM program for a cotton farm (dryland or irrigation) that has a problem with *Helicoverpa*.

### TAKING IT FURTHER

- 1 Research the lifecycle of a damsel bug and *Helicoverpa*. Investigate how the damsel bug is used to control this pest, using diagrams to support your explanation.
- 2 Create a biosecurity checklist that could help cotton producers reduce major pests and diseases entering their property. Use the Farm Biosecurity website to research more about biosecurity on farms.



Weblink

Farm Biosecurity

## 8.6 Social and ethical issues

### Genetically modified cotton

The main ethical issue that arises with the production of cotton is the widespread use of transgenic or genetically modified (GM) cotton varieties. In Australia today, the cotton industry is made up almost entirely of GM cotton. When cotton became a major export commodity for Australia during the 1980s, its sustainability was questioned due to the heavy reliance on pesticides and herbicides. GM technologies offered an alternative solution by altering the genetic make-up of cotton plants so that they could produce their own insecticide proteins or reduce their sensitivity to environmentally friendly herbicides.

In the 1990s, insecticidal genes (such as Ingard®) were introduced into Australian cotton to repel major caterpillar pests. Different genes have been incorporated over time to prevent other pests attacking crops and to design herbicide-resistant strains of cotton. Less than ten years after the initial Australian release of this GM cotton variety, it was replaced by a better product called Bollard that contains two introduced genes and in-built resistance management properties.

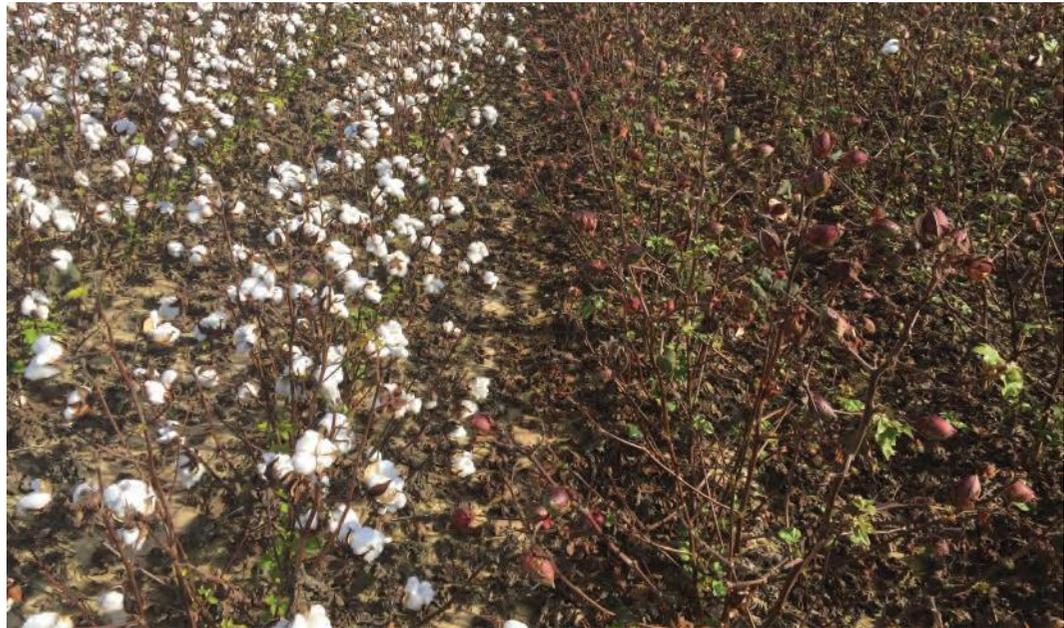
GM technology also focused on developing a herbicide-resistant variety using the Monsanto RoundUp Ready® gene, which makes plants tolerant of the herbicide glyphosate. This variety was released commercially in 2000. The introduction of herbicide-tolerant GM varieties has enabled a 62% reduction in the use of herbicide chemicals and a 33% reduction in the use of broadleaf herbicide. It has also reduced the labour costs associated with mechanical cultivation and hand chipping of weeds.

GM cotton varieties continue to be developed as new GM traits become available and approved by regulatory authorities. Other traits for higher yields, better fibre quality and more tolerance to other pests and disease are also being incorporated into new varieties.

With all the benefits of GM cotton varieties, there remain some concerns, making it an ethical issue.

**Table 8.6** Arguments for and against the use of GM cotton

Arguments for	Arguments against
Increased populations of beneficial insects in cotton crops	Potential to create 'superweeds' resistant to RoundUp
Reduced chemical run-off from pesticides	Expensive seed owned by multinational companies
Decrease in fuel consumption from spraying	Contamination of neighbouring organic and non-GM farms
Reduced production costs	Pests becoming resistant to GM cotton biopesticides
Improved soil quality	Potential introduction of allergenic genes



© Dominic Reisig

**Figure 8.13** Bt vs non-Bt cotton growing in a field**LET'S DISCUSS**

- 1 Do the benefits of using GM crops outweigh the concerns? Why?

**AG IN FOCUS****INSECT RESISTANCE TO GM COTTON****Identify**

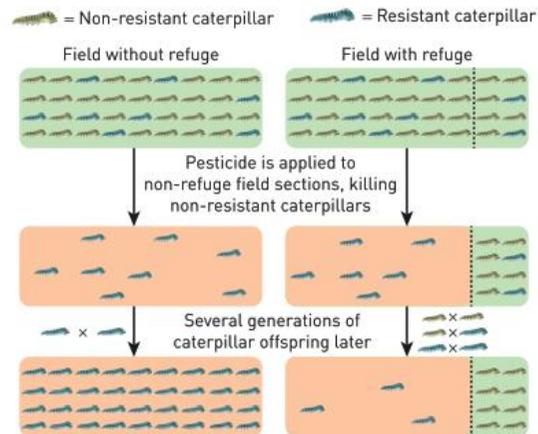
*Bacillus thuringiensis* (Bt) is a naturally occurring bacterium in the soil that produces insect-killing proteins. These Bt proteins have been used in biotechnology to develop insect-resistant crops such as corn and cotton. When targeted insects consume plants with these proteins, they ultimately die. Bt proteins are not considered harmful to humans, other mammals or wildlife.

## AG IN FOCUS

### Understand

Within any insect population there are always a small number of individuals that are tolerant or resistant to Bt proteins. It is possible that, over time, these resistant insect populations can breed and build a Bt-resistant population within a paddock. In this case, the Bt plant species would be ineffective.

Farmers can prevent insect resistance to Bt proteins by building a plant 'refuge'. This is a strip or section of conventional crop that does not contain a Bt species. The insects in the **refuge** strip are not exposed to the Bt protein and a small number of susceptible insects will live. These insects have the opportunity to mate with those that have the resistant gene in neighbouring paddocks, potentially diluting the resistant population. This practice is known as insect resistance management.



**Figure 8.14** Refuges in crops can prevent Bt resistance in insects.

**refuge** safe or sheltered area

### Discussion

- 1 Outline what insect resistance to Bt is.
- 2 Describe how insect resistance to Bt occurs within a paddock.
- 3 Develop a pamphlet for farmers to demonstrate practical on-farm activities they can use to reduce the occurrence of insect resistance within paddocks.
- 4 Research how Bt cotton is created and create a flowchart describing the steps.
- 5 In teams, set up a debate with one team for genetically modifying crops and the other against. Each team will need to create a clear set of arguments to support their view.



## LET'S REVIEW

### LOOKING BACK

- 1 What does 'genetically modified' mean?
- 2 How can Bt cotton help control *Helicoverpa*?
- 3 List three GM cotton species used in Australia and identify the characteristic they have been enhanced with.
- 4 When were GM cotton species first introduced to the Australian cotton industry? Discuss why they were introduced.
- 5 Make a table of the advantages and disadvantages of using GM plants, including cotton.

### FOR YOU TO DO

- 1 Research and describe two problems arising from the use of pesticides.
- 2 Investigate other plants that are genetically modified. Create a table that includes their names, products obtained for profit, the traits that have been improved and why they required improvement.



### > TAKING IT FURTHER

- 1 Research and make a flowchart (using diagrams) explaining how GM plants are created.
- 2 Design a new species of genetically modified cotton. Draw it and label the characteristics that you have altered. Identify where the new characteristics have been sourced from in nature.

## 8.7 Sustainability

### Sustainable practices and methods

#### Water use

Producing cotton is a water-intensive activity, with a global average water consumption of 10 000 litres per kilogram of cotton produced. This means that the average cotton T-shirt, weighing around 250 grams, needs about 2500 litres of water to produce.

Due to the limited water supplies in Australia, cotton research and development has spent a lot of time and money on addressing the high-water footprint issue. As a result, Australian irrigated cotton producers can now produce higher lint yields per hectare than most other cotton producing countries. In the past decade, water consumption per hectare has reduced by 40% and irrigated cotton producers have almost doubled the bales per megalitre of water (known as the irrigated water index).

Cotton producers have adopted a variety of practices to create these changes in water usage, such as:

- research and development by the CSIRO to breed new species of cotton that are suited to the varied regions of cotton farms in Australia
- accurate water metering systems to deliver only the desired amount
- use of technology such as neutron probes to measure soil moisture
- changes to irrigation methods or materials such as changing siphon sizes, slower flow and siphon monitoring systems
- use of precision agriculture to laser-level fields, using GPS guidance equipment, for efficient drainage
- use of conservation tillage practices to help retain soil moisture
- mulching and stubble retention to maintain soil moisture between harvest and planting.

**Table 8.7** Comparison of water consumption per hectare between four common irrigated crops

Crop	Average water consumption (megalitres per hectare)
Cotton	7.8
Rice	12.6
Fruit and nut trees	5.6
Cut flowers	4.9

## Sustainable technology

### IrriSAT

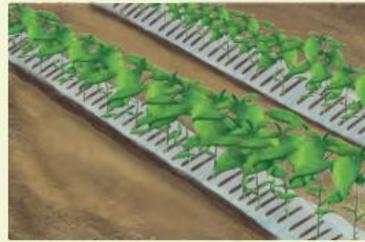
Water is a limiting factor for cotton production, and therefore much of the industry's research and development is based around technologies to reduce wastage. IrriSAT is a weather-based irrigation scheduling technology that helps farmers make sensible water use decisions. Advantages of applying this technology can be:

- a decrease in water and energy consumption during the growing season
- allowing growth monitoring in real time
- accessing updated weather forecasting tools.

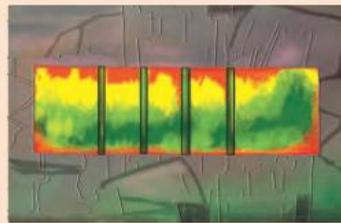
This cloud-based app uses remote sensing to provide crop management information by combining satellite imagery observations and weather forecasts. The app provides daily irrigation maps with a five-day forecast, using innovative computation methods. IrriSAT can also provide daily crop water use calculations and a seven-day crop water use forecast for a paddock through accessing evapotranspiration data from weather stations.

IrriSAT can assist cotton producers to apply the right amount of water at the required time to improve crop productivity and reduce wastage.

**Biodegradable film** placed over rows at planting to increase soil temperatures and can retain soil moisture.

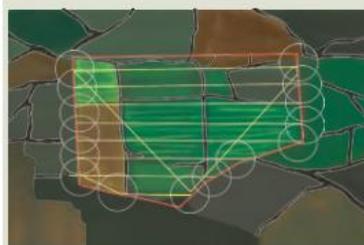


**Normalised Difference Vegetation Index (NDVI)**



to calculate biomass index using satellite images. This can be used to apply variable rate technology on the farm to use fertilisers in areas required instead of across the whole paddock.

**Automated precision broad-acre irrigation systems** reduce water loss.



**Aerial imagery** improves precision agriculture applications to reduce water usage, reduce fertiliser usage and improve yield.

**Figure 8.15** Other sustainable technologies employed by the cotton industry



Worksheets

Practice using IrriSAT yourself and analyse NDVI data with the *Using agricultural technology* worksheet.

## Sustainable decision-making

Many of Australia's introduced plant species grown as crops, such as cotton, require more water than is naturally available by annual rainfall. This leads to farmers using irrigation to modify the environment to make these plants grow successfully.

In the short term, the use of irrigation allows farmers to produce higher cotton yields from their crops. Irrigation reduces plant stress caused by insufficient rainfall and farmers are not reliant on natural precipitation to sow their crops. This short-term benefit is attractive because water is predictable and, to some degree, so is plant growth and maturity.

In the long term, the use of irrigation can cause detrimental effects on the soil, underlying water table and the water source the irrigation water is being removed from. Reduced downstream river flow may cause the disappearance of ecologically important wetlands or flood forests and along with it, the reduction of dependent flora and fauna. Reduced discharge into the sea at the river's mouth can have consequences such as coastal erosion and salt water increases in estuaries, restricting habitats for breeding fish and other aquatic species. Reduced flow also reduces availability of household and drinking water downstream.



## LET'S DISCUSS

- 1 Discuss the issues relating to the long-term sustainability of cotton production in the current cotton-growing areas of Australia.

## AG IN FOCUS

### MURRAY-DARLING BASIN AND WATER LICENSES

#### Identify

In 2012 the four states and territories that share the Murray–Darling Basin (NSW, Queensland, South Australia and the ACT) all signed on to the 'Murray–Darling Basin Plan' to cater to the expansion of agriculture along its system and minimise further damage.

#### Understand

The plan's primary focus is to recover at least 2750 GL of water for the environment through buyback of water licenses and more efficient use of the river system. The federal government committed millions of dollars to buying back water licenses from holders. The buyback, however, has been a difficult part of the plan to execute because many license holders are farmers who are hesitant to give them up because they feel they need it for their crops, especially during drought periods. Communities think that this part of the plan may see many farms go out of business and locals lose their jobs, which will in turn affect local communities, businesses and schools as people move away for work. Environmental groups also see this plan as flawed, saying there needs to be much more water returned to the system to make a long-term impact.

#### Water licenses

A Water Access License is an authority granted under the *Water Management Act 2000* (or similar Acts in other states) to take and/or interfere with surface water, overland flow water or underground water.

Licenses entitle holders to specified shares in the available water within a water management area or water source. They also specify times, rates or circumstances that water can be extracted and from specified areas or locations. A water sharing plan establishes rules for sharing water between the needs of the environment and between different types of water use such as domestic supply, stock water, industry and irrigation. While these water licenses are carefully issued and irrigation farmers are required to record the amount of water removed from the source, the question still remains: are these licenses sustainable for our natural environment? Many would

argue growing crops such as cotton, which require large amounts of water, should be left to countries that have enough natural rainfall to ensure crop success.

### Cubbie Station

Cubbie Station is the largest irrigation property in the southern hemisphere and is located near Dirranbandi, Queensland. The property is 240 000 acres and was created by joining 12 properties within the Murray–Darling Basin. As a result, Cubbie Station holds 51 water licenses for access to water along the Culgoa River.

The property is licensed to take 460 000 megalitres of water from the Murray–Darling Basin. This is the equivalent of all other irrigation licenses downstream in north-western NSW. In an average year, the station records an average usage of 200 000 megalitres of water, and good years can see up to 500 000 megalitres consumed. As a result, the station is often criticised for its water usage requirements, especially when much of the area is in drought and the Murray–Darling system is under stress.

### Discussion

- 1 Outline the short-term consequences of the water licence buyback scheme for both farmers and the environment.
- 2 Do the short-term economic benefits of growing cotton outweigh the long-term consequences of continuing to extract water from the environment?
- 3 Discuss why Cubbie Station is an important feature for the Murray–Darling Basin. Give pros and cons for Cubbie Station having access to 51 water licences along the system.



## LET'S REVIEW

### LOOKING BACK

- 1 What is the average water consumption for producing one kilogram of cotton?
- 2 Use an illustration to demonstrate how much water it takes to produce a T-shirt.
- 3 Outline three ways cotton producers have reduced water consumption in Australia.
- 4 Name and describe one technology used to improve water consumption on Australian cotton farms.

### FOR YOU TO DO

- 1 Create a graph representing the average water consumption of cotton, rice, fruit and nut trees and cut flowers.
- 2 Access the NelsonNet weblink to watch the IrriSAT visual tutorial. Make a list of the functions available through the app and explain how they would be of use to an irrigated cotton farmer.

### TAKING IT FURTHER

- 1 Research one other technology used to reduce water consumption in cotton production and create a marketing flyer to promote this product to cotton farmers.
- 2 Research the cotton industry in a developing nation. Discuss the range of sustainability issues the industry is facing both in Australia and overseas, and the impact it is having on both society and the environment.



Video

IrriSAT visual tutorial

## 8.8 Marketing

### The market

Australia produces around 3% of the total world production of cotton, but is the third-largest exporter, after the USA and India. Australian producers must compete with around 100 other cotton producing countries for trade. About 99% of cotton produced in Australia is exported, generating about \$1.9 billion annually. The majority of the export market is based in the Asia Pacific region, with China the largest market. Other buyers in the Asia Pacific region include Thailand, Indonesia, Hong Kong, Bangladesh, Vietnam, Taiwan, Malaysia and India. Outside of the Asia Pacific region, Australian cotton is purchased by countries such as Italy and Belgium.

Australian cotton is generally of very high quality with low contamination, which means that producers receive a premium price on the world market. The price received per bale is influenced by many factors and can change dramatically each season. The state of the world economy, current exchange rates on the Australian dollar, politics, synthetic fibre price, natural disasters and supply and demand are all considerations.

Apart from cotton lint for textile production, Australia also produces and exports cottonseed. Around 40 million tonnes of cottonseed is produced worldwide annually and existing export markets include Japan, Korea, China and the USA. Exported cottonseed is primarily crushed and used in stock feeds. In Australia it is the second-largest source of vegetable oil after canola. Cottonseed prices fluctuate according to the global price of feed grains.

#### DID YOU KNOW?

In an average year, Australia's cotton growers produce enough cotton to clothe 500 million people.

### AG IN FOCUS

#### COTTON FARMING IN PAKISTAN

##### Identify

Pakistan is largely dependent on cotton production and its related textile sector. It is one of four major cropping enterprises within the country and 15% of the landmass in Pakistan is taken up by cotton growing during the monsoon months of May to August. This is known as the kharif period.

##### Understand

Pakistan is one of the world's leading cotton producers, occupying fourth position behind China, India and the USA. During the 2014/15 season, Pakistan reportedly produced a record 15 million bales of cotton seed, weighing around 210 kg each. Raw cotton exports from Pakistan hold third position on the world ladder and it is the world's largest exporter of cotton yarn. Cotton exports account for 55% of the country's export earnings.

Cotton is grown primarily in two provinces, Punjab and Sindh. Punjab accounts for approximately 79% of the nation's cotton production and Sindh accounts for 20%. It is estimated that around 1.6 million Pakistani farmers engaged in cotton growing in 2013, growing more than 3 million hectares of crops, mostly on small farms of less than 5 hectares.

Cotton has been grown in Pakistan for thousands of years. Archaeologists have found cotton samples in burial sites dating back to 6000 BCE. However, in more recent history, there was a considerable increase in production between the early 1980s and early 1990s, making the industry more profitable. The growth in production has been attributed to better pest control, improved seed types and increases in the use of fertilisers. Local firms dealing with seed production in Pakistan also create their own cotton hybrid species by crossing the Bt gene into traditional varieties.

### Discussion

- 1 Describe where Pakistan fits into the world's leaderboard of cotton production, consumption and exports.
- 2 Using a map of Pakistan, locate the two provinces that grow the most cotton. Can you identify any geographical features that may be beneficial to cotton growing in these regions?
- 3 Discuss how cotton production in Pakistan could affect cotton producers in Australia.
- 4 Compare and contrast how cotton is grown on a typical Pakistani farm and a typical dryland cotton farm in Australia.

## Specifications

The price received for a bale of cotton depends on the graded quality of the bale. Grades are determined by colour, fibre length, staple length, micronaire, neps, stickiness and trash content. Determining quality for cotton is the job of a cotton classer. Both quantitative and qualitative measurements are taken. Visual methods are based on the Universal Standards for Grades of American Upland Cotton, which are produced and provided by the United States Department of Agriculture (USDA) and quantitative measurements are given in imperial measurements, not metric. Classers assess cotton based on the following key characteristics listed in Table 8.8.

**Table 8.8** Key characteristics assessed for cotton grading

Characteristic	Key features for classing
Colour	Visual assessment of colour of a cotton sample in comparison with the universal USDA standards. This is completed under specific light conditions by a cotton classer, or by a high-volume instrument.
Leaf or trash	Measurement of the amount of leaf material remaining in a cotton sample after ginning. Leaf grades range from 1 (low amounts of trash) to 5 (high amounts of trash).
Staple length	Classed using HVI measurements, this is a measurement of the length of a sample of fibres known as a 'pull'.
Micronaire	Unit of fibre thickness that indicates its function. Lint placed in a chamber and compressed to a set volume under a set pressure. Fibre is classed on a scale from G0-G7 (G0 being the lowest and least desirable thickness, G7 the highest).
Strength	Measured by clamping a bundle of fibres between a pair of jaws and increasing the separation force until it breaks. Strength is measured in grams of force per tex and ranges on a scale of weak to very strong.

Bales that meet the market specifications receive the base price at time of sale. Underperforming bales receive lower prices and there are incentives for exceeding the base specifications.

## INDUSTRY IN FOCUS

### COTTON CLASSER

#### Identify

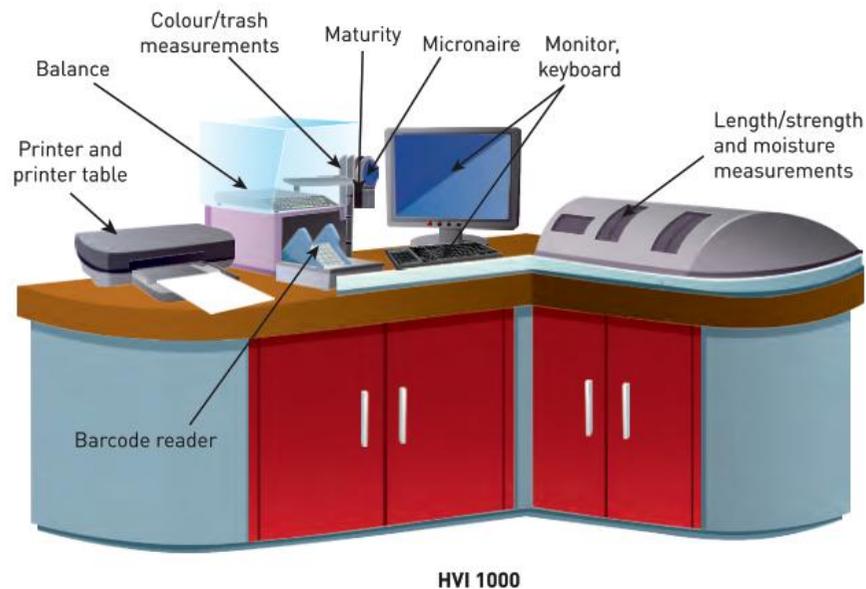
After cotton is grown, ginned and baled, samples are taken from each bale and sent to a classing facility. There, they are classed according to colour, strength, length, micronaire and trash content. This is overseen by an expert called a cotton classer or grader.

Cotton classers classify bales according to industry standards, awarding each bale various grades. These grades are then recorded on the bale identification tags and shipping receiving or sales receipts. After classification is complete, the results are immediately returned to the growers and merchants. The grades allocated by the expert determines the processing route that the bale will take.

Cotton merchants use the information to determine the price paid to the farmer; high-quality cotton receives a premium, low-quality can incur a deduction. The merchant will also use the information to sort bales into shipments for their buyers.

Cotton producers use the grading information to make on-farm decisions for future crops.

In Australia, both visual and mechanical methods are used for cotton classing. A cotton classer uses visual methods of grading and this can be seen as subjective, whereas the high-volume instrument is able to give an objective measurement. As a result, cotton classing jobs are becoming less common in the industry today.



HVI 1000

Figure 8.16 High-volume instrument used in cotton classing

## Discussion

- 1 Describe the role of a cotton classer.
- 2 Explain why the information from cotton classing is important to merchants and farmers.
- 3 Discuss why the role of cotton classing is becoming less common in Australia.
- 4 Research the steps required to become a cotton classer and create a flowchart as a visual representation.



### LET'S ENGAGE

## EXPLORING COTTON FIBRES

### PURPOSE

To see first-hand the characteristics of the cotton fibre

### MATERIALS

- Five samples of cotton from different paddocks or farms
- Ruler

### METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 For each sample, conduct the following simple tests and rank them from 1 to 5 (1 being the most desirable, 5 the least desirable)
  - a Measure the average length of the fibres.

- b Class them from brightest white, to the least white.
- c Estimate the amount of leaf or trash in the sample.

### DISCUSSION

- 1 Order your samples based on their rankings for each of the characteristics above.
- 2 Analyse the differences between your top-ranked sample and bottom-ranked sample.
- 3 Discuss the on-farm activities that could have influenced the main differences between the top sample and bottom sample.
- 4 Discuss why visual classing is subjective, not objective. Which one is more accurate? Why?



Template

Risk assessment template

## Marketing strategies

Generally, cotton producers sell their cotton to one of several independent Australian merchants. Merchants operate on behalf of producers to sell cotton to processing mills or spinners, aiming to get the highest possible price. They bring in similar grade cotton from several farms to meet the quantity requirements of the spinning companies they sell to. Australian cotton producers have a highly competitive, open marketing system with a range of available selling options. Two of the marketing options include the cash market and forward contracts.

The price of cotton on the world market can change daily and is usually sold in US dollars per pound of cotton. A farmer with cotton bales ready to sell may choose the marketing option to sell for the daily price, on the day of the transaction. In this option, the farmer is completely reliant on world cotton prices and cannot predict early in the season the profit they may gain. The price of cotton in Australia is very dependent on what is happening internationally. If major cotton producing countries have short supply due to unfavourable conditions, such as natural disasters, then the price goes up for other producers. If, however, other major cotton producing countries have favourable years and large supplies, this causes a glut or oversupply, and the price goes down.

Another option available to cotton producers to market their product is forward contracts. Forward contracts involve a farmer and a buyer having a customised agreement in writing for the farmer to produce a set amount of cotton at a certain quality for a fixed price. The amount delivered and price paid are determined early in the season. This ensures the farmer a set income for the product, regardless of the world prices.



## LET'S REVIEW

### LOOKING BACK

- 1 What percentage of the world's total cotton does Australia produce?
- 2 List the characteristics that are used to grade cotton.
- 3 Where does most of Australia's cotton crop go?
- 4 Explain the major influences on the price the farmer receives for cotton.

### FOR YOU TO DO

- 1 Discuss the marketing options available to cotton farmers. Evaluate the effectiveness of these marketing options.
- 2 Create a marketing chain for a cotton T-shirt from the farmer to the retail store.
- 3 Using the NelsonNet weblink, find the current world price for cotton and answer the questions below.
  - a What is the current daily price in US cents?
  - b If a farmer has 100 bales of cotton to sell at the daily market price, how much would they receive (bales usually weigh approximately 500 pounds)? Convert this price into Australian dollars using the current exchange rate.
  - c If the farmer was given the option for a forward contact early in the season to sell the 100 bales at \$400 per bale, calculate which option would be more profitable.
- 4 Investigate information using the NelsonNet weblink to collect data on the amounts of cotton exported from Australia over the past ten years.
  - a Create a graph representing the data and describe the trends.
  - b Visit the Australian Bureau of Statistics website to find the most recent year's amount of cotton produced and exported. Has the amount increased or decreased? Add this total to your graph.
- 5 Research strategies which farmers could implement to achieve market specifications.



Weblink

World cotton prices



Weblink

Cotton Australia statistics



Weblink

ABS Agriculture

### TAKING IT FURTHER

- 1 Research cotton spinning and create a flowchart that shows the steps involved, including diagrams to support the descriptions.
- 2 Find out how cotton that has been spun into thread is processed into knitted and woven cloth. Draw up a flowchart that shows the steps involved, including the dyeing and/or printing of the cloth.
- 3 Investigate cotton prices over the past five years. Create a timeline to show price fluctuations and major world events that coincide particularly in cotton producing countries.
- 4 Analyse how organic cotton clothing is promoted in Australia. Give an example of a current marketing campaign in your answer.
- 5 Design a print/radio/podcast/TV advertisement to promote an organic cotton clothing range. Write a detailed report describing your promotional techniques, the target audience and any other significant features of the promotion.

# Let's summarise

## How is cotton used as a food and a fibre?

Cotton is the most widely produced natural fibre in the world. Its softness, absorbency and unique fibre structure make it a perfect choice for textile production, including clothing. Create a mind map listing all the different products made from cotton and noting from which part of the cotton plant they are made.

## How is cotton produced from seedbed preparation to marketing?

There are many processes along the journey to go from seedbed preparation to cotton bale marketing. Use the table provided to draw a flowchart explaining what happens at each step of the production cycle.

Step	Process
1	Seedbed preparation
2	Planting
3	Growing
4	Weed, pest and disease control
5	Irrigation (for irrigated cotton production)
6	Harvesting
7	Off-season activities

## How does the cotton industry produce high-quality products while ensuring they are environmentally sustainable?

The cotton industry in Australia spends a lot of time and money on research and development to improve sustainability of the industry while increasing yield and quality of the fibre.

Create an outline of a yearly calendar for a cotton crop. On the inner circle add the activity that occurs (e.g. seedbed preparation). On the outer circle for each activity in production, add a technology used and a brief statement of its impact on production or sustainability of the enterprise.

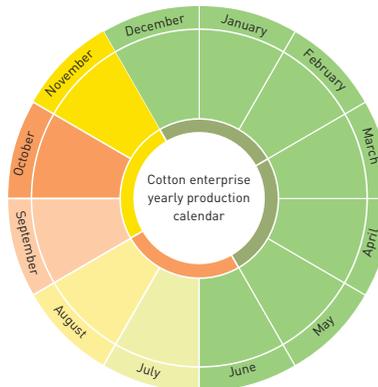


Figure 8.17 Sample yearly production calendar

## How does genetically modified cotton affect production in Australia?

Australia is seen as a world leader in sustainable cotton production. Advances in technology have seen improvements in water conservation and reduced pesticide and herbicide use. However, these advances in technology, such as GM species, raise ethical concerns for the public. Split into two teams and use the PEEL debate structure on NelsonNet to build structured arguments to conduct a group debate on the benefits and detriments of using GM cotton in Australia.



Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about cotton production.



Scaffold

Use the PEEL debate scaffold to assist you



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# Canola

## CHAPTER SUMMARY

Canola is a relatively new crop in the market, steadily rising in popularity due to increasing demands for canola oil both locally and globally. Many mixed-farming enterprises incorporate canola as a valuable rotational crop that complements wheat and pasture, providing a beneficial disease and weed break while being a highly profitable crop in itself. Farmers can choose to grow specially bred varieties that are herbicide resistant, but conventional varieties grown according to sustainable criteria are becoming increasingly popular as Australian canola becomes sought after as a valuable export crop for biodiesel production.

**How can canola be grown profitably and in an environmentally friendly way?**

**Why do farmers choose to grow canola?**

## 9.1 Introduction

Canola is an oilseed crop from the *Brassica* family. It is a **cultivar** of the rapeseed plant from which rapeseed oil is produced. Rapeseed oil was used as an industrial lubricant because it was unsuitable for human or livestock consumption due to its high levels of **erucic acid** and **glucosinolates**, compounds that make the oil unpalatable. In the early 1970s breeders in Canada developed canola as an oilseed variety with a reduced amount of erucic acid and glucosinolates, making it more suitable for human consumption. Its name was appropriately derived from its development: **Canadian Oil Low Acid** = canola. After suffering setbacks in production due to high susceptibility to disease, canola has become a widely grown crop in Australia since the high-yielding, disease-resistant varieties were developed. Australian canola is a high-quality oil, making it extremely sought after in the international marketplace.



Figure 9.1 A canola field in central New South Wales

**cultivar** a plant variety that has been specifically developed for a market

**erucic acid** a monosaturated omega-9 fatty acid considered toxic to humans and livestock in high concentrations

**glucosinolate** compound found in canola and other plants in the *Brassica* family, associated with the hot and bitter taste in mustard

## 9.2 Functions and structures

### Uses of canola

Canola produces approximately 43–45% oil when processed. A by-product of the crushing process is a meal that comprises 38–40% protein.

#### Industrial oil

The chemical components of canola make it ideal for use as an industrial lubricant. It is biodegradable, has low aquatic toxicity and is an excellent substitute for petroleum-based products. For example, it can be used as an ingredient in tyre manufacturing, increasing their flexibility. Canola oil can even be used to make non-toxic adhesives such as glue and tape.

#### Cooking oil

The majority of canola grown in Australia is used for food production. Canola oil is high in unsaturated fats, it contains no cholesterol or trans-fats and has the lowest saturated fat content of any vegetable oil. These properties make it a popular choice for use in home kitchens and the commercial food industry. Canola oil can be used for salad dressings and for frying. It is also made into spreads such as margarine and shortening.



Figure 9.2 Canola oil is used in a variety of food products.

## Livestock feed

Meal is produced as a by-product of the oil crushing process. It is used as a high-protein livestock feed by the pig, poultry and dairy industries. The meal contains valuable nutrients, minerals and fibre and can also be used as a natural fertiliser to improve soil structure. Canola as a plant can be grazed by livestock and can be cut and baled for hay as long as this is completed before the plant flowering.

## Fuel

Canola's high oil content makes it an efficient oilseed that can be converted into biodiesel for use in diesel engines. Canola oil is favoured over other vegetable oils such as soybean, sunflower and corn, because it is a cleaner fuel for machinery and engines, producing only 12% of CO<sub>2</sub> compared with petroleum production. A large proportion of Australian canola is grown for the European biodiesel market.

## Bioplastics

Canola oil can be used to make polyurethane plastic that is biodegradable.

### DID YOU KNOW?

Recycled canola oil can be used by bacteria to make biodegradable plastic.



Worksheets

Review your knowledge about the structure and uses of the canola plant with the *Structure of a canola plant* worksheet.

## Structures: the canola plant and seed

The canola plant is classified into the *Brassica* family of cabbage, mustard, cauliflower and broccoli. All of the plants in this family contain compounds used defensively by the plant. These are erucic acid and the sulfurous compounds, such as the glucosinolates that are responsible for the hot flavour of mustard.

Canola seeds develop on the lower branches of the plant and reach maturity approximately 30–40 days after the flower is fertilised. Seeds are black when mature and have an oil content of 43–45%. The seeds are crushed to remove the oil and leave behind a highly nutritious protein meal that is used as a livestock feed.

Once the seed is harvested, it is important that it is handled and stored correctly to prevent cracking. The high oil content means the seed cannot be stored for long periods because the oil concentration is negatively affected by high temperatures and moisture stress.

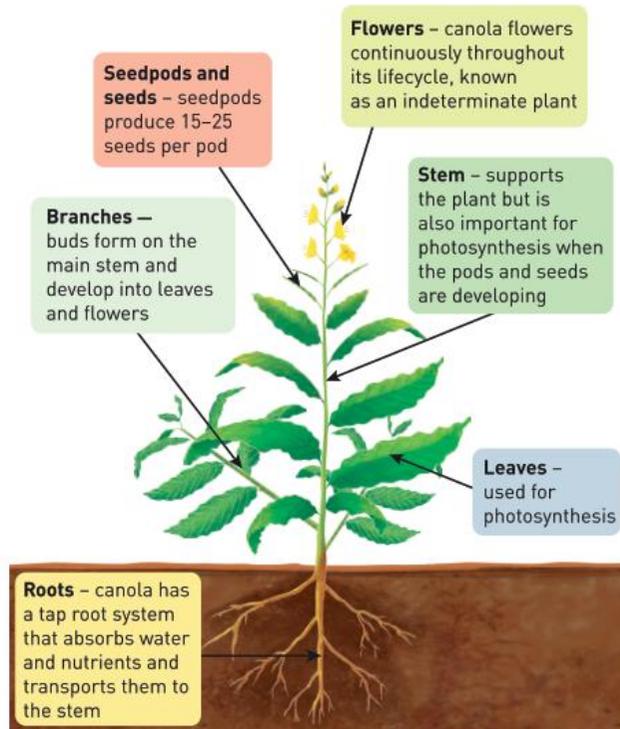
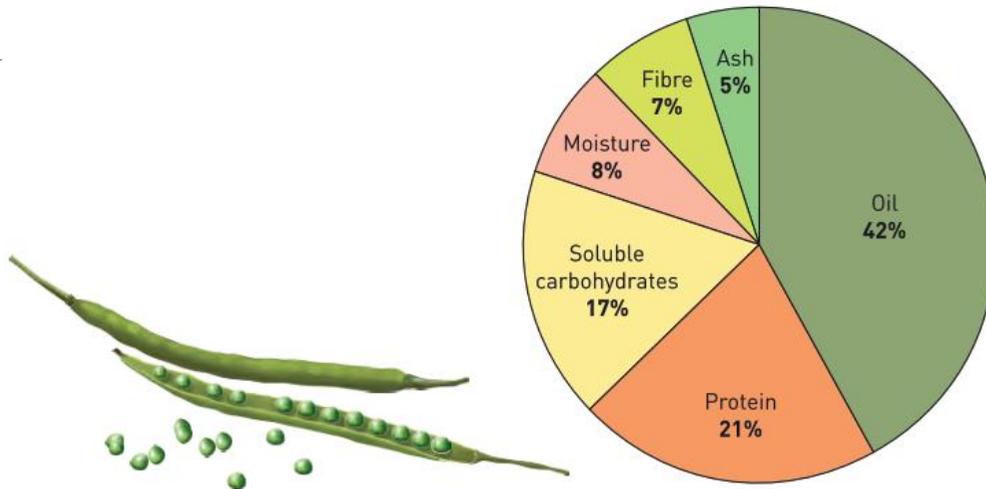


Figure 9.3 The structure of a canola plant

Shutterstock.com/Crepesoles



**Figure 9.4** The main components of a canola seed.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify the main uses of canola oil.
- 2 What was the biggest setback to canola production in Australia and what was done to increase production?
- 3 Why is it important for canola seeds to be handled and stored correctly after harvest?

### FOR YOU TO DO

- 1 Research alternative uses for canola in non-edible products. Identify three uses not already mentioned.
- 2 When canola oil is exposed to light and oxygen, it can develop an unpleasant taste and smell. What can be done by manufacturers to ensure the quality of the oil is preserved?
- 3 Draw and label a diagram showing the structure of a canola plant, and the role of each part.

### TAKING IT FURTHER

- 1 Research erucic acid. How do high concentrations make it unpalatable to humans and livestock? What chemical properties make it good for industrial uses?

## 9.3 Production

### Production cycle

Canola is an annual plant that completes its lifecycle in approximately three and a half months. Most varieties of canola are *Brassica napus*, but a related variety, *Brassica juncea* (juncea canola or Indian mustard), has similar oil quality and the same market end use as canola. *Brassica juncea* is becoming increasingly popular with growers due to its drought and heat tolerance. However, it is not as high yielding as *Brassica napus*. The canola plant has seven different growth stages, as seen in Figure 9.5.



Weblink

Find out more about juncea canola.



Worksheets

Compare *Brassica juncea* and *Brassica napus* using the NelsonNet worksheet.

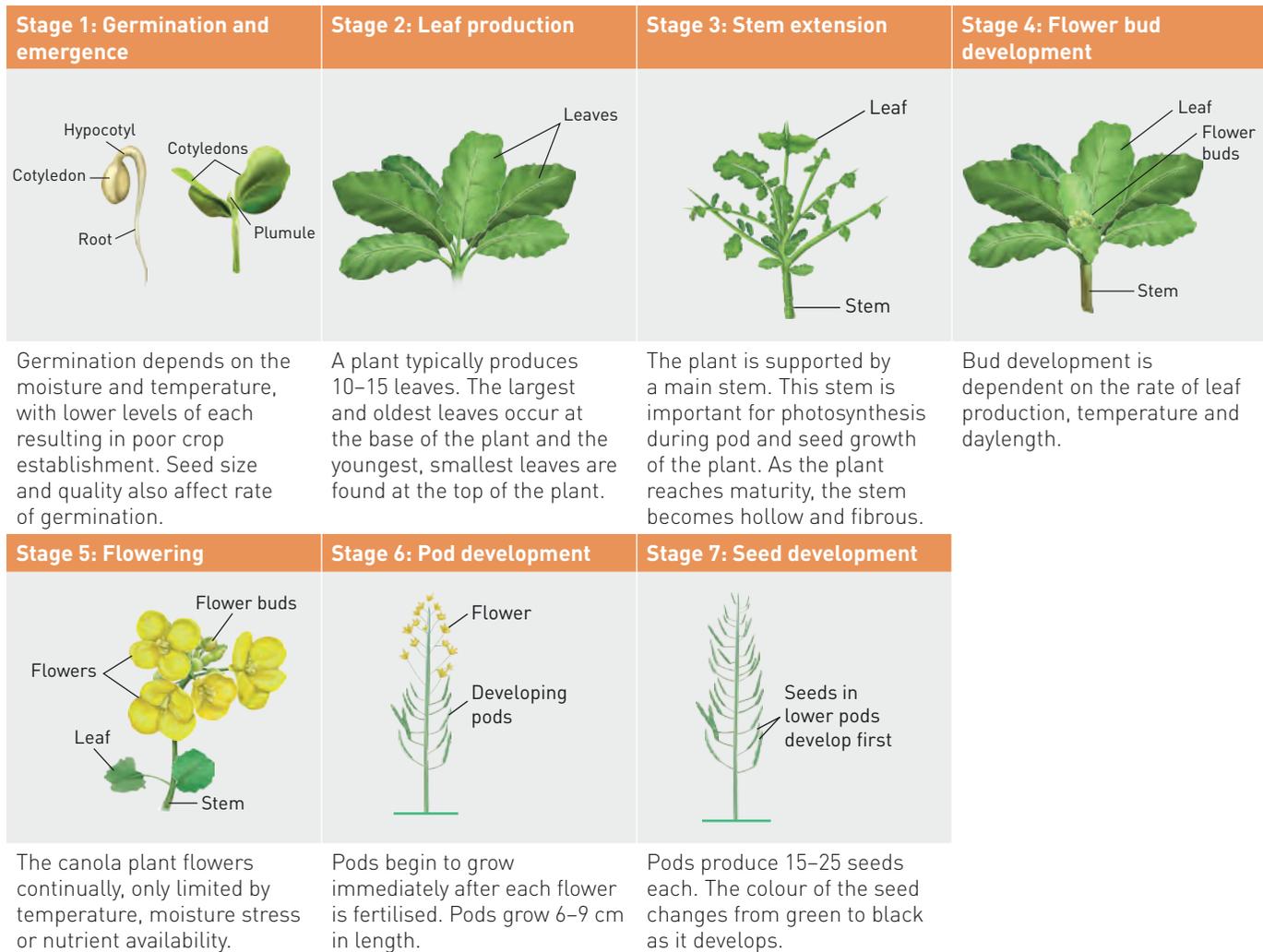


Figure 9.5 The growth stages of the canola plant



LET'S ENGAGE

## FOLLOW THE GROWTH OF A CANOLA PLANT

### PURPOSE

To sow and grow a canola plant, monitoring it at each stage. When growing canola, many management practices are carried out at specific stages.

### MATERIALS

- Large pots – you can grow as many plants as you like; five to ten plants are recommended.
- High-grade, nutrient-rich potting mix
- Ruler
- Canola seeds
- Watering can
- Camera

### RISK ASSESSMENT



Using the template found on NelsonNet, complete a risk assessment based on the following hazards: potting mix, slips, trips and falls.

Identify any additional hazards in your area and make sure you list them in your risk assessment.

### METHOD

- 1 Fill all the pots with soil or potting mix to the top of the pot and level with a ruler.
- 2 Sow two to three seeds per pot at a depth of 1.5 cm (you will thin out seedlings after germination to ensure only one plant per pot remains).





- 3 Water the pots with a watering can until the soil is wet, but do not flood the pot.
  - 4 Place the pots in a sunny position and monitor every couple of days.
  - 5 When all seeds have germinated and are 10–15 cm high, thin the seedlings until only one plant per pot remains.
  - 6 Monitor the plants' growth and take photographs every two to three days or daily if you prefer. You may even set up a time lapse camera to monitor the plants' growth and development. Day 0 will be the day you sowed the seeds. Record the number of days until the plant reaches growth stage 7. This will take approximately 12.5 weeks.
  - 7 As the canola is growing, record the daily temperatures and daylength when the plants reach each growth stage. Construct a table to record results.
- 2 Did all of the plants grow and mature at the same rate? Why or why not?
  - 3 Observe the data collected. Was there a relationship between the growth and development of the plant with temperature or daylength? Did any growth stage correlate with changes in either condition?
  - 4 Canola is generally sown from late autumn to mid-winter. Predict what would happen if canola was sown out of season.
  - 5 Create either a poster or PowerPoint presentation that demonstrates the growth stages of the canola plant. If a time-lapse camera was set up, this can be made into a video with captions indicating the growth stages.
  - 6 Explain why it is important for a farmer to be able to correctly identify the growth stages of the plant.

#### DISCUSSION

- 1 How many days did it take the plants to reach the seven different growth stages?



Template

Risk assessment template

## Production systems

The production of canola is heavily dependent on consistency within a crop to ensure that seeds reach maturity at the same time for effective harvesting resulting in maximum yields. Canola is generally sown from early April to mid-May and it is essential that appropriate varieties are selected for specific areas and that timing of sowing is precise. When canola is ready to harvest, the pods appear a pale brown colour with the seeds a dark brown to black colour. Farmers can test the pods by carefully shaking them – if they rattle then they are sufficiently dry to harvest.

### Continuous cropping

When crops of canola are grown successively each season to meet market demand, it is called continuous cropping. If using this method, a farmer must rely on the strength of the crop to compete with weeds. While this system may be effective and profitable in the short term, it inevitably results in yield losses because over time there is a significant build-up of disease and weeds that become increasingly difficult to control.

### Rotational crop

Canola is commonly grown as a rotation crop with wheat. Because canola has a similar growing season to wheat, it can be successfully grown in a two-year rotation to provide disease and weed breaks, ensuring higher yields of both crops.



Worksheets

Investigate the advantages of each production system with the *Growth and production of canola* worksheet.

**vernalisation temperature**  
a period of cold days required for a plant to initiate flowering

## Mixed farming enterprise

When canola is sown early, it can produce a large amount of vegetative growth that can be grazed by livestock. This can be advantageous to a farmer by providing high-quality forage for livestock during winter and it can also prevent the risk of losses to frost, which can be an issue for early sowing. This is an effective system as long as it is timed appropriately to ensure that the crop is left with enough leaves for the plant to adequately flower and produce seed. There are also dual-purpose varieties of canola available requiring a specific **vernalisation temperature** to flower, allowing for a longer grazing period during winter.

Canola can also be successfully grown under irrigation.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify three factors that affect the germination and establishment of a canola seedling.
- 2 How does seed colour change as the canola plant develops?
- 3 Describe the difference between conventional canola, *Brassica napus*, and juncea canola, *Brassica juncea*.
- 4 Outline the different production systems indicating the benefits of each.

### FOR YOU TO DO

- 1 Draw a diagram of the lifecycle of a canola plant. Be sure to include all the different growth stages.
- 2 Evaluate the suitability of different production systems for your local region. What would be the most effective production system for your region or location? Justify your answer.

### TAKING IT FURTHER

- 1 Evaluate continuous cropping as a production system in terms of short-term and long-term benefits for the farmer.
- 2 Compare the two species of canola, *Brassica napus* and *Brassica juncea*. Evaluate the selection and use of each type with respect to climate change.
- 3 Use the NelsonNet weblink to research different canola varieties available to farmers and suggest which variety would be the most suitable for your region.



Weblink

Canola varieties

## 9.4 Management

### Environmental management

With effective management procedures, growers can achieve high yields of canola of up to 1.5t/ha. The environment must be carefully managed to ensure conditions are ideal for establishment, growth and development of the crop.

### Distribution

Canola is generally grown in the higher rainfall areas of the Australian grain belt and is best suited to temperate zones. More recently, with an increasing number of new varieties available,

canola production is extending to the south-eastern areas where it can be successfully grown under irrigation.

## Climate

Growers must select appropriate varieties for their climate because frost, moisture stress and heat stress are the most significant factors that contribute to losses in yield, oil content and oil quality. The effects of frost can be minimised by the following:

- selecting frost tolerant varieties
- manipulating sowing time to ensure frost does not occur during flower bud development because this can damage the buds, thereby limiting flower and seed production, resulting in lower yields
- managing stubble because it can provide a soil heat bank.

Temperatures of greater than 32°C can accelerate flowering, causing pods to drop prematurely. This can be alleviated by additional watering because moisture is critical at this time.

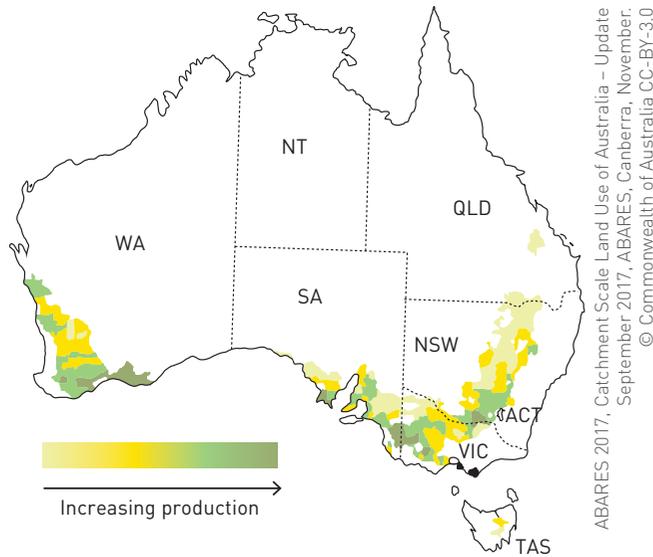


Figure 9.6 Areas of canola production in Australia

ABARES 2017, Catchment Scale Land Use of Australia – Update September 2017, ABARES, Canberra, November. © Commonwealth of Australia CC-BY-3.0



## LET'S DISCUSS

- 1 How can canola farmers mitigate the effects of climate change both in the short and long term?

## Soil

Canola has generally adapted to a wide range of soil types but is best suited to clay soils with a high organic matter content. The crop does not perform well on:

- highly acidic soils, particularly where there is manganese and aluminium toxicity to which it is extremely sensitive
- soils that exhibit crusting at the surface
- **sodic soils.**

As with other high yielding crops, soil testing is recommended before sowing.



Figure 9.7 Soil surface crusting

Shutterstock.com/S.Narongrit99

**sodic soils** contain a high level of sodium ions that cause the soil to lose its structure and rapidly disperse in water; structurally unstable; limit the movement of air and water through the soil



## LET'S ENGAGE



Template

Risk assessment template

## DETECTING SODIC SOILS

### PURPOSE

To conduct a soil dispersion test to find out if the soil is sodic

### MATERIALS

- Shovel
- Clean jars for each sample taken; five to ten samples are ideal depending on the size of the area you are testing
- Distilled water
- Hand trowel
- Bucket

### RISK ASSESSMENT

Using the template found on NelsonNet, complete a risk assessment based on the following hazards:



- shovel and hand trowel
- slips, trips and falls.

Identify any additional hazards in your area and make sure you list them in your risk assessment.

### METHOD

- 1 You will need to collect soil aggregates (clumps of soil). Care must be taken when collecting the aggregates to ensure they are intact and not disturbed. Carefully dig into the soil and subsoil and collect five to ten aggregate samples.
- 2 Carefully place an aggregate in the bottom of one of the jars and fill with distilled water. You need to ensure that the water does not fall directly on to the aggregate. If necessary, place the trowel over the aggregate and pour the water over it so it falls on the sides of the jar. Repeat for all samples.
- 3 Leave the samples to stand for 10–30 minutes. Compare your sample with the tables below. Some samples may take 2–4 hours to show signs of dispersion depending on their level of sodicity.



**Figure 9.8** Soil dispersion indicators for sodic soil

### DISCUSSION

- 1 Did the soil test indicate any sodicity in your soil? Would the soil be suitable to plant canola?
- 2 What are the implications for sodic soils for farmers?
- 3 Research the effects of sodic soils on canola. Identify three to five visual symptoms of areas that are suspected to be sodic.
- 4 What chemicals can be applied to alleviate the effects of sodic soils?
- 5 Identify and describe three management practices that can prevent or improve sodic soils.

## Enterprise management

### Varietal selection

Varietal selection is key in ensuring a high-quality, high-yielding crop. Growers must select varieties that are most suited to their environment and needs. These needs include:

- flowering time, to ensure development occurs under favourable conditions
- pest and disease resistance
- management practices, such as irrigation and herbicide application
- oil and protein content.

### Sowing

For canola to be successfully grown, it is important that plants establish well early after sowing. For this to occur, sowing management is critical. Canola is a relatively small seed of approximately 3–6 g in weight, which means sowing depth must be carefully controlled to ensure germination is consistent. The ideal sowing depth is 1–3 cm and depends on the moisture content of the soil. This also influences germination rate and establishment of the plant. Direct drilling is the preferred method of sowing, but canola seed can also be deep-furrow planted when there is adequate soil moisture. Broadcast seeding is not recommended due to the size of the seed.

Time of sowing is critical for the seasonal management of the crop:

- early sowing results in higher oil yields – crops are stronger and are better able to compete with weeds, but plants are also at risk of frost damage and **lodging**
- late sowing increases the chance of the seed developing in hot, dry conditions, which reduces yields and makes the plant more susceptible to pests and diseases.

### Nutrient management

Canola responds well to the addition of fertilisers. The application of nitrogen encourages growth of a dense leaf canopy that can reduce soil evaporation. Canola needs a lot of phosphorus but is efficient at using it. Canola also benefits from the application of sulfur where there is a deficiency in the soil. Sulfur is important for oil production but must be applied at the seedling stage because this is when demand is the greatest.

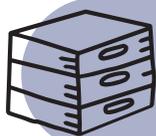
When applying fertiliser at sowing, it is important that it is applied in a band surrounding but not in direct contact with the seed. This is to ensure that, as the seedling emerges, it is not damaged or ‘burnt’ by contact with the fertiliser.



Data scenario

Further investigate the importance of sowing with the data scenario, *The effects of sowing time on canola yields and oil content*.

**Lodging** when crops bend lower in the stem, causing the plant fall to the ground



#### LET'S EXPERIMENT

### SOIL NUTRIENTS AND CANOLA PRODUCTION

#### PURPOSE

To compare the effects of different fertilisers on the growth and development of canola

#### FORMULATE YOUR HYPOTHESIS

What effect do you think the different fertilisers will have on the growth of the canola plants? Write a suitable hypothesis for this experiment.

#### MATERIALS

- 60 pots (10 per treatment, including one lot that will have no fertiliser; this will be the control group). Medium-sized pots are recommended to enable the fertiliser to be placed at the perimeter of the pots because canola seeds are sensitive to direct contact with fertiliser.





Template

Risk assessment template

- All-purpose potting mix
- Pencil
- Pot labels
- Ruler
- Canola seeds, approximately two to three per pot
- Fertilisers
  - Nitrogen (e.g. urea)
  - Phosphorus (e.g. superphosphate)
  - Potassium (e.g. potash)
  - Sulfur (e.g. powdered sulfur)
  - NPK all-purpose fertiliser
- Watering can

### RISK ASSESSMENT

Using the template found on NelsonNet, complete a risk assessment based on the following hazards:



- potting mix
- fertilisers (you can find safety information on the fertiliser labels)
- slips, trips and falls.

Identify any additional hazards in your area and make sure to include them in your risk assessment.

### METHOD

- 1 Fill each pot with potting mix to surface of the pot, ensure that the potting mix is level with the edge of the pot.
- 2 Divide the pots into groups of 10. For each group of pots, number and label each pot with the treatment. Ensure one group is labelled as the control.
- 3 Using the ruler, measure 15 mm and mark this level on the pencil. This will be your sowing depth and will ensure all seeds germinate consistently.
- 4 Sow each pot with two to three seeds of canola. These will be thinned to one plant after they have all germinated.
- 5 Apply a small amount of fertiliser to each pot. You will need to calculate an appropriate amount according to the manufacturer's instructions. Make sure the fertiliser is applied to the perimeter of the pot and away from the seeds.
- 6 Carefully water all the pots and place them in a warm, sunny location or in a glasshouse. You will need to rotate the pots regularly to ensure they are not kept in the same location for the duration of the experiment.
- 7 Once all the seeds have germinated and the seedlings established, thin the pots to one plant per pot.
- 8 Over a period of 12 weeks monitor the plants and at the completion of the experiment, record plant height and number of pods. Observations should also be recorded. Make sure to include things such as the general appearance of each plant and colour of the leaves.

### RESULTS

- 1 Construct your own table and for each of the 10 plants per treatment group record the:
  - a number of pods per plant
  - b the plant height (cm).
- 2 Calculate the means for each treatment and record in the table.



## DISCUSSION

- 1 Interpret your results and answer the following questions.
  - a Which plants grew the tallest?
  - b Which plants produced the most seeds?
  - c Which plants showed the most leaf growth?
- 2 Which fertiliser treatment produced the best leaf growth and colour? What specific nutrients were contained in the fertiliser treatment?
- 3 Explain why leaf growth is important for producing high oil yields.
- 4 What are the benefits of using individual fertilisers as opposed to an all-purpose fertiliser?
- 5 Explain the implications of too much or too little fertiliser on a canola crop.
- 6 Which fertiliser treatment would you recommend that canola farmers use?
- 7 Design an experiment to test the effect of fertilisers on canola in a field test situation. How would you ensure the experiment was a fair test?

## CONCLUSION

Was your hypothesis correct, incorrect or partially correct?

## Weed management

Weeds are a significant problem in canola production and must be effectively managed. Weed control early in crop establishment is important, particularly for the control of broadleaf weeds in the *Brassica* family such as wild radish and wild turnip. If left unchecked, these weeds can contaminate canola seed for processing, resulting in the crop being rejected. The table below shows the main strategies for weed management in canola.

**Table 9.1** Weed management

Strategy	Description
Herbicides	Pre- or post-emergent Selective or non-selective
Crop rotations	Rotate different crops to outcompete the weed
Grazing	Livestock can graze the weeds Pasture crop outcompetes the weeds
Mechanical methods	Cut and slash areas prior to sowing
Herbicide tolerant varieties	GM canola crops bred to be herbicide resistant
Row spacing	Sow crops in narrow rows, increase competitiveness of crop to weeds

The management of weeds is highly dependent on the implementation of an integrated strategy that allows for the rotation of herbicides to ensure that **herbicide resistance** does not develop.

### Precision agriculture

Weed control requires consistent monitoring and management, often requiring large-scale blanket applications of herbicide.

Spray application technology, such as variable rate application, determine crop



Agrometius BV

**Figure 9.9** Tractor mounted sensors can be used for variable rate application of herbicides.



Worksheets

Explore different weed management strategies by designing an IPM approach with the *Weeds management in canola* worksheet.

**herbicide resistance**  
the ability of a plant to withstand application of a particular herbicide

and soil patterns and adjust applications as required. Sensors can be mounted on the tractor to scan the crop and detect weed infestations, particularly after emergence. The spray equipment can be programmed to deliver precise applications, reducing costs and environmental impact. Variable rate application can also be used for pesticide application where pest population spikes can also be detected by tractor-mounted sensors or drone sensors.



## LET'S ENGAGE



Weblink

Weed identification



Weblink

Agriculture Victoria A-Z of Weeds



Weblink

DPI Weeds



Weblink

Queensland Government Weed identification



Weblink

Plant Net

## KNOW YOUR ENEMY: IDENTIFYING WEEDS

### PURPOSE

To identify weeds on your farm or agricultural plot, to ensure appropriate control methods are employed

### MATERIALS

- Camera
- Paper, pen and clipboard
- Computer or smart device with internet access

### METHOD

- 1 Walk around your school, farm or other selected location and find some weeds. Do you have weeds in your paddocks or garden plot that are a problem? Take a photo of them. Try to include the flowers where possible as this helps with identification. For each weed, note any distinguishing features such as spikes or thorns, leaf type or plant structure. Try to find at least three different weeds.
- 2 Have a look at all the pictures of weeds you collected. Use the weblinks to identify the weed. You may need to start looking at some of the

weeds listed on these websites to scale down the options.

- 3 Once you have identified the weeds, start a weed collection or database for others to use. You could also create posters to place around your classroom.

### DISCUSSION

- 1 Explain why it is important for a farmer to identify weeds early in the development of a crop.
- 2 Explain why correct weed identification is important, particularly when selecting herbicides to use.
- 3 Why is it important to recognise a number of distinguishing features when identifying weeds?
- 4 Some weeds pose a serious threat to production, the environment or human health. These weeds are classified as noxious. Research two noxious weeds of NSW. Create a warning poster that advises people of what actions to take if the weeds are found on a property.

## Harvesting

There are two options available to farmers to harvest their canola. The use of each method depends on the production system, and reasons for selecting either method include:

- the variety of canola
- the amount of canola
- weather at the time of harvest
- farm infrastructure and equipment available.

### Windrowing

Windrowing is when the crop is cut and laid in rows in the field where the cut stems are kept 10–20cm off the ground. The crop is cut before it is fully mature, when 40–60% of the seeds have turned from green to black. After being cut, the



Figure 9.10 Windrowing a canola crop

Alamy Stock Photo/Design Pics Inc



Weblink

Watch a video of canola being windrowed.

Pods continue to ripen and the seeds continue to mature. When the seeds are at 9% moisture, the windrows are picked up by the harvester and the seeds are separated from pods. This method has a number of benefits including:

- minimising seed losses in drier conditions
- accelerating seed maturity
- ensuring that all pods are mature when picked up by the harvester
- making the seeds less susceptible to weather damage
- giving the farmer flexibility at harvest time.

### Direct heading or harvesting

Direct heading is when the canola is harvested without windrowing first. It is increasing in popularity and is a good option for farmers growing early-maturing varieties. The benefits of direct heading compared with windrowing are that:

- it is cheaper
- it requires less machinery usage
- it results in less seed losses due to strong winds and hail
- the increase in yield potential and oil quality and quantity is maximised.

If the canola crop is grown in rotation with wheat, the same headers can be used. The crop can also be chemically desiccated prior to heading. This involves a herbicide application that destroys crop leaves but leaves the pods intact and results in consistency of seed maturity at harvest.

### Aboriginal harvesting practices

Aboriginal peoples were the first to incorporate the practice of windrowing when harvesting a crop. Native millet, a perennial grain crop, was grown extensively across Australia before colonisation. When the grain matured, it was cut with stone knives and laid in rows in preparation for threshing. After harvesting, the grain was ground and used to make bread or stored for later use.

## Records and financial management

### AG IN FOCUS

#### USING A GROSS MARGIN BUDGET TO MEASURE PERFORMANCE

##### Identify

A canola grower would like to compare an irrigated crop against a dryland grown crop of canola to establish which production system is the most profitable.

##### Understand

The income and variable costs are listed below.

Production system	Irrigated	Dryland
Gross income/ha	\$1300.00	\$736.00

Variable costs	Irrigated	Dryland
Sowing	\$69.00	\$65.54
Fertiliser	\$280.00	\$200.48
Herbicide	\$24.00	\$36.45
Insecticide	\$21.00	\$79.85
Contract-harvesting	\$84.00	\$86.24
Levies	\$17.00	\$7.51
Crop insurance	\$43.00	\$30.18
<b>Total variable costs</b>		

**Discussion**

- 1 Calculate the total variable costs for each production system and record them.
- 2 Calculate the gross margin for each crop rotation.

**Gross margin = Gross income – Variable costs**

- 3 Which production system resulted in the highest gross margin?
- 4 How might a farmer use this information to determine future management practices?
- 5 Evaluate the use of both production systems. Explain why one is more profitable than the other.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify three favourable characteristics that growers look for when selecting canola varieties for their farm.
- 2 Describe the soil type required to successfully grow canola.
- 3 Outline the nutrient requirements for optimal canola growth and development.

### FOR YOU TO DO

- 1 Explain the importance of effective weed control early in the growth of the crop.
- 2 Explain the difference between windrowing and direct heading of canola. Using the weblink, draw up a table of pros and cons of each method.
- 3 Research nutrient deficiencies in canola. What are signs that a canola crop might be deficient in nitrogen, phosphorus or sulfur?
- 4 Design a new variety of canola to be used in your school region.
  - a Think about your local environment (climate, common pests, etc.) and determine three traits a new breed of canola should have.
  - b Design a leaflet marketing your new canola variety to local farmers.

### TAKING IT FURTHER

- 1 Effective weed management requires the implementation of an integrated strategy that uses a variety of control measures. Design an integrated weed management strategy for the control of broadleaf weeds in canola.
- 2 Research smart apps available to farmers to assist them with managing their record keeping and finances. Download one of the apps and find out how to use it to manage farm data. You can use data from your own school farm or download data from the weblink on NelsonNet. Write a review of the app and explain why you would or would not recommend the app to a farmer.



Weblink

Direct heading vs windrowing



Weblink

Winter crops gross margin budgets



- 3 Growers must implement effective management strategies to minimise the effects of frost. Signs of frost can often be confused with signs of heat and drought stress. Using the link provided, copy and complete the table below describing climatic effect, crop symptoms and production strategies.

Weather event	Symptoms	Management strategies
Frost		
Heat		
Spring drought		



Weblink

Diagnosing frost damage

## 9.5 Pests and diseases

### Pests

#### Pests of canola seedlings

The main pests that attack canola at the seedling stage are:

- mites, including blue oat mite and redlegged earth mite
- lucerne fleas
- false wireworms.

All of these pests attack the leaves on seedlings, preventing establishment of the crop. These pests must be controlled at sowing time when insecticides can be applied as a seed treatment prior to sowing, or as a spray applied after germination and emergence of the seedling. Other methods of control include:

- weed management because weeds can harbor pests
- planting crops in rotation that are not susceptible to pests.



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By Aaron D. Smith, Rebecca Dornburg, and Quentin D. Wheeler – [2014]. "Larvae of the genus *Eleodes* (Coleoptera, Tenebrionidae): matrix-based descriptions, cladistic analysis, and key to late instars". *ZooKeys* 415: 217–268. DOI:10.3897/zookeys.415.5887. CC BY 4.0. <https://commons.wikimedia.org/w/index.php?curid=47676405>

Figure 9.11 Redlegged earth mite, lucerne flea and false wireworm

#### Pests of canola flowers and pods

Other significant pests attack canola crops when they are flowering or developing pods.

These are:

- aphids
- budworms and cutworms
- Rutherglen bug.

**vegetative stage** the growth stage of a plant that occurs after germination but before flowering, when the plant produces most of its leaves

Populations of these pests increase rapidly when conditions are warm and dry. Control methods include insecticides, biopesticides and weed control. Biopesticides can be used in the **vegetative stage** and do not harm beneficial insects.



**Figure 9.12** Aphids, budworm and Rutherglen bugs all attack canola at its reproductive stage.

## Diseases

The main diseases affecting canola are blackleg and sclerotinia, both of which are a problem in areas with high rainfall.

Blackleg is a fungal disease and was a significant problem in the 1970s, so much so that it completely shut down canola production until disease-resistant varieties were developed. It still remains the most damaging disease of canola today. Blackleg affects the uptake of water and nutrients to the plant and causes the plant to lodge. The disease is carried over by the previous year's canola stubble and can be managed to a certain extent by crop rotations. Disease management strategies include:

- fungicidal seed treatments and foliar sprays
- selection of resistant varieties
- stubble management and isolating the crop from the previous year's stubble
- crop rotations.

Sclerotinia stem rot is a problem in irrigated areas or when there are prolonged wet conditions. The disease depends on the season and generally infects the crop at the late flowering stage of growth. While it can be controlled by the use of clean seed and fungicide application, crop rotations are the most effective option for long-term management of the disease.

## INDUSTRY IN FOCUS

### PLANT PATHOLOGIST

#### Identify

A plant pathologist is a 'plant doctor' who studies diseases that affect a plant's growth and development. Plant pathologists study all the conditions that influence plant health, including the soil and the plant's environment. They also strive to understand the organisms, pathogens and vectors that cause plant disease. Plant pathologists work with research companies, chemical companies, farmers, agronomists and plant breeders to discover how best to prevent, control and eliminate diseases in plants. Plant pathologists have interests in biology, chemistry, genetics, plant physiology, agriculture, ecology, soil and the environment. They test different plant varieties, develop medicines for plants for prevention and cure of diseases, and advise farmers of effective integrated management strategies to



Worksheets

Investigate other careers in the canola industry with the NelsonNet worksheet.

monitor and control diseases in plant crops. A wide variety of industries employ plant pathologists, including:

- government departments
- universities
- plant nurseries
- agricultural companies and organisations
- botanical gardens.

### Discussion

- 1 Identify three to five skills and attributes required to be a plant pathologist.
- 2 Discover the career pathway to becoming a plant pathologist. What avenues of study must be undertaken to become a plant pathologist?
- 3 Entomology is the study of insects. Explain how a knowledge or understanding of entomology assists plant pathologists with preventing or curing disease.



## LET'S REVIEW

### LOOKING BACK

- 1 Which growth stages of the canola plant are pests most likely to cause damage?
- 2 Identify the growth stage of canola where biopesticides can be used.
- 3 Outline two weather conditions that encourage pest populations to increase.
- 4 Describe three environmental conditions that encourage the development of diseases.
- 5 Identify five disease-management strategies.

### FOR YOU TO DO

- 1 Explain what is meant by the term 'beneficial insects'. There are many beneficial insects of canola, including hover fly larvae, ladybugs, lacewing larvae and parasitoid flies and wasps.  
Using the weblinks on NelsonNet select one of these insects to investigate. Create a poster that helps growers identify the beneficial insect and indicate on the poster:
  - a how to identify the beneficial insect
  - b the best pest management strategies a grower can use on their canola crop to best preserve the beneficial insect.
- 2 Often, canola is used as a rotation crop. Identify three pests that affect both canola and other crops. How do these pests affect the planning and management of crop rotations?
- 3 Explain how the timing of sowing can affect the impact a disease has on a canola crop.

### TAKING IT FURTHER

- 1 Design an integrated pest management strategy for controlling pests that attack:
  - a at emergence and seedling stage
  - b at flowering and podding stage.
- 2 Evaluate the effectiveness of crop rotations vs chemicals on the management of pests and diseases.



Weblink

Canola council beneficial insects



Weblink

Beneficial garden organisms

## 9.6 Social and ethical issues

### Herbicide-tolerant varieties

Herbicide-tolerant crops allow farmers to use selective herbicides that can control weeds, such as wild turnip and wild radish, that are similar in biology to canola without affecting the canola. There are many varieties of herbicide-tolerant canola, such as:

- 1 *triazine-tolerant varieties* – these have genes for tolerance to the triazine group of herbicides. They are used in situations where weeds cannot be controlled by conventional methods. The triazine group of herbicides specifically target *Brassica* weeds.
- 2 *RoundUp Ready® canola* – a genetically modified (GM) variety that uses plant enzymes to protect the plant from glyphosate and then degrade the glyphosate. Glyphosate is a non-selective herbicide that controls a wide spectrum of weeds.
- 3 *Clearfield®* – a commercial variety that has been bred by traditional plant breeding methods to be tolerant to imadazoline herbicide, which is used to control broadleaf weeds.

These varieties can be successfully used as part of an integrated weed management program, but their use does involve the continued use of herbicides, which has environmental consequences such as herbicide resistance and loss of biodiversity. The use of GM crops could become an issue for the wider community with many consumers turning away from GM products and increasing demand for organically grown crops.



Worksheets

Test herbicide-tolerant varieties of canola to see if they are successful, with the practical NelsonNet worksheet.



### LET'S DISCUSS

- 1 What are the potential consequences of the use of GM crops such as herbicide-tolerant canola, to individuals, populations and the environment?

### AG IN FOCUS

#### DON'T PLANT SO CLOSE TO ME

##### Identify

Cross-contamination between farms growing GM and conventional varieties have implications for both growers and consumers.

##### Understand

GM crops are becoming increasingly popular with growers due to many benefits such as increased yields and lowered costs of production. There are also a number of farmers who choose to grow conventional varieties and others that wish to use organic production systems for growing their crops. Australian canola is highly sought after by European countries due to their preference for non-GM varieties, and growers have responded by growing conventional varieties specifically for that market. While organic farms are at risk of losing their organic certification if contaminated by GM crops, GM growers must battle a higher proportion of pests and diseases due to the lack of chemical control in neighbouring organic crops.

How can all canola growers maintain the integrity of their crops, regardless of which variety they choose to grow? This issue has become increasingly important in today's society when consumer preferences can determine the direction of agricultural production. The threat of farmers being held liable for cross-contamination of crops will no doubt affect production systems and management practices, but the extent of this remains unknown.

### Discussion

- 1 Which growth stages of the canola plant should be monitored carefully to reduce the risk of crop contamination to neighbouring properties?
- 2 How can farmers adjust their production systems to mitigate the risk of contamination to neighbouring crops?
- 3 What are the implications for the price of canola if farmers become liable for crop contamination in surrounding areas?



## LETS REVIEW

### LOOKING BACK

- 1 Identify three types of herbicide-tolerant varieties of canola and describe the type of weeds each can assist with.
- 2 Identify two problems with using herbicide-tolerant varieties of canola.

### FOR YOU TO DO

- 1 Using the NelsonNet weblink, research herbicide-tolerant canola varieties and explain which variety you would use in the following situations:
  - a to control broadleaf weeds
  - b after a pasture rotation, in preparation for sowing a new canola crop
  - c where annual ryegrass is a problem
  - d to control the emergence of a different variety of canola that was planted in a previous season.



Weblink

Herbicide-tolerant canola

### TAKING IT FURTHER

- 1 Conduct a survey in your local community to identify consumer preferences regarding use of herbicide-tolerant varieties of canola.
- 2 Discuss the implications in terms of sustainability, profitability and management for a local organic farmer when their neighbour decides to start using RoundUp Ready canola.

## 9.7 Sustainability

### Sustainable methods and practices

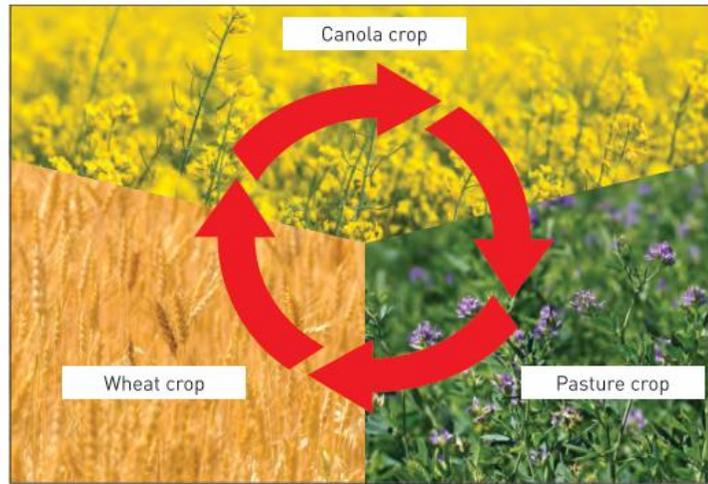
#### Crop rotations

Canola is used extensively as a rotation crop and, in a mixed farming enterprise, can dramatically reduce weed, pest and disease populations, resulting in higher yields all round. When used as a rotation crop with wheat, canola can have many environmental benefits.



Investigate how different varieties of canola can improve the sustainability of an enterprise with the *Omega-3 canola oil could save declining fish populations* worksheet.

Canola's taproot brings moisture and nutrients to upper levels of the soil and breaks weed and disease cycles, especially in controlling cereal diseases such as crown rot.



Top: Shutterstock.com/Taras-studio;  
Bottom left: Shutterstock.com/Punetha;  
Bottom right: Shutterstock.com/Michael G McKinn

**Figure 9.13** A crop rotation of canola, wheat and pasture can assist with weed and disease management while improving soil fertility.

A ley-pasture cropping system is when a crop is rotated with a pasture that can be grown for hay or silage, or grazed by livestock. A legume pasture ley can improve soil structure and nutrition, benefitting successive crops. It can also greatly reduce herbicide pressure on crops and manage weeds that are herbicide resistant by allowing them to be grazed out.

## AG IN FOCUS

### ECO-GOATS

#### Identify

Goats are being used to manage landscapes through targeted grazing of weeds as an alternative to herbicides.

#### Understand

Leo Phelan operates a vegetation management company that uses goats to provide effective weed control that allows for regeneration of native species. Initially, Leo was granted government funding to establish a project to use goats on steep terrain on land that was originally used for banana and pawpaw production. The land had a high disease load and an infestation of Mexican sunflower (*Tithonia diversifolia*). Leo implemented a system of targeted grazing using goats, which successfully grazed out the weed.



Shutterstock.com/vaaka

**Figure 9.14** Goats can be used to target weed flowers and seed heads, removing them at the right time to reduce the number of weeds in the following crop.

Leo believes that most landscapes can be managed with goats, but the success of a strategy such as this is heavily dependent on having a thorough knowledge of animal behaviour, the ruminant digestive system and plant growth. In this case, Leo discovered that the Mexican sunflower was high in protein and favoured by the goats. Electronets and mobile goat yards were used to restrict the goats to specific areas and cameras were used to identify the goats' browsing actions. Leo researched the plant's ability to reproduce viable seeds and found that less than 1% remained viable after rumen processing.

This kind of controlled grazing can be successfully utilised in any environmental or agricultural situation. Goats are browsers and will selectively graze plants that have seed, flowers, fruit and bark, which make them excellent primary weeders. A system that employs intensive, controlled grazing that is specifically timed to target the lifecycle of specific weed species can significantly reduce the use of herbicides for weed control.

### Discussion

- 1 Explain how Leo used goats to eradicate the Mexican sunflower plant.
- 2 Some of the most significant weeds in canola are *Brassica* weeds such as wild turnip and wild radish, which are highly palatable to goats. Design an integrated weed management strategy that incorporates goats to control *Brassica* weeds in canola after a pasture rotation.
- 3 Explain why it is important to have a thorough understanding of the ruminant digestive system and the characteristics of specific plants to ensure the success of a grazing strategy to control weeds.
- 4 Leo provides goats to assist landowners to manage weeds. What are the possible biosecurity implications of moving livestock on and off different properties?

## Sustainable technology

### Controlled traffic farming

Controlled traffic farming, also known as tramline farming, is a system that matches the wheel tracks of all machinery used on the farm to ensure that common tracks are created. This ensures that the same area is consistently driven over, reducing the amount of soil compaction. This method can be taken a step further with the use of self-driving tractors that are programmed to follow a specific course. Benefits of this system include improved soil structure and increased yields. This is particularly beneficial for canola farms that use machinery for windrowing as well as for harvesting.



**Figure 9.15** Self-driving tractors can help to preserve soil structure.

iStock.com/Scharfism86

## Sustainable decision-making

Canola is an extremely versatile crop, providing oil for food production, high-protein livestock feed and biodiesel. Canola biodiesel is highly efficient and is an environmentally friendly fuel that only produces 12% of the carbon dioxide that petroleum diesel produces. Biofuels made from Australian canola must meet sustainability requirements for the European market. Growers can obtain International Sustainability Carbon Certification to provide sustainable biodiesel.

Growers can benefit in the short term by selling their canola at a premium price even though it may initially add to their production costs. Biofuels reduce the use of fossil fuels and have long-term benefits for the environment. However, the increased production of biofuels also results in increased land degradation through declining soil fertility and increased erosion due to the machinery required for the intensive production needed for biofuel production.



### LET'S DISCUSS

- 1 How would growing canola for fuel instead of food affect long-term food security?

## AG IN FOCUS

### THE CROP THAT FUELS AND FEEDS THE ENVIRONMENT

#### Identify

Canola can be grown in a closed loop system whereby the crop is grown, processed into biodiesel and then used in machinery on the farm, while the by-product meal is fed to livestock.

#### Understand

A company in Victoria has developed a closed loop system in which they grow canola and have specialised machinery that converts the canola to biodiesel, which is then used on the property. The by-product of this process is a high-protein meal that is then pelletised and fed to dairy cattle. Other by-products of the oil processing are waste water and glycerine, which are used to generate power through the use of a digester system. Any surplus meal is then used as fertiliser for successive crops. This system is highly efficient, resulting in the outputs being used as the inputs for production, hence the closed loop system. The enormous benefits to a system such as this include:

- reduced carbon footprint of production
- soil improvement due to the use of organic fertiliser
- reduced dependence on fossil fuels
- reduced overall environmental impact
- financial
- reduced fuel costs
- reduced feed costs
- reduced power costs.

This kind of production system also has the potential to work for other oilseed crops.

#### Discussion

- 1 What are the advantages of the canola close loop system?



- 2 Research this closed loop system further using the weblinks. Create an infographic of the canola closed loop system to create a fact sheet or poster highlighting how the system works.
- 3 Evaluate the short-term and long-term effects of a farm using a closed loop system.
- 4 What are some of the flow-on effects of this system on the wider farming community?



Weblink

Ecofuels



Weblink

Biomass producer



## LET'S REVIEW

### LOOKING BACK

- 1 Identify the different combinations of crop rotations that can be implemented in canola production.
- 2 Describe why canola is a good oil crop for biodiesel production.
- 3 What are the environmental benefits of tramline farming used in canola production?

### FOR YOU TO DO

- 1 Create a calendar of operations for an enterprise that grows canola as a primary crop with a wheat rotation every second year. The enterprise also grazes steers for the local market.
- 2 Growers sometimes burn the stubble of the previous crop before sowing new crops. Research Aboriginal fire management and compare this practice, explaining why these methods are different.

### TAKING IT FURTHER

- 1 Research the criteria for growers to obtain International Sustainability Carbon Certification.
- 2 Certification of canola for biodiesel encourages sustainable practices. What are the short-term and long-term effects of implementing the criteria for certification?
- 3 Research different tillage methods in canola production. Compare conservation tillage to conventional tillage methods. What are the advantages and disadvantages of each method?

## 9.8 Marketing

### The market

Canola is Australia's third-largest broadacre crop with Australian annual production averaging 3.5 million tonnes. It is a highly profitable crop with around 1.5 million tonnes being exported overseas in 2018–19 to Asia and Europe. Globally, market demand has grown rapidly with the increasing demand for vegetable oils. Australian canola is a valuable export crop because it is favoured for its high quality. Export markets for Australia's surplus seed are Japan, Pakistan, Bangladesh and China. The European Union is the largest export market for Australian canola, which is used for the production of renewable biodiesel. Australia is

the second-largest exporter of canola in the world, with Canada the biggest exporter of canola, supplying over 70% of global exports. The main domestic markets for canola are oil processing and protein meal, with the remainder going to the certified seed industry allowing for re-sowing of the crop.

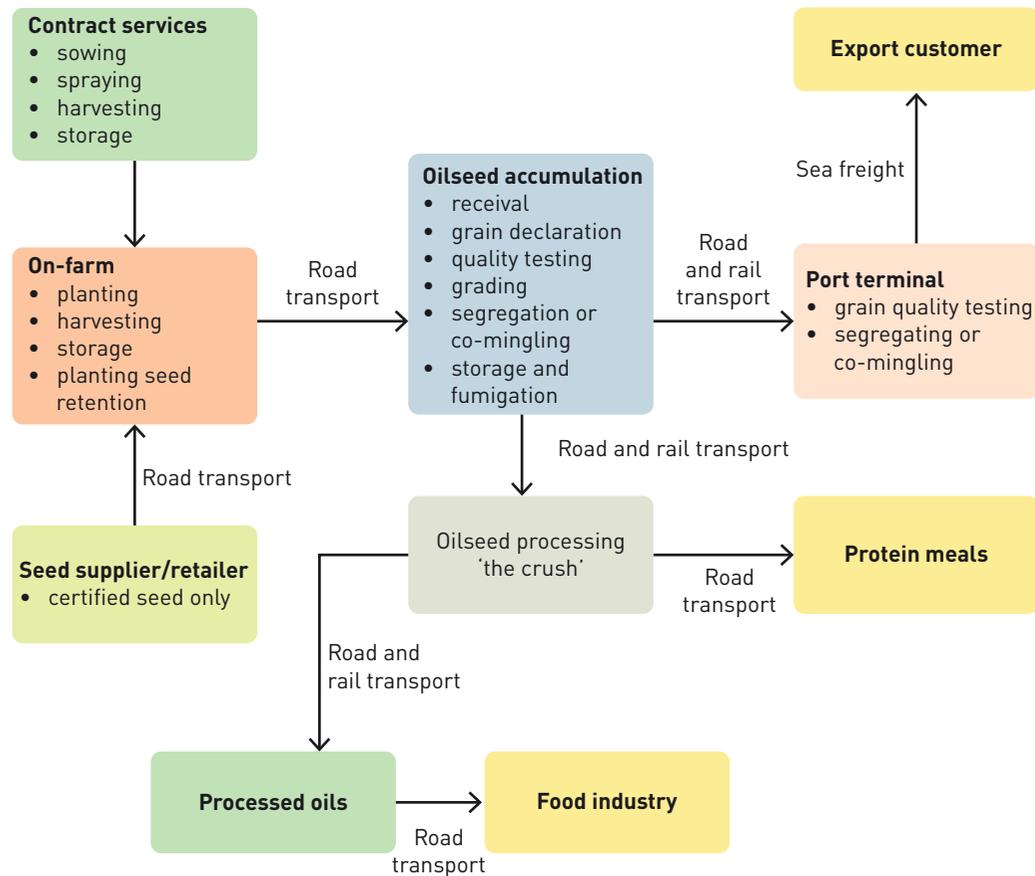


Figure 9.16 The marketing chain for canola

## Market specifications

The standards for the quality of canola have been developed by the Australian Oilseeds Foundation and define what is commercially acceptable. Premiums and penalties exist for levels above or below these criteria. These standards are shown in the table below.

Table 9.2 Market standards for canola

Criteria	Specification
Oil %	42.0
Free fatty acid %	1.0
Moisture content %	9.0
Test weight min (kg/hl)	62.0

All seed sold must be free of contaminants such as weeds, seeds, insects and other foreign material.

## Marketing strategies

The price received for canola is largely dependent on global markets and selling time can depend on the specific time of year, the access to market and the relative value of canola



Worksheets

Find out more about the different methods of processing canola oil with the worksheet on NelsonNet.



Worksheets

Investigate how each different processing method affects marketing of canola with the NelsonNet worksheet.



Data scenario

Investigate the quality standards for Australian canola oil over the past 16 years.

compared with other crops. There are two options available to growers when it comes to selling their canola, these are:

- *contract selling via oilseed marketers* – where a fixed price is determined prior to harvest to deliver a fixed quantity and quality of seed in accordance with Australian Oilseeds Federation trading standards. This option provides a grower with price certainty and a guaranteed income for their crop. However, it can also mean that if the price of canola goes up, then the farmer still only receives the negotiated price.
- *cash price at harvest* – when growers accept the price as it stands at that particular time. This can be beneficial when prices are high, but there is a risk that if prices are low then a grower may not cover production costs.

### Value-added canola products

While the majority of canola oil is sold as a commercial food product, canola oil can be further value-added to produce spreads and shortenings. Canola can also be used as a component in a number of different products such as:

- pre-prepared meals and baked goods
- cosmetics and skin care products.



#### LET'S ENGAGE

### VALUE-ADDING OIL INTO SOAP

#### PURPOSE

To turn canola oil into a natural soap, free from animal products, scented as you wish

#### MATERIALS

- Digital scales (must be accurate)
- Two heat-resistant plastic or glass jars
- Long-handled spoon (stainless steel or plastic is preferable)
- Hotplate
- Thermometer
- Spoon
- Large stainless steel pot (approximately 2 L or more)
- Stick blender
- Loaf pan or tray

#### Ingredients

- 280 g canola oil
- 180 g olive oil
- 180 g coconut oil
- 210 mL distilled water
- 85 g caustic soda (sodium hydroxide 98%)
- 1 tbsp lavender oil (this can be substituted with any essential oil)

#### Personal Protective Equipment (PPE)

- chemical resistant gloves
- safety goggles
- protective apron

#### RISK ASSESSMENT

Using the template found on NelsonNet, complete a risk assessment based on the following hazards:

- caustic soda
- hotplate
- stick blender
- glass jars
- slips, trips and falls.

Identify any additional hazards in your area and make sure you list them in your risk assessment.



#### METHOD

Weigh all ingredients and set aside.

##### Part A

- 1 Make sure you are correctly wearing your PPE. Part A must be performed in a fumehood or outside.
- 2 Put 210 mL distilled water in the heat-resistant jug.
- 3 Under supervision of the teacher, carefully and slowly sprinkle the caustic soda into the jug. Make sure you add the caustic soda to the water, not the other way around. Stir carefully until the caustic soda dissolves. Caution must be taken as the solution will get very hot. Once dissolved, leave



Template

Risk assessment template

>

in a protected area until the solution has cooled to room temperature.

**Part B**

- 1 Place the canola oil, olive oil and coconut oil into the metal pot and place over a gentle heat to melt the coconut oil. Once the coconut oil has melted, immediately remove from heat. Cool the mixture to room temperature.
- 2 When both the caustic soda solution and the oils have cooled to room temperature, pour the caustic soda solution slowly into the oils, stirring constantly.
- 3 Keep stirring slowly, making sure that no air is incorporated into the mix. The mixture is ready when it thickens and reaches the consistency of a thick custard. Please note, this can take up to an hour. Do not allow the mixture to separate. You can use a stick blender for this stage if you wish. You must keep the blender part below the surface of the mixture.

**Part C**

- 1 When the mixture has thickened, add the essential oil and carefully but quickly work into the mixture. Do not use the stick blender for this step.
- 2 Pour the mixture into the tray and cover the surface with plastic wrap. Refrigerate for 24–48 hours.
- 3 When the mixture has hardened, you can cut the soap into bars. You must wear gloves for this step. Refrigerate for another 24 hours.
- 4 Remove the soap and stack to ensure there is airflow around the bars. The soap must mature for 2–4 weeks, after which it is ready to use.

**DISCUSSION**

- 1 Explain the reasons why you would make your own soap.
- 2 What are the benefits of value adding canola oil to make soap?
- 3 Investigate the market for plant-based skincare. Explain why consumers might prefer plant-based products.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify the main export markets for Australian canola.
- 2 Identify the main domestic markets for canola.
- 3 How do the market specifications for canola determine the price received?
- 4 Outline the two marketing strategies growers can use to sell their canola seed.
- 5 Besides oil for cooking, what other products can canola oil be used for?

### FOR YOU TO DO

- 1 Research the properties of canola oil. How do these properties make canola oil an ideal ingredient in cosmetics and skin care products?
- 2 Canola is widely used in the food industry and in domestic kitchens. Identify three reasons why canola oil is favoured over other oils, such as olive oil and animal fats. Create an A4 full-page advertisement for canola oil addressing the reasons why consumers should select it over other oils and animal fats.
- 3 Create a marketing chain diagram for canola biodiesel.

### TAKING IT FURTHER

- 1 Explore the Summary of Australian Statistics for Canola available from the Australian Bureau of Agriculture and Resource Economics and Sciences website link. Explain two possible reasons as to why there was an increase in canola production from 2010 onwards.
- 2 If canola was grown only as a rotation crop in a mixed enterprise farm, what would be the best option for a farmer to sell their canola? Why?



Weblink

Agricultural commodities  
trade data

# Let's summarise

## How can canola be grown profitably and in an environmentally friendly way?

Management decisions ensure a farmer can grow canola profitably and without harming the environment. Crop rotations with pasture or wheat can be used with canola, which helps the soil retain moisture and prevents weeds. This results in greater yields for the farmer, as well as ensures the soil does not degrade.

Create a table identifying other management decisions that can be made, which will benefit both profit and the environment.

Management decision	Benefit to profit or production	Benefit to the environment

## Why do farmers choose to grow canola?

Growers can elect to grow canola as a rotation crop to manage weeds and disease that provides benefits for successive crops. Canola is a valuable fuel source that also provides high-protein livestock feed as a byproduct of the production process.

Create a mind map that explains all aspects of production and management of canola, determining its end use.



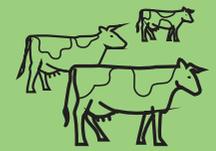
Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about canola production.

# Animal enterprises

Section

3



## CHAPTER 10



# Dairy cattle

## CHAPTER SUMMARY

Dairy cattle produce one of the most versatile products in the world: milk. Milk can be made into many different products such as yoghurt, ice cream and butter. Livestock produce around 10% of Australia's greenhouse gas emissions, with dairy cattle contributing 40% of these emissions, so dairy farmers work hard to find new, more sustainable methods of production. Dairy farmers are faced with economic uncertainty brought about from the supermarket push for \$1/L milk, and as a result, need to find more efficient ways of production to ensure a profit.

**How can dairy farmers ensure high welfare and economic returns on their farm?**

**How can dairy farmers reduce greenhouse gas emissions?**

**How can farmers manage the production cycle to produce high-quality milk?**

## 10.1 Introduction

Cows have been kept and milked for centuries because milk can be made into a range of products such as yoghurt, cream, cheese, butter, flavoured and condensed milk, custard, ice cream and milk powder. Sheep, goats and buffalo also have their milk harvested for human consumption.

Dairy production is very important to Australia, as the third-largest agricultural industry, making \$4 billion annually from milk and milk products. Although Australia only produces a small amount of milk compared with other countries, around 30–40% of the total produced is exported. This makes Australia the fourth-largest exporter of dairy products in the world (as of 2018–19).

The dairy industry is always looking for ways to increase profitability and environmental sustainability, with new practices helping to reduce methane emissions and effluent use. Alongside the growing consumer concerns regarding climate change are concerns about the welfare of dairy cows. Farmers must therefore react and adapt to continue producing a financially viable product.

## 10.2 Functions and anatomy

### Functions

**pasteurised** treated with heat to destroy bacteria

**homogenised** the process of breaking up the fat particles in milk so the milk does not separate

**lactose intolerant** an inability to process lactose, the key carbohydrate found in dairy products

Cow's milk is **pasteurised** and **homogenised** and then sold as fresh milk, or manufactured into a wide range of products, including cream, yoghurt, cheese, ice cream, powdered milk and butter.



### LET'S DISCUSS

- 1 Consider all of your favourite meals. Do they contain milk or a product made from milk?
- 2 Are any class members **lactose intolerant**? Discuss the difficulties that come with avoiding milk products.

Sheep, goat and buffalo milk can also be made into similar products. In Australia, sheep milk producers mainly make cheese. Buffalo milk can be made into famous cheeses such as buffalo mozzarella, which is popular at Italian restaurants.

### DID YOU KNOW?

Dairy cattle share 80% of their genes with humans.

## Milk breeds

### DID YOU KNOW?

The record holder for milk production is a cow in the USA that produced around 35 000 litres in one lactation cycle in 2017.

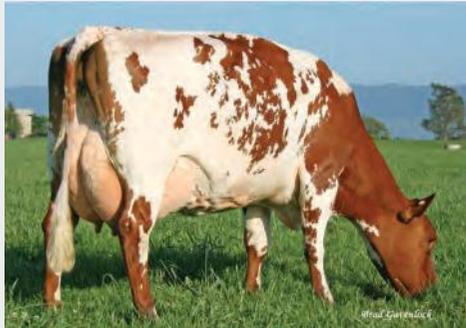


Worksheets

Explore different breeds of dairy cow with the NelsonNet worksheet.

**Table 10.1** Dairy cattle breeds

<p><b>Holstein</b></p>  <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Shutterstock.com/VanderWolf Images</p> <p><b>Figure 10.1</b> Holstein cow</p> <p>Origin: The Netherlands            Traits: Large size, black or red and white            Average production: 12 000 litres per lactation</p>	<p><b>Jersey</b></p>  <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Shutterstock.com/Cameron Watson</p> <p><b>Figure 10.2</b> Jersey cow</p> <p>Origin: Isle of Jersey            Traits: Small to medium size, light - grey or mouse brown colour to black            Average production: 5000–7000 litres per lactation, high butterfat and protein content</p>
<p><b>Ayrshire</b></p>  <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Shutterstock.com/Margo Harrison</p> <p><b>Figure 10.3</b> Ayrshire cow</p> <p>Origin: Scotland            Traits: Medium size, red and white or white and red            Average production: 8500–10 000 litres per lactation</p>	<p><b>Illawarra</b></p>  <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Shutterstock.com</p> <p><b>Figure 10.4</b> Illawarra cow</p> <p>Origin: Australia            Traits: Medium to large frame, dark rich red            Average production: 10 000 litres per lactation</p>
<p><b>Guernsey</b></p>  <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Dreamstime.com/Chris Moncrieff</p> <p><b>Figure 10.5</b> Guernsey cow</p> <p>Origin: Isle of Guernsey            Traits: Medium to large frame, yellow to reddish-brown with white patches            Average production: 7000 litres per lactation</p>	<p><b>Brown Swiss</b></p>  <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Shutterstock.com/O.C.Ritz</p> <p><b>Figure 10.6</b> Brown Swiss cow</p> <p>Origin: Switzerland            Traits: From a light brown/grey to a dark grey/brown            Average production: 9000 litres per lactation</p>

Aussie Red	Australian Milking Zebu
 <p><b>Figure 10.7</b> Aussie Red cow</p> <p>Origin: Australia (Scandinavian red/Australian red breeds such as the Ayrshire or Illawarra)</p> <p>Traits: Medium size, red or red and white colour</p> <p>Average production: 7500 litres per lactation</p>	 <p><b>Figure 10.8</b> Aussie Milking Zebu cow</p> <p>Origin: Australia (Jersey cow/Sahiwal and Red Sindhi cross)</p> <p>Traits: Color markings and shape of Jersey, tropical influence of the Sahiwal and Red Sindhi breeds through the ability to sweat and discard ticks from a highly mobile, loose skin</p> <p>Average production: 2700 litres per lactation</p>

**Crossbreeds**

Crossbreeds are cows that have been bred from two distinct pure breeds of dairy cattle. Crossbred cows are used to achieve **hybrid vigour**. The first cross between purebred parents results in offspring that perform better than the average of the two parental breeds. For example, farmers will cross a Holstein and a Jersey to get offspring that are smaller than Holsteins, but larger than Jerseys. The offspring produces high volumes of milk (from their Holstein genes) with high levels of butterfat (from their Jersey genes). They also tend to be healthier and more disease-resistant than their parents.



Data scenario

What breed of cow do you think grows the fastest? Investigate the effect of breed on calf growth with the data scenario.

**hybrid vigour** the improved performance of a crossbred species compared to the average performance of its parents

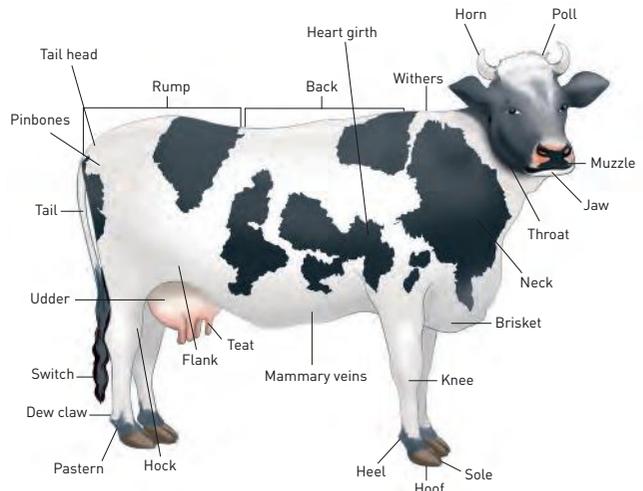


**LET'S DISCUSS**

- 1 In terms of physical appearance, how do you think dairy cattle differ from beef cattle? Why is this so?

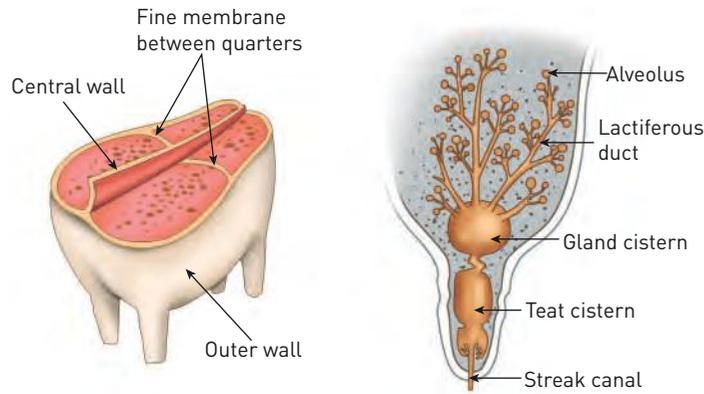
**Anatomy**

Figure 10.9 shows the anatomy of a cow.



**Figure 10.9** Anatomy of a cow

Arguably the most important part of a cow is the mammary system. The mammary system represents the dairy cow's ability to produce milk. The system should have four functional quarters, each with one teat. Figure 10.10 shows the structure of an udder.



**Figure 10.10** Anatomy of an udder

When purchasing new stock, farmers can assess the mammary system of the stock to be assured of their milk production ability. An udder should be normally formed and have no evidence of scars from previous udder infections (such as mastitis). A deep udder cleft means the ligaments that support the udder are strong and intact. The mammary vein is a large vein that passes just under the skin towards the udder on the underbelly. To make 1 litre of milk, 500 litres of blood has to flow through the udder. If this vein is large, we know the udder has a high level of blood flowing through it and is therefore very productive.

### DID YOU KNOW?

Cattle are often born with more than four teats and the extras are usually removed.



Worksheets

Review your knowledge of how udders work with the *Producing milk* worksheet.



Worksheets

Practise judging the mammary system of live or virtual dairy cows with the guide on NelsonNet.



## LET'S REVIEW

### LOOKING BACK

- 1 List ten different products you can create from milk.
- 2 Describe five breeds of dairy cattle used in Australia.
- 3 What is the mammary system?
- 4 Draw and label a diagram of a cow's udder.
- 5 Why do farmers crossbreed cows?
- 6 Describe the benefits of crossbreeding Jersey cattle with Sahiwal or Red Sindh cattle.

### FOR YOU TO DO

- 1 Research the differences between beef cattle and dairy cattle. Describe the key physical differences between these cattle.
- 2 Create a poster describing the different cattle breeds of Australia.
- 3 A farmer is considering purchasing Holstein semen to use on their Jersey cows. Discuss the advantages and disadvantages of keeping a pure Jersey herd versus a Jersey/Holstein crossbred herd.
- 4 Construct two bar graphs with the following data:

Breed	Litres per production average	% protein in milk
AMZ	2700	3.5
Illawarra	10000	3.9
Holstein	12000	3.15
Ayrshire	8500	3.3
Brown Swiss	9000	3.42
Guernsey	7000	3.38
Jersey	6000	3.7



WebLink

Aussie Red

### > TAKING IT FURTHER

- 1 Investigate the most common cow breeds used in the USA. Compare the breeds used in Australia with those of the USA.
- 2 Discuss how environmental conditions influences choice of breed for dairy farmers.
- 3 Research the benefits of Aussie Red cows.

## 10.3 Production

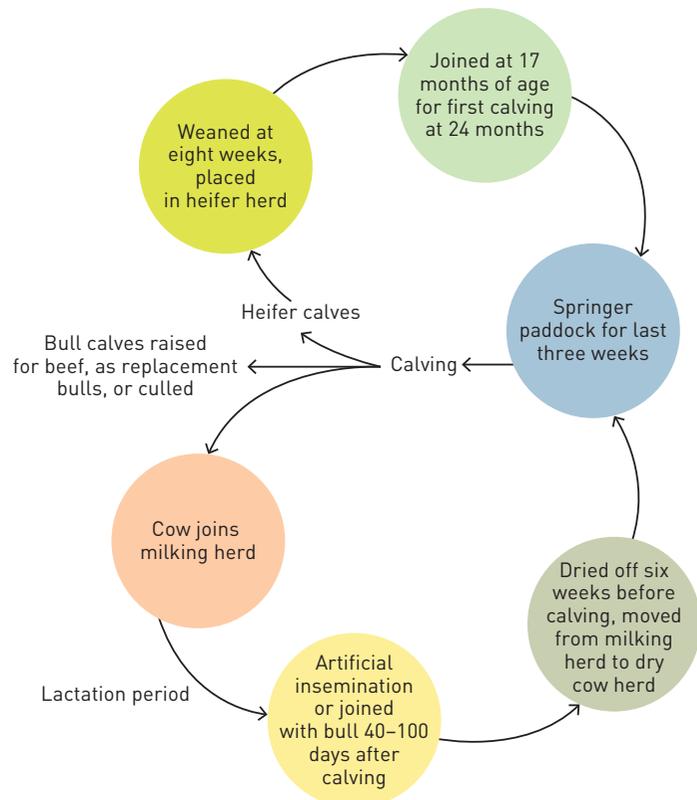
### Production cycle

A number of terms are used to describe dairy cattle at different stages of their lifespan.

**Table 10.2** Dairy cow terms and definitions

Term	Definition
Bull	Male with intact testes, capable of reproduction, used for breeding
Cow	Mature female that has calved two or more calves
Calf	Young animal with no permanent incisor teeth or secondary sex characteristics
Dry cow	Cows who are not lactating, are usually pregnant and due to calve within a few months
Fresh cow	A cow who has recently calved
Heifer	Young female that has not yet produced a calf, or has calved her first calf
Springer	A cow showing signs of nearing calving

Dairy production is dependent on the process of pregnancy and calving. Cows only lactate in the period after calving so farmers must join cattle at the correct times to ensure there are always lactating cows in the herd, thus keeping a constant supply of milk.



**Figure 10.11** The dairy production cycle

A cow must have a calf to lactate and produce milk. The lactation cycle refers to the period of time when a cow produces milk. A cow's cycle in the dairy starts when she gives birth to a

calf. **Colostrum**, a special milk produced in the first few days after calving, is milked off the cow. The calves are separated from the cows and bottle-fed colostrum. Calves are put into a calf pen or hutch and will be fed milk, pellets and straw and grown out, resulting in either future dairy cows for the herd or they will be sold at market.

Meanwhile, the cow joins the milking herd. Lactating cows are fed a high-energy, fibre and protein diet to ensure high production. A lactation cycle lasts approximately 12 months, with a 5–10% drop in milk production each month. At some point between 40 and 100 days after calving, the cow will be joined and become pregnant again. When nearing the end of the lactation cycle, the cow is dried off. It is taken out of the milking herd and placed into the dry cow herd and is not milked. This dries up the cow's milk. The last three weeks before calving are spent in a springer paddock. After calving, the cycle is repeated.

## DID YOU KNOW?

A heifer is not fully grown until it is four years old.

**colostrum** the special milk produced in the first few days after calving, containing essential immune-fighting antibodies that protect the calf until they can produce their own

## Production systems

### Rotary system



Shutterstock.com/Mark Brandon

**Figure 10.12** A rotary dairy system

In a rotary dairy system, cows walk onto a slowly rotating platform to be milked. Milk cups are placed onto the cow's teats and while the platform is revolving slowly, the cow is milked. Once the platform has done a complete cycle, the milking cups are automatically removed and the cow is able to back off the platform and return to her paddock. A rotary system can hold between 24 and 100 cows at one time, depending on farm needs and costs.

### Robotic system

The rotary dairy system can be fully integrated with a robotic system. However, high costs tend to prevent this on many farms in Australia.



Worksheets

Investigate whether robotic dairies make cows calmer with the NelsonNet worksheet.

Robotic milking is when a robot called an automatic milking system (AMS) replaces a person to do all the jobs involved in milking a herd of cows. The system is set up to:

- guide the cows to the milking shed
- identify each cow individually
- milk the cows
- check the milk
- record data about each cow.



## LET'S DISCUSS

- 1 Why might a farmer want to use an AMS despite the high costs?
- 2 What problems might occur from using robotic milkers over humans?

## Herringbone system

The herringbone system is the most common milking system used in Australia. It is suitable for most small and medium-sized farms. Cows stand on an elevated platform in an angled or herringbone fashion facing away from the operator area.

Herringbone parlours are located on the end of a rectangular holding area, allowing cows to enter in single file directly into either side of the parlor. On completion of milking, the cows exit by walking straight ahead and out of the parlour. Designs of a herringbone system can vary, with both single-sided and double-sided systems used, depending on the number of animals being milked.



Alamy Stock Photo/Chris Robbins

**Figure 10.13** A herringbone dairy system

## Organic dairy systems

Organic dairy farmers use no synthetic chemicals in any shape or form. This means the farmer does not treat the animals with any antibiotics, drenches or sprays. No inorganic fertilisers can be used to produce the pastures the animals eat. The farmer may use a natural spray such as pyrethrum, made from a naturally occurring plant extract, to help with production issues such as flies in the dairy. Cows needing to be treated with antibiotics are usually removed from the herd and sold, as the status of the farm's organic certification can be affected by this.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the following terms: lactation, colostrum and dry period.
- 2 Describe three different dairy production systems.



- 3 Draw a flowchart diagram of the milk production cycle.
- 4 Define 'organic farming'.

### FOR YOU TO DO

- 1 Some cattle diseases, including vibriosis and neosporosis, result in cows failing to fall pregnant or suffering early pregnancy loss. Explain the impact of low fertility rates on dairy farms.
- 2 Which system allows for better monitoring of the cows: robotic or traditional dairies?

### TAKING IT FURTHER

- 1 Investigate how a robotic AMS works and describe it in a short paragraph.
- 2 Research organic dairy production and the potential impact on a farmer. Do you think organic certification is worth the time and effort? Make a recommendation to a new farmer. Consider costs, time, potential income and environmental impact.

## 10.4 Management

### Environmental management

#### Distribution of dairy farms and climate

Dairy farms in Australia tend to be located near water sources. Water is needed for both the cattle and irrigation of pastures. Most dairies tend to be located on the coast or within a few hours of it. Dairies located more than four hours from the coast have access to irrigation systems or **groundwater** to water their pastures. On the coast, dairies rely on regular rainfall as well as irrigation to grow their pastures. Use of nutritious, improved pastures, coupled with the need to milk cows twice a day, means that dairies usually have higher stocking rates than beef enterprises. New Zealand has more regular rainfall, so dairies are located more frequently throughout the country.

**groundwater** water located underground or in rocks

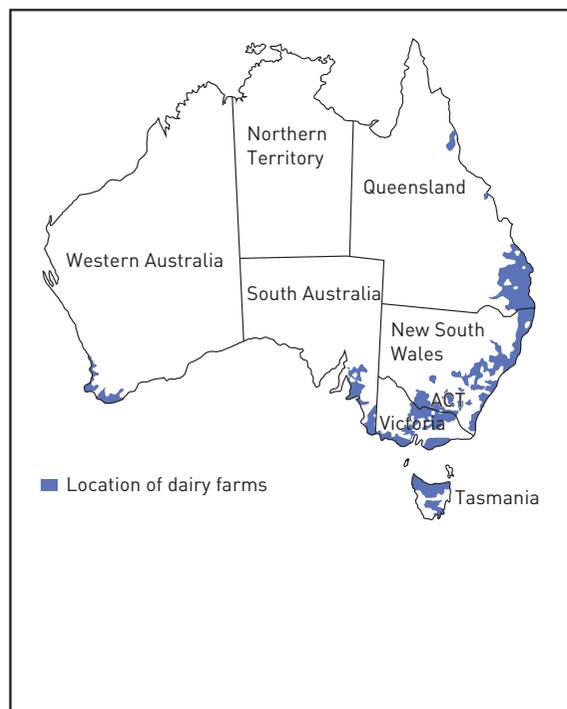


Figure 10.14 Location of dairy farms around Australia

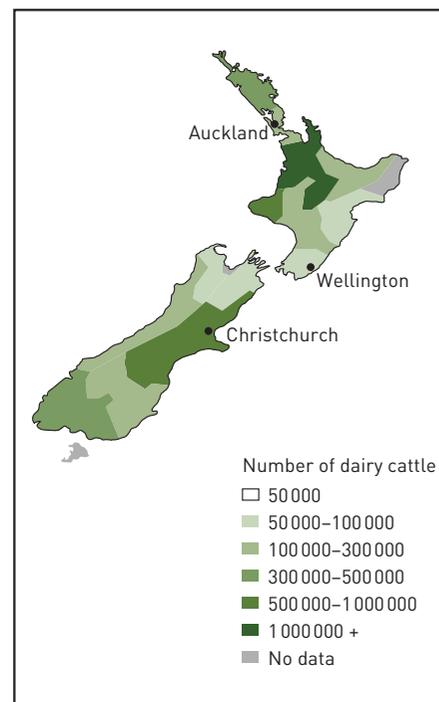


Figure 10.15 Number of dairy cattle around New Zealand

The New Zealand industry is larger compared to the size of the country than Australia's dairy industry. This is because New Zealand receives greater rainfall, thus allowing for high protein feed to be produced and supplied all year round.



## LET'S DISCUSS

- 1 What effect do you think temperature has on the location of dairy farms?

## Pasture management

### Improved pastures

An improved pasture is one that is sown by the farmer to allow a constant supply of pasture for their animals to eat throughout the year. It can be a mix of grasses, legumes and herbs. Dairy cattle require a highly nutritious diet to be able to produce large volumes of high-quality milk. Australian native grasses are generally not nutritious enough for dairy cattle to make high-quality milk. Therefore most dairy cattle are run on improved pastures. Table 10.3 shows the advantages and disadvantages of using improved pastures.

**Table 10.3** Advantages and disadvantages of improved pastures

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Produces more feed than natives due to higher growth rates and productivity in terms of <b>dry matter</b> availability</li> <li>• High energy and protein content</li> <li>• Maximises animal production (e.g. protein is required for milk production)</li> <li>• Hybrid plants such as ryegrass are more vigorous and productive because of crossbreeding.</li> <li>• Pest/disease resistance</li> <li>• Environmental adaptability (e.g. frost resistance)</li> <li>• Can withstand heavy grazing</li> </ul>	<ul style="list-style-type: none"> <li>• Requires costly inputs – fertiliser, irrigation, pesticide and herbicide spraying, soil preparation</li> <li>• Short production life as they are eventually invaded by weeds and must be re-sown annually</li> <li>• Not well adapted to some environments; for example: <ul style="list-style-type: none"> <li>• temperature extremes</li> <li>• low fertility soils such as rugged tableland areas</li> </ul> </li> <li>• Overconsumption leads to possible animal disease problems such as bloating</li> <li>• Hybrids are expensive to produce</li> </ul>

**dry matter** the material remaining as food after water is removed; the required nutrients are contained in the dry matter



## LET'S DISCUSS

- 1 Would you recommend a dairy farmer uses improved pastures? Debate this question with reference to environmental sustainability and profitability.

### Types of improved pasture

Dairy farmers use a combination of different species such as lucerne, clover, ryegrass and kikuyu. Legumes also play an important role in any dairy farming system. Legumes are plants that live in symbiosis with special bacteria and can fix or convert nitrogen from the atmosphere, changing it into a form that is usable by the plant. The two most commonly used legumes in dairy production are clover and lucerne.

**Table 10.4** Different types of improved pastures grown by dairy farmers in Australia

Type of pasture	Description
 <p>Shutterstock.com/Daikano</p> <p><b>Figure 10.16</b> Ryegrass</p>	<ul style="list-style-type: none"> <li>• Likes to grow in cooler seasons so good as a food source in autumn and spring</li> <li>• Highly competitive plant that grows quickly</li> <li>• Very nutritious and high in protein, which lactating dairy cows need</li> <li>• Recovers very quickly after being fed to animals so is a reliable source of feed for cattle</li> </ul>
 <p>Shutterstock.com/Armandus Basson</p> <p><b>Figure 10.17</b> Kikuyu</p>	<ul style="list-style-type: none"> <li>• Subtropical grass that was introduced into Australia because of its ability to thrive in summer</li> <li>• Not high on nutritious content, but gives animals food to eat and survives when the summer heat kills many other species</li> <li>• Cows can produce up to 14 L milk/day grazing kikuyu compared with 20–22 L milk/day from ryegrass</li> <li>• Kikuyu is a great feed source for dry cows up until late pregnancy because it maintains the cow, gives enough energy for foetal development but doesn't allow the cow to get to fat, which can cause dystocia.</li> </ul>
 <p>Shutterstock.com/anmo</p> <p><b>Figure 10.18</b> Lucerne</p>	<ul style="list-style-type: none"> <li>• Legume crop</li> <li>• Grown to replenish nitrogen levels in the soil or for conserving, either in form of hay or silage</li> <li>• If cattle are to be allowed to graze on it, it tends to get damaged at the crown and is unable to rejuvenate after grazing has ceased</li> <li>• High protein compared with grasses</li> <li>• Cheaper alternative to get protein into the feed (compared with cost of concentrates/grains/pellets)</li> <li>• Can rejuvenate after harvesting two or three times</li> </ul>
 <p>Shutterstock.com/KariDesign</p> <p><b>Figure 10.19</b> Clovers</p>	<ul style="list-style-type: none"> <li>• High quality, fed to dairy cows who are lactating</li> <li>• In New Zealand the white clover is the most important clover that is grown for production due to its ability to grow in the dairy regions</li> <li>• Clovers fix nitrogen levels in the soil</li> <li>• Great for rotations with cereal crops that might be grown for cattle's grain</li> </ul>

## Enterprise management

### Digestion

Cows, sheep, alpaca, llamas and goats are **ruminant** animals. This means that they have four stomachs: the rumen, reticulum, omasum and abomasum. The function of the digestive tract in animals is to break down food so that it can be absorbed into the body. Ruminant digestive organs are different in structure and function. Each stomach in the ruminant has a specific task to allow the best absorption of nutrients and minerals from the animal's diet.

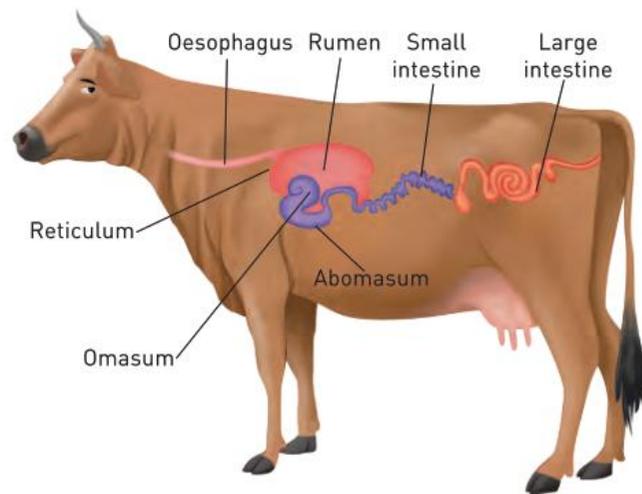
**ruminant** an animal with four stomachs

### DID YOU KNOW?

Hardware disease occurs when a metal object such as a nail or piece of fencing wire is swallowed and settles in the reticulum. It can then penetrate through the stomach wall straight into the heart, causing the animal to die.

Ruminants digest their food using microbial fermentation. Microbes such as bacteria, fungi and protozoa break down the food so that the cows can process it. Table 10.5 describes the role of each part of the digestive system in more detail. The process of microbial fermentation creates gases in the stomach (methane and CO<sub>2</sub>). Cows will belch these gases out. Bloating can occur if a cow does not belch.

Cows ruminate for up to eight hours per day. Rumination is the act of regurgitating feed from the reticulum, rechewing it into smaller pieces and mixing it with saliva before swallowing it again. The saliva not only lubricates the food, it also contains bicarbonate, which makes the food less acidic.



**Figure 10.20** A cow's digestive system

**Table 10.5** The roles in a cow's digestive system

Part of system	Role
Rumen	Microbial fermentation occurs: microbes break down tough, fibrous plant materials and provide animal with a source of energy, protein and some vitamins.
Reticulum	Microbial fermentation and sorting of particles by size, with large particles being regurgitated back into the mouth for rumination.
Omasum	Water is extracted and absorbed.
Abomasum	Most similar to human stomachs, the site of chemical digestion. Any microbes that pass through are killed and then digested as a source of protein.
Oesophageal groove	In calves, milk travels straight from the oesophagus to the abomasum, via this groove, bypassing the rumen.
Small intestine	Site of further digestion and then absorption of nutrients.
Large intestine	Formation and storage of faeces.

## Nutrition

In Australia 99% of dairy farms are in pasture-based systems, as opposed to the US model where cattle are often kept in housing all year round. Rotational grazing occurs on irrigated, improved pastures, meaning cattle will rotate around various paddocks, allowing the previous ones to regrow. Cows are usually provided with a fresh paddock of grass in the morning after milking and another fresh paddock of grass in the evening after milking. While most Australian cattle are on pasture systems, feeding of concentrates (such as grain pellets) and hay or silage is often required to supplement the pastures. High production of quality milk requires high levels of nutrition. Cows must also be fed roughage (such as hay) to produce milk fats. Cows can also be fed special proteins that pass through the rumen without being broken down by microbes. This is

### DID YOU KNOW?

The digestive tract capacity of the ruminant is as follows:

- rumen: 80%
- reticulum: 5%
- omasum: 7%
- abomasum: 8%

called rumen bypass protein, and results in more protein being available for milk production (as opposed to being used during the rumination process).

### Total and partial mixed rations

Cattle can also be fed on a total or partial mixed ration system. Total mixed rations (TMR) are when a farmer blends all necessary food and nutrients, such as grasses, legumes, grains or pellets, into one foodstuff that can then be fed to the cattle. This allows farmers to very accurately control the amount of nutrients cows get at different stages of the lactation cycle. Partial mixed rations (PMR) are when a portion of a TMR is fed to cows along with their pasture grazing. PMR allows additional nutrients to be given to cows that they may not receive from their pasture grazing.

TMR or PMR are often given via a feed pad. Cattle have regulated access to the feed pad (a big covered area with a concrete base and feeding troughs), meaning that less feed is wasted than if it was just placed in the paddock. Feed pads are important during droughts and sometimes in lean seasons.

### DID YOU KNOW?

Lactating cows can drink up to 70 L (about as much as a bathtub) of water a day. For every rise of 10°C, cows' water intake almost doubles.



Data scenario

Body condition scoring is a visual measurement of the nutrition of a cow. Investigate whether it has an effect on milk production with the data scenario.

### Feed requirements

At different stages of the lifecycle and lactation cycle, cows will require different levels of nutrition. For example, a lactating cow requires more food to produce a greater quantity of milk. Table 10.6 indicates some of the different requirements across a cow's lifespan.

**Table 10.6** Feed requirements for dairy cows across their lifespan

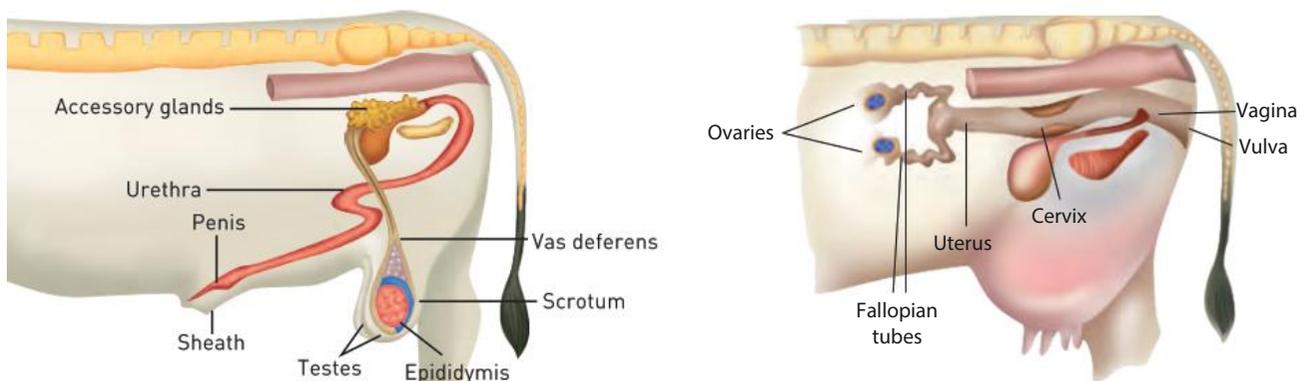
Stage of life	Time on feed	Food	Housing	Reasoning
Heifer calf	2 days to 6 weeks of age	<ul style="list-style-type: none"> <li>Milk</li> <li>Hay</li> <li>Calf weaner protein pellets</li> </ul>	Calf shed	<ul style="list-style-type: none"> <li>Very rapid muscle and bone development</li> <li>High-energy and high-protein diet for growth</li> </ul>
Young heifer	7 weeks to 12 months of age	<ul style="list-style-type: none"> <li>Pasture (average quality)</li> <li>Hay</li> <li>Calf weaner protein pellets</li> </ul>	Heifer calf paddocks	<ul style="list-style-type: none"> <li>Very rapid muscle and bone development</li> <li>High energy and protein diet for growth</li> </ul>
Heifer	12 to 18 months of age	<ul style="list-style-type: none"> <li>Pasture (average quality)</li> <li>Hay</li> <li>Silage</li> </ul>	Farm paddocks	<ul style="list-style-type: none"> <li>Rapid muscle and bone growth is slowing</li> <li>High-energy and high-protein diet for growth to reach sexual maturity for first mating</li> </ul>

Stage of life	Time on feed	Food	Housing	Reasoning
Cow (lactating)	Mature 36 months and older	<ul style="list-style-type: none"> <li>Pasture (high quality)</li> <li>Fodder oats and sorghum</li> <li>Bypass protein</li> <li>Dairy meal protein pellets, depending on the available pasture quality</li> <li>Hay</li> <li>Silage</li> </ul>	Farm paddocks	<ul style="list-style-type: none"> <li>Muscle and skeleton are fully developed</li> <li>High energy and protein diet for milk protein production, mating and pregnancy</li> <li>High fibre required for milk fat production</li> </ul>
Dry cow		<ul style="list-style-type: none"> <li>Pasture (medium quality)</li> </ul>	Farm paddocks	<ul style="list-style-type: none"> <li>A diet containing medium levels of energy and protein</li> <li>The cow is recovering from milk production and is in her last third of pregnancy</li> </ul>

## Reproduction

The entire dairy production system is based on the availability of lactating cows. This means that a cow needs to become pregnant to have a calf, which then leads to lactation. Controlling and managing the reproduction of a herd is essential for dairy farmers to ensure they will always have lactating females.

### Reproductive system



**Figure 10.21** The reproductive systems of a cow and a bull

In sexual reproduction, fertilisation occurs when a sperm (from a bull) joins with an egg (from a cow). Once fertilised, the egg travels through the fallopian tubes and embeds itself in the uterus, where the calf will grow. Tables 10.7 and 10.8 show the functions of the male and female bovine reproductive systems.

**Table 10.7** Functions of the male reproductive system

Part	Function
Accessory glands	Produces the liquid in semen, which helps the sperm move
Urethra	Carries urine and sperm to the penis
Penis	Used for insemination – the penis ejaculates to expel sperm into the reproductive system of a female. Also used to expel urine.
Sheath	Protective skin covering the penis
Testes	Produces testosterone and sperm
Epididymis	Site of storage and maturation of sperm before they are transported to the vas deferens
Vas deferens	Transports sperm from the epididymis to the urethra
Scrotum	Where the testes are located; a protective covering holding them outside the body

**Table 10.8** Functions of the female reproductive system

Part	Function
Ovaries	Produces oestrogen, progesterone and the ova
Fallopian tubes	Location of fertilisation; sperm travels up the tube to reach the ova
Uterus	Where the foetus develops
Cervix	The 'neck' of the uterus, opens during birth to allow calf to move to birth canal
Vagina	Birth canal, and also where a male penis deposits semen
Vulva	External opening of vagina

## The oestrus cycle

The oestrus cycle is a 21-day cycle during which a mature egg, or ova, is released by an ovary into the fallopian tube. A cow goes into 'heat' when this occurs, causing changes in physiology and behaviour. This is how a farmer knows when to mate a bull and cow to get the cow pregnant. If the farmer misses a cycle, they will need to wait another 21 days until they can try again. This costs time and money because the calf will be born later than planned.

'Standing heat' is the term used when a cow is ready to be mated, referring to the length of time a cow will stand and allow a bull to mount her. Different breeds have different lengths of heat, but a cow's heat will usually last 12–24 hours.

Farmers try to synchronise a herd's heat. This means several cows will come into heat at the same time. By syncing heat, farmers can make reproductive management much easier.

A dairy farmer will try to stagger calving throughout the year to ensure there is always a supply of milk. This is particularly common in the fresh milk market because farmers supplying this market need to have milk available all year round.

### DID YOU KNOW?

In Australia, 38% of farmers have a split-calving herd, meaning they stagger calving into two or more splits across the year.

## Natural mating

There are two ways to **inseminate** a female cow: natural mating or artificial insemination.

Natural mating is when a bull can mount a cow and directly place the semen in the vagina via his penis. Most dairy farmers don't use natural mating as the main reproduction technique because it makes it more difficult to know when a calf is due to be born. However, if a cow doesn't get pregnant from use of artificial insemination, a farmer will use a 'mop-up bull' to try again.



Worksheets

Review your knowledge of cattle physiology with the NelsonNet worksheet.



Video

Heat detection methods

**insemination** the placement of semen into the female reproductive system to achieve pregnancy

There are some disadvantages of natural mating. It can result in decreasing the gene pool available, and any negative trait from the bull will be passed on to all the calves he sires. Most dairy farmers will therefore specifically select sperm from a national database. This allows them to choose exactly which traits they want in their herd.

### Artificial insemination

Artificial insemination is when an instrument is used to take the semen from the bull and place it in the female reproductive system. There are both advantages and disadvantages to using artificial insemination compared with natural mating.

**Table 10.9** Advantages and disadvantages of artificial insemination

Advantages	Disadvantages
Allows for wide use of excellent, top sires (hence good traits are passed on)	Expensive artificial insemination technicians need to perform the process
Allows for very accurate selection of sires	More labour-intensive; natural mating reduces the need for heat detection
Can introduce new blood from overseas herds	Lower conception rates than natural mating
Can crossbreed easily	Can lead to over-reliance on sperm from top performing bulls, reducing genetic variation in herds
Safer as bulls may be aggressive	

## INDUSTRY IN FOCUS

### ARTIFICIAL INSEMINATION TECHNICIAN

#### Identify

An AI technician is a person who is responsible for the insemination of cattle on the farm.

#### Understand

Artificial insemination is usually performed by a specialised technician who has a thorough understanding of anatomy. As well as the process of artificial insemination, the technician prepares and handles the semen and may be responsible for pregnancy testing to check for conception. Pregnancy testing can also be done by the farmer or vet. An AI technician can be responsible for overseeing or assisting with heat detection to ensure that cows are not missed coming into heat. Many AI technicians give advice to the farmer in relation to industry trends, sire selection and new reproductive techniques that may be arising with technological advances. An advantage of using an AI technician is that they keep accurate records of all treatments and insemination records, so the farmer doesn't have to, saving them time to focus on other management tasks.

#### Discussion

- 1 List some of the tasks required of an AI technician.
- 2 Research what qualifications would be needed to become an AI technician.
- 3 Why might farmers need to use an AI technician rather than do it all themselves?
- 4 What qualities would you need to become an AI technician?

## Embryo transfer

An embryo is the early stages of development in a fertilised egg. Embryo transfer allows an embryo to be transferred from one cow to another.

Usually, a cow will produce six to seven calves in her lifetime, via one egg being produced at each ovulation. However, hormones can be injected to increase a cow's ovulation rate so that she releases several eggs per cycle. Artificial insemination can be used to fertilise these eggs, after which they can be collected and implanted into several surrogate mothers. By using embryo transfer, a cow could have up to 50 calves or more in her lifetime.

**Table 10.10** Advantages and disadvantages of embryo transfer

Advantages	Disadvantages
More calves can be obtained from top cows (hence good traits are passed on)	Expensive technician needs to perform the process
Can obtain more calves from top cows more quickly – meaning more rapid genetic gain in a herd	More management required by farmer to ensure hormones given correctly
Embryos can be frozen for use later	Could lead to genetic mutations being passed down from cow
Embryos can be sexed, allowing only female embryos to be implanted (in the dairy industry)	

## Genetic selection: estimated breeding values

Estimated breeding values (EBVs) are an indicator used across livestock to decide which animals to breed. The Australian dairy industry developed their own system, based on the principal of EBVs, called Australian Breeding Values (ABVs). ABVs are an objective measurement used to measure the performance of an animal. Farmers can use ABVs to select a bull to use on their farm, or to select semen for use in artificial insemination.

Examples of ABVs include:

- milk (litres)
- protein (kg and %)
- fat (kg and %)
- structure and udder.

The measurements are numbers that indicate how far above or below the average measurement the bulls' calves will be. For example, milk L-501 means that on average the bulls' heifer calves will produce 501 L above the average each year. To work out these measurements, data is collected from the calves of each bull and compared to the breed average. Milk, protein and fat measurements are based on monthly milk samples taken from each female. Visual assessments of females' mammary structure, temperament and body shape are also undertaken.

By using ABVs, a farmer can choose a bull or semen that will best suit the cows and heifers getting pregnant, and which can improve on any faults the cows may have.

## Reproduction monitoring

Rumination collars are a new form of calving detection. These sensors sit around the cow's neck and monitor how long a cow ruminates. At calving, there is a steep decline in duration of rumination, which alerts farmers to the impending birth. In a recent study of pasture-based dairy cows, rumination duration decreased 33% over the two days before calving. Technology



**Figure 10.22** Rumination collars can be used to detect calving by measuring the duration of rumination.



Worksheets

Use the *Breeding dairy cattle* worksheet to explore different methods of reproduction.



Weblink

Explore Australian Breeding Values



Weblink

Australian Dairy Sire Catalogue

such as this reduces farmer stress because they are able to spend more time away from the herd at calving time.

## Milking

During the milking process it is important to keep the dairy equipment and udders clean to prevent infections such as mastitis, which is caused by bacteria entering the udder teat. The milking machine cups are placed on the udders and removed when the flow of milk ends. Some machines have automatic removers so cups are released as soon as flow ends to avoid discomfort.

Once a cow has been milked, the milk must be stored and cooled to around 4°C. It is refrigerated at the farm until a dairy tanker collects it. A tanker will reject milk if it is above 4°C. Bacteria is more likely to grow rapidly at temperatures above 4°C.

## Calf husbandry

Once separated, the calf's navel is sprayed with iodine to prevent umbilical infections. Calves are placed in a calf pen or hutch and fed colostrum. Identification tags are placed in their ears.

Dehorning usually occurs between two and six weeks of age. (You can find out more about dehorning in Chapter 11.) Calves may suffer from calf scours (diarrhoea), which can be a sign of several diseases. Calf scours will occur in approximately 80% of Australian cattle farms each year and must be carefully managed to ensure it does not spread around a herd. Colostrum reduces the incidence of calf scours.

Calves are weaned around eight weeks of age or when they reach the target weaning weight (around 100 kg for Holsteins).



LET'S ENGAGE

### ESTIMATING CALF WEIGHT USING A WEIGHT TAPE

#### PURPOSE

Weight tapes are an easy and inexpensive way of estimating the body weight of dairy calves. The heart girth is a reasonably accurate predictor or weight for Holstein cows under two years of age.

#### RISK ASSESSMENT



Use the Animals in Schools website to assist you to complete a risk assessment.

#### MATERIALS

- Dairy calf weight tape (available at produce stores or online)
- Calves

#### METHOD

- 1 Calves should be measured at the same time of day (for example, before feeding in the morning).
- 2 Make sure the calf's head is up and the animal is standing square.
- 3 Place the tape around the chest just behind the shoulder, ensuring it contacts the body all the way around.

- 4 Read the weight off the tape at the point where the end overlaps the tape.

#### DISCUSSION

- 1 Why should we use the same method and time for each measurement?
- 2 Examine your tape. What types of cows can it be used on? Would this tape work for beef calves or calves from other dairy breeds or crosses?
- 3 If your school has live weight scales, weigh the calves and comment on the accuracy of the calf tape.
- 4 Weigh the calves every day for two weeks. Collect your data in a table and construct a line graph of weight gains during that time.
- 5 Were there any changes in their growth rates during this period? Can you account for these differences and trends?



Web link

NSW Animals in Schools



Template

Risk assessment template

## Records and financial management

### AG IN FOCUS

#### COLLECTOR CREEK DAIRY

##### Identify

A local farmer has 292 hectares and is milking 500 cows. This produces 4 million litres of milk per year.

##### Understand

The farmer undertakes the following management tasks throughout the year:

- vaccinates all cows with a 7-in-1, annually in March
- vaccinates cattle for three-day sickness prior to high-risk periods, which is the autumn wet season
- cows are artificially inseminated as they come in heat in bulk every four months, starting in March. The farmer batches his cows seasonally so milk supply is available all year.
- cattle are drenched quarterly, at the beginning of each season, for internal parasites
- herd recording on milk production is done monthly
- gestation period is nine months
- the farmer has a 95% calving rate. The ratio of bull calves to heifer calves born is 50:50.

##### Discussion

Chapter 4 can assist with the below questions.

- 1 Create a calendar of operations for two individual cow batches on the farm, those who give birth in December and those who give birth in August. (Hint: those who give birth in December must be artificially inseminated in March, and those who give birth in August must be artificially inseminated in November according to a nine-month gestation period).
- 2 The farmer sells milk at \$0.46/litre and bull calves at \$70/calf. The farmer also culls 50 older cows a year, at \$350/cow. Conduct a gross margin profit analysis for the farm using the information above and the following variable costs. You can use the gross margin template on NelsonNet to assist you in your calculation.

Variable costs	
Purchased feed	290 tonnes of pellets at \$500/tonne
Breeding/AI costs	500 milkers @ \$35/cow
Vet/vaccination costs	500 animals @ \$18.50/head
Pasture crops	Soil preparation, sowing seeds and fertiliser: 200 hectares @ \$880/ha
Freight	\$25 000
Dairy supplies	\$16 250
Fuel	\$5 150
Contract services (machine maintenance and hay and silage making)	\$13 500
Farmhand wages	\$50 000

- 3 What changes could the farmer make to reduce his variable costs?



Template

Gross margin template



## LET'S REVIEW

### LOOKING BACK

- 1 Why are the majority of Australian dairies located within four hours of the coast?
- 2 What is an improved pasture?
- 3 Describe the benefits of three types of improved pasture species.
- 4 Explain the following terms: rumination, microbial fermentation, heat, synchronisation of oestrus, total mixed rations and partial mixed rations.
- 5 Describe the role of the four stomachs in a ruminant animal.
- 6 Describe the difference between natural mating, artificial insemination and embryo transfer.
- 7 What is an ABV?
- 8 What is colostrum?
- 9 Explain the difference between sexed semen and sexed embryos.

### FOR YOU TO DO

- 1 Investigate how smart apps can help a dairy farmer improve production. Download one of these apps and investigate what it can do. Write a review of the app for dairy farmers.
- 2 Look at local saleyard prices for bobby calves vs weaner age calves and compare the prices.
  - a What is the difference between a bobby calf and a weaner calf?
  - b Why might a farmer decide to keep male calves longer?
  - c Make a recommendation to a farmer on whether they should sell their bobby calves or weaner calves. Consider issues such as sell price and extra farm costs.
- 3 Recommend a diet for the following animals, making sure to give reasons for your recommendations:
  - a a weaning heifer calf
  - b a lactating cow
  - c a dry cow
- 4 Write a story about the life of a heifer calf from birth until she enters the milking herd.
- 5 Discuss the benefits of using ABVs to select bulls to breed.

### TAKING IT FURTHER

- 1 Evaluate the use of embryo transfer over natural mating as a strategy for breeding.
- 2 Research technology that can be used to help farmers detect heat in cows.
- 3 Design a pasture rotation plan for a new farmer who plans to inseminate their cows in January for birth in September. (Hint: think about the different nutrition needed at different stages of the gestation period as well as soil management).

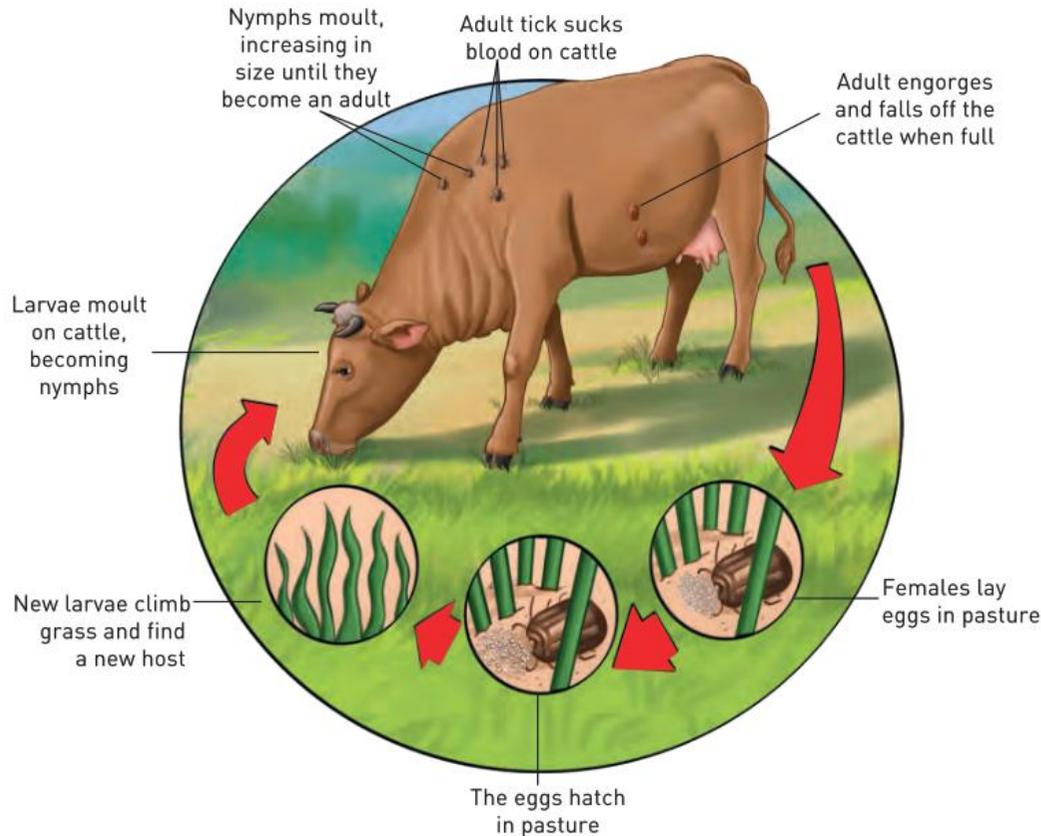
## 10.5 Pests and diseases

### Pests

#### Ticks

Cattle ticks are an external parasite. They suck the blood from cattle and drop off once they are full. This causes anaemia (red blood cell deficiency) in cattle. Tick infestation causes **tick-worry**, blood loss and a decrease in milk production. Ticks are also carriers of tick fever, an even more serious condition that can result in death. In Australia, ticks cost the cattle industry \$156 million every year.

**tick-worry** a general state of unhappiness and distress in cattle due to tick infestation



**Figure 10.23** The lifecycle of a tick

Farmers can control ticks through a variety of methods such as:

- chemical – medicinal treatment such as using a spray on cattle that deters ticks, or vaccinations such as the tick fever vaccination
- genetic – selective breeding of tick resistant cattle
- cultural – pasture spelling. Pasture spelling is when a paddock or pasture is rested for a period of time. This allows time for the tick larvae to die out without finding a host.

As with any pest control attempt, the best control consists of a combination of methods in an integrated pest management program.

**DID YOU KNOW?**

European breeds of cattle are more susceptible to tick fever.

## Diseases

### Mastitis

Mastitis is a disease affecting the mammary system of dairy cattle. It is a huge problem across the dairy industry in Australia, with approximately 5–10% of a herd being affected during each lactation cycle. Mastitis is caused by bacteria entering the teat canal and infecting the udders. Some cases of mastitis are environmental (due to bacteria entering the teat canal from the environment) and some are contagious (caught from other infected cows). Mastitis can also be caused by injury to the udder, such as by over-milking a cow. It can result in a lot of pain for the cow and is therefore a serious animal welfare issue. Other signs include redness, heat and sensitivity of udders and a high temperature.

In addition to the serious animal welfare concerns arising from mastitis, it also greatly affects the financial returns of dairy farmers.

Some effects include:

- contaminated milk being thrown out
- permanent damage possibly occurring to cows' udders
- high labour costs requiring attention to infected cows
- medicinal costs
- culling of chronically affected cows.



Worksheets

Investigate the causes and control of mastitis in more detail with the NelsonNet worksheet.

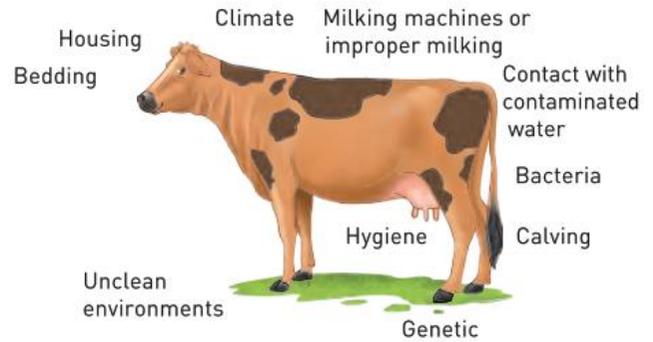


Figure 10.24 Sources of mastitis infection in cattle

### Milk fever

Milk fever is an illness that occurs in cows around the time of calving. It is caused by low calcium levels in the cow and results in the cow being unable to stand up or becoming stiff in the legs. About 1 in 20 infected cows die from the disease, with the illness affecting between 3–10% of cows in Australia. The majority of cases occur within a day of giving birth because the production of colostrum for the new calf decreases the amount of calcium available for the cow.

#### DID YOU KNOW?

High-producing dairy cows are more likely to be affected by milk fever as their calcium levels suffer a greater fall.

Milk fever can be related to both age and diet, with older, fatter cows most susceptible. Prevention can be managed by ensuring correct diet in the lead up to calving. A low calcium diet (hay over pasture) is required during the dry period to ensure calcium levels aren't too high at birth (and therefore can't fall too far). Crops such as clover should be completely avoided in susceptible cows.

## AG IN FOCUS

### MYCOPLASMA BOVIS IN NEW ZEALAND

#### Identify

In March 2018, New Zealand authorities announced the plan to cull 22 000 dairy cows on the South Island, to destroy an outbreak of *Mycoplasma bovis*. New Zealand was one of the only countries in the world not affected by *M. bovis* and therefore the outbreak was an extremely serious issue.

#### Understand

*M. bovis* is a serious disease characterised by lameness, mastitis, abortions and pneumonia, often resulting in death of all affected. The disease was discovered on 30 farms on the South Island of New Zealand. The disease can spread quickly, hence authorities

thought the best hope of eradication was to cull all infected cows. In May 2018, authorities gave the order to begin culling cows. By July, 32 000 cows had been culled. By December, this rose to 50 000, with authorities estimating 100 000 will need to be culled in total.

New Zealand farmers have been greatly affected by the outbreak and subsequent cull, with many losing large portions, or all, of their herds. While New Zealand authorities compensated farmers for their losses, many farmers on the ground state the costs of the eradication program outweigh the benefits, with slow payouts and an uncertainty over whether the disease will ever be eradicated. Many farmers are now at risk of closing their businesses due to the loss of production.

Early detection of the disease is key to preventing such massive culling in future. Early detection would ensure farmers could separate infected cattle from the rest of the herd, hence preventing the spread.

### Discussion

- 1 Describe how *M. bovis* affects dairy cattle.
- 2 What ethical considerations should be made when deciding to mass-cull cattle?
- 3 How can *M. bovis* be prevented?
- 4 Discuss the long- and short-term impacts of the mass culling on the New Zealand farmers.



## LET'S REVIEW

### LOOKING BACK

- 1 Describe the impact and treatment of one cattle pest.
- 2 What are the signs of mastitis?
- 3 How is milk fever caused?
- 4 Describe three causes of mastitis.

### FOR YOU TO DO

- 1 Draw a diagram of the lifecycle of a tick.
- 2 Research what the 'withholding period' means.
- 3 Design a mastitis prevention plan for your school farm. Consider cultural, biological, genetic and chemical methods.

### TAKING IT FURTHER

- 1 Research Bovine Johne's disease and prepare a report for dairy farmers detailing the signs of disease, prevention and management strategies.
- 2 Research the different type of chemicals a farmer may use to treat parasites on their cattle. Construct a table with their name, use, and how they impact on future selling of the cattle (i.e. withholding period).

## 10.6 Social and ethical issues

### Bobby calves

Bobby calves are considered a waste product of the dairy industry. Bobby calves are:

- male
- 30 days old or younger
- less than 80 kg weight
- usually a dairy breed.

Male calves that are born on dairy farms are destined to be slaughtered because they cannot be used for milk production. Calves are often subject to intense stress because they are separated from their mothers and fed little before being transferred to an abattoir from five days onward. However, all calves born on farms are subject to animal welfare regulations. By law, bobby calves must be fed colostrum before they are sold. Some bobby calves are sold into the veal market or for products such as leather. The age that they are sold at depends upon the farmer's plan of production.

Dairy farmers are working to improve outlooks for bobby calves, and strategies being implemented include:

- crossbreeding dairy cows with beef genetics, so young bobby calves gain traits that will make them more appealing to the beef market
- use of sexed semen to limit the number of bobby calves produced in dairy herds
- integrating a dairy and beef farm business model
- new recording tools to measure performance of crossbred bobby calves.

### Sexed semen

Sexed semen allows farmers to choose only female semen to produce female calves. The current technology results in an approximately 90% success rate. However, the technology is expensive. In addition, it results in a reduced conception rate. Therefore sexed semen is primarily recommended for use in virgin heifers as they tend to fall pregnant more easily.

### Sexed embryos

Sexed embryos are becoming more popular within the dairy industry because these highly valued, genetically superior calves will be desirable females. The cost to purchase the embryo is significantly higher, but many farmers are willing to pay this to obtain genetically superior heifer calves.

## AG IN FOCUS

## HOW NOW DAIRY: A 'KIND' MILK ALTERNATIVE

## Identify

How Now dairy is a small farm in Wunghnu, northern Victoria. Their mission is to create 'happy milk', on a farm where animal welfare is their main concern and bobby calves are no longer an issue.

## Understand

How Now is a family-run dairy, a small niche farm operation that started with just 25 milking cows. Compared with conventional dairies, How Now do not cull any of their calves, nor do they separate the calves from their mothers.

In traditional dairies, almost all male calves and many of the female calves (those that aren't chosen to join the dairy herd) are slaughtered or sold. How Now instead raise all their calves alongside their cows.

On average, cows can produce 20 litres of milk a day, and calves only drink a portion of this. How Now harvest the rest of the milk each day, still a substantial amount. They sell milk, as well as value-add by creating cheese and cream. Their strong focus on animal welfare allows them to sell milk at a higher price than supermarket milk to small suppliers across Victoria. In markets such as this, identified customer bases are often willing to pay more to be guaranteed the high welfare. How Now mix traditional farming with cutting edge technology, using expensive sexed semen technology to limit the number of bobby calves born on their farm (though when bull calves are born, they are kept). How Now also buy bobby calves from other farms when they can afford to. In the future, they hope to offer a 'Rescue a Bobby Calf' program so subscribers can pay to help support bobby calves. How Now believe there is huge demand for milk from farms like theirs, with their products regularly sell out at their stockists.

## Discussion

- 1 How does How Now dairy differ to traditional dairies?
- 2 How has How Now ensured economic returns do not suffer because of their focus on welfare?
- 3 Evaluate the success of How Now's model of putting animal welfare as the unique selling point of their product.



© HOW NOW DAIRY, Ethical Dairy Company

**Figure 10.25** At How Now dairy, cows are not separated from their calves.

## Veganism and the rise of alternative milks

Many people believe that we should not harvest any product from animals. This is a personal choice and those individuals lead a lifestyle that involves using no animal products, including drinking milk, eating meat or using leather. The rise of veganism as a lifestyle choice, alongside an increasing consumer awareness about health, has resulted in a rise in alternative milks. Alternative milks are milks made from plants, such as almond milk, soy milk or oat milk. These supply vegans, and others such as allergy sufferers, with alternative milk for cereal, coffee and tea.

The availability of alternative milks and reduced demand by some consumers for dairy products puts further financial pressure on dairy farmers.



Video

Watch the *Landline* episode about the rise of nut milks in Australia.



## LET'S REVIEW

### LOOKING BACK

- 1 Describe two social and ethical issues facing dairy farmers.
- 2 How old are bobby calves when they are sold?
- 3 What are farmers doing to address the ethical issue of bobby calves?
- 4 Why are consumers looking for alternative milks?
- 5 What is veganism?

### FOR YOU TO DO

- 1 Research how one alternative milk is made.
- 2 You are tasked with proposing a solution to the bobby calf issue in dairy farms. You need to:
  - a Research the issue.
    - Find at least three sources.
  - b Discuss the issue with at least one farmer, for example:
    - interview a local farmer
    - ask a question on the #agchatoz Twitter feed
    - ask your teacher to invite a dairy farmer to your class.
  - c Propose a solution.
    - Your solution can include several components or just one.
  - d Create a report for the dairy industry on what you have researched and your proposed solution.

### TAKING IT FURTHER

- 1 Debate the statement: 'Economic returns do not have to come at the expense of animal welfare.'
- 2 Discuss the effect of veganism on dairy farmers.

## 10.7 Sustainability

### Sustainable methods and practices

#### Effluent management

Effluent is water contaminated with faeces and urine from the dairy cows. The dairy and surrounding yards must be washed down after each milking, and the effluent water produced must be managed properly. Effluent contains high levels of nutrients and can cause algal blooms if allowed to flow into waterways. Algal blooms can lead to eutrophication, where water is stripped of oxygen resulting in dead zones, killing aquatic species and affecting other organisms that drink or use the water.



**Figure 10.26** Run-off effluent from dairy farms can cause eutrophication of waterways.

Environmental protection legislation states that all effluent from the dairy, feedpad and other areas must be contained and reused. Milk is also considered effluent and cannot be released in to waterways.

Pond systems are used to store liquids, while solids are often separated and stockpiled to be used a fertiliser. Some dairies dry-scrape yards before hosing them to reduce the amount of water used for cleaning and the volume of effluent produced.

Faecal contamination of waterways by cattle can also be reduced by fencing off dams and creeks. Programs such as the Clean Rivers program in Tasmania encourage farmers to invest in effluent management systems and provides cash to encourage farmers to participate; over 350 of Tasmania's 430 dairy farmers now participate.

## Sustainable technology

### Methane

During the rumination process, cows produce methane when they belch. This methane is a large contributor to greenhouse gas emissions. In Australia, about

10% of total greenhouse gas emissions come from livestock in agriculture. Emissions from livestock and manure account for 56% of the total Australian methane emissions, with dairy cattle the top offenders over beef cattle and sheep.

**DID YOU KNOW?**

Most methane emissions come from cow belches and burps, not flatulence!

### AG IN FOCUS

#### METHANE REDUCTIONS IN DAIRY CATTLE



**Figure 10.27** Anaerobic digesters are being used on dairy farms to reduce methane emissions.

#### Identify

Since 1996 Australian farmers have been at the forefront of the fight to reduce greenhouse gas emissions. Australian primary industries have decreased their emissions by 63% in 20 years. The livestock industry used to produce 25% of total emissions in Australia but this has decreased to just 10%, driven by new technologies.



Video

Watch the *Landline* episode that discusses how a dairy farmer uses a biodigester to reduce waste.



Video

Watch the *Landline* episode discussing how leucaena might help reduce methane emissions from cattle.

## Understand

Anaerobic digesters have been developed to capture the methane found in manure and turn it into electrical energy. Farms can collect the manure then heat it up in the fermenter where microbes produce methane as they digest these animal wastes. The gas is then captured and converted into electrical energy that can power the farm. The technology was originally designed for mining companies to destroy their waste, but farmers have been able to apply the same technology to dairy farming, with one farm able to provide one-third of their annual electricity usage from just one digester and 50 cows.

Another new discovery is that seaweed can assist in reducing methane emissions from belching. Initial research indicated that as much as 99% of methane emissions could be reduced in cattle by feeding them seaweed. In the long term, this research would greatly reduce the amount of methane in the air, helping global efforts to reduce the effects of climate change. Other new technologies designed to fight methane emissions include:

- changing rumen microbes to encourage species that produce less methane
- feeding supplements and vaccines
- trialling different plants, including leucaena, a fodder tree that is a good source of feed in northern Australia and may help reduce methane emissions from cattle.

iStock.com/Liontmila  
Korelidou

## Discussion

- 1 Describe the trend of greenhouse gas emissions from Australia's primary industries.
- 2 Describe two new technologies helping to reduce dairy farmers emissions.
- 3 Evaluate the potential of leucaena as a viable crop for dairy farmers looking to reduce methane emissions. Consider the nutritional value and pasture management considerations in addition to the potential environmental impact.
- 4 Research and design a new solution to reducing methane emissions from dairy cattle.

**Figure 10.28** Leucaena is being trialled as a feed to reduce methane emissions from beef cattle.

## Sustainable decision-making

### AG IN FOCUS

#### FENCING DAMS



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**Figure 10.29** Wildlife can suffer without fencing around dams, and diseases like mastitis are more common.

## Identify

Dairy farms can use dams to store water, which can then be used for stock or pasture irrigation.

## Understand

Traditionally, many farmers have allowed their livestock to access dams and waterways. In the short term this is a cost-effective way of providing drinking water to dairy cattle as no fencing, piping, pumps or troughs are needed. However, livestock damage dam walls as they clamber in and out of the water, causing erosion. Dam water becomes contaminated with silt, faeces and urine. For dairy cows, accessing dams can also result in mastitis when their teat canals become infected with bacteria from the water.

Fencing dams and installing troughs for drinking water is more expensive in the short term. Revegetation of riparian zones and dam walls can be labour intensive and costly. The long-term benefits of these strategies are significant: improved water quality and biodiversity, stabilised dam walls and reduced rates of mastitis make a farm more sustainable and productive. Cattle are also likely to drink more readily from cool, uncontaminated trough water, increasing their milk production.

## Discussion

- 1 Why might a farmer choose to not fence their dam?
- 2 Explain how fencing could increase environmental sustainability of the farm.
- 3 Discuss the short- and long-term benefits to a dairy farm from fencing dams. Use the following table to assist you.

	Free access	Fenced
Economic		
Production		
Environmental		
Other		



## LET'S REVIEW

### LOOKING BACK

- 1 What is eutrophication?
- 2 Describe three methods farmers are using to decrease effluent run-off.
- 3 What is methane?
- 4 Describe, using statistics, how Australian agriculture contributes to greenhouse gas emissions.

### FOR YOU TO DO

- 1 Debate the statement: 'Environmental sustainability should be the most important concern for dairy farmers.'
- 2 Create a promotional video informing dairy farmers of ways they can reduce greenhouse gas emissions on their farms.

### TAKING IT FURTHER

- 1 Research the role genetics plays in reducing methane emissions in cows.
- 2 Evaluate different solutions to reduce methane emissions for dairy farmers.
- 3 'The production of almond and other nut milks is not more environmentally friendly than the production of cow's milk.' Research the production and management of a nut milk and debate this statement. Do you think dairy farming is less sustainable than nut milks?

## 10.8 Marketing

### The market

Australians like dairy products. As a nation, Australians drink about 1.5 million litres of milk annually. Meanwhile Australians also eat 149 000 tonnes of cheese. Dairy products were the fourth-highest earning agricultural commodity in 2018–19. But despite this, the number of dairy farms has decreased dramatically in the past 20 years. This is due in part to the deregulation of the dairy industry in 2000–2001. Before 2001, each state had policies determining milk prices, resulting in farmers who sold in the domestic market receiving higher prices than those exporting. Deregulation decreased the prices, which are now determined by market forces, that is, how much milk is selling for in the international market. This affects the size of the dairies. The number of small, family-run businesses are declining because they are not economically viable with the new market prices. Instead, big companies are buying out smaller producers, expanding the milking numbers into the thousands. More US-style production systems are becoming common, where large numbers of cattle are produced on small areas of land, allowing for more efficient, cheaper production. The deregulation has, however, allowed Australia to become a large exporter of dairy products because the industry can now compete on the international level, with Australia exporting around 30–40% of all milk produced.

#### DID YOU KNOW?

South Australian dairy farmers receive the lowest price for their milk in Australia, at an average of just 42.9 cents per litre in 2017/18.



#### LET'S DISCUSS

- 1 How has deregulation affected Australian dairy farmers?
- 2 Was the deregulation of milk the right thing to do?

**Table 10.11** Australian farmgate milk prices

State	2014/15	2015/16	2016/17	2017/18
NSW (cents/litre)	52.8	51.0	49.0	50.5
VIC (cents/litre)	47.1	42.8	38.0	44.2
QLD (cents/litre)	57.4	58.5	60.0	57.7
SA (cents/litre)	49.1	42.5	37.1	42.9
WA (cents/litre)	49.0	52.3	50.6	49.9
TAS (cents/litre)	49.6	43.7	39.0	47.0
AUST (cents/litre)	48.5	44.9	40.9	46.0

## AG IN FOCUS

### DAIRY MARKET GIANTS

#### Identify

The vast majority of fresh milk sold domestically goes to a few key processing companies, which then sell to mainstream supermarkets such as Coles and Woolworths. In 2011, Coles cut their price on milk to \$1 a litre and were closely followed by Woolworths.

#### Understand

Dairy farmers argue that \$1 milk has resulted in lower farmgate milk prices because consumers do not value the product. Dairy farmers have been further hurt by drought that has driven production costs up. The low prices coupled with the drought has caused the closure of many dairy farms across Australia.

However, an Australian Competition and Consumer Commission report in 2017 argued it was not the \$1 milk that was to blame, but the power imbalance between farmers and processing companies, as dairy farmers have little negotiating power.

In early 2019, Woolworths announced an end to selling milk at \$1 per litre, it would now sell milk at \$1.10 per litre, with the extra 10 cents going directly to the farmer who sold the milk. Other supermarkets disagree with Woolworths' decision, arguing this bypasses normal supply chains (because the processing company does not receive this additional profit).

Meanwhile, supermarkets have created temporary measures to assist the drought-affected dairy farmers, with Coles introducing a temporary 10% cost increase on 3L milk bottles, and Woolworths creating a new range of milk titled 'Drought Relief' milk that costs 10% more. All the money raised from these initiatives is supplied to dairy farmers.

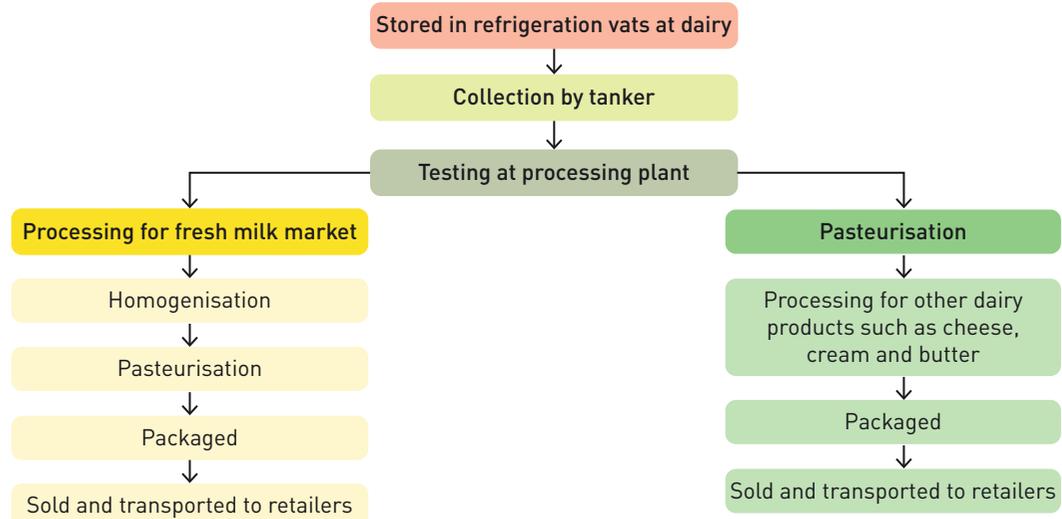
#### Discussion

- 1 Draw a flowchart showing the relationship between dairy farmers, processing companies and supermarkets.
- 2 Discuss the possible reasons for low farmgate milk prices.
- 3 What have major retailers done to assist dairy farmers?
- 4 Discuss the implications of \$1 per litre milk with regards to assisting dairy farmers.
  - a Do you think it is the responsibility of major retailers to assist dairy farmers?
  - b Do you think major retailers have done enough to assist dairy farmers?
- 5 Create a new marketing plan for Woolworths Drought Relief milk.

## Specifications

### Dairy marketing chain

Dairy farmers must follow a process that enables them to meet the strict product specifications for milk. This involves a process of tanker collection, testing, pasteurisation and homogenisation.



**Figure 10.30** The dairy marketing chain

## Storage

Milk needs to be cooled after milking, and therefore it is kept in refrigerated storage vats at 4°C or less. Milk is stored at the farm for less than 48 hours before a tanker will arrive to collect it and conduct testing.

## Testing

Transport tankers will conduct some on-site testing of the milk, whilst further, more intensive testing is completed at the processing factory. For each test, a farmer has a target to hit whereby they will receive either a price penalty or premium. This encourages farmers to aim for quality milk to ensure they are not penalised. Milk is tested for:

- bacteria: maximum of 15 000 bacteria per mL
- butterfat: premium paid for 3.95% +
- protein: premium paid for 3.15% +
- somatic cell count: white blood cell count, maximum of 500 000 per mL
- chemical contamination: testing for antibiotics, iodine, cleaning detergents and water
- other contaminants: blood, faecal matter, sediment.

Milk will be rejected if it contains some of these contaminants, such as blood or antibiotics.

## Pasteurisation

Pasteurisation involves heating the milk up to above 72°C and then quickly cooling it. This kills all bacteria and prevents the milk from spoiling, hence increasing shelf life.

## Homogenisation

Homogenisation involves pumping the milk through a sieve machine that evenly distributes the fat molecules throughout the milk, ensuring the milk does not separate.



## LET'S EXPERIMENT

## INVESTIGATING THE pH OF MILK

### PURPOSE

To test the effect of temperature on the pH of milk

### HYPOTHESIS

What effect do you think temperature will have on the pH of milk? (Hint: remember milk sours.)

### RISK ASSESSMENT



Complete a risk assessment using the template on NelsonNet.



Template

Risk assessment template

### MATERIALS

- Milk
- Litmus paper
- Clingfilm wrap
- Pens
- 12 x 100 mL beakers/jars
- Thermometer
- Fridge
- Labels

### METHOD

- 1 Fill up each of the 12 beakers with 75 mL of milk. Label the beakers 1 to 12.
- 2 Using the litmus paper, measure the pH in each of the beakers. Record their starting pH.
- 3 Use a thermometer to measure temperature of each of the beakers. Record their starting temperature.
- 4 Cover each sample with cling wrap to make sure no bugs or dust can enter the samples.
- 5 Place four beakers in the fridge, four beakers on a shaded shelf and four beakers in bright sunlight (such as on an inside window ledge).
- 6 Each day, for five days, use the litmus paper to measure the pH of each of the 12 samples. Record the pH for each sample. Then use the thermometer to measure the temperature. Record the temperature for each sample.

### RESULTS

- 1 Construct a table to record the daily pH and temperature of each beaker.
- 2 Calculate the mean daily pH and temperature for each treatment (fridge, shade, sun) and add to the table.
- 3 Construct a stacked line graph representing these results.

### DISCUSSION

- 1 Interpret your results. How did the temperature affect pH?
- 2 Did this experiment adequately use replication? How could replication be improved?
- 3 How do your findings affect dairy farm management?
- 4 Design an experiment where you could add a third variable, a type of milk, to the experiment.

### CONCLUSION

Was your hypothesis correct, incorrect or partially correct?

# Marketing strategies

## Types of marketing

**Table 10.12** Types of marketing strategy for milk

Contracts	Co-operatives
<p>Farmers are contracted to supply their produce to processing and/or retailing companies.</p> <ul style="list-style-type: none"> <li>Processors such as Fonterra contract farmers to produce a set amount of milk per year for a set price.</li> <li>Payments can be negotiated between farms and processors.</li> <li>Processing equipment owned by big company, not farmer. Processing is done offsite.</li> </ul>	<p>Owned (shareholders) and managed by a group of dairy farmers, such as Dairy Farmers Milk Co-operative NSW.</p> <ul style="list-style-type: none"> <li>All farmers supply milk to the co-operative.</li> <li>The co-operative stores, processes, packages, promotes, markets and distributes milk and milk products.</li> <li>Co-operatives can collectively bargain for cheaper inputs.</li> <li>Management decisions made by co-operatives, not individual farmers.</li> </ul>
Direct/Niche marketing	Marketing boards
<p>Milk is processed on the farm and sold locally.</p> <ul style="list-style-type: none"> <li>Farmers are required to invest in processing equipment.</li> <li>Farmers vertically integrate (own more than one step in the process such as production and processing).</li> <li>Vertically integrated farms (which process on site) can contract direct to retailers, cutting out the processors.</li> <li>Prices are negotiated between growers and buyers – can also be done through auction.</li> <li>Farmer sells their produce directly to the consumer.</li> </ul>	<p>State or Australian bodies that market produce locally and internationally. Responsible for sale of milk before deregulation.</p> <ul style="list-style-type: none"> <li>Dairy Australia seeks out and develops export markets and promotes Australian dairy products internationally.</li> <li>Dairy NSW promotes milk products and educates the consumer on the health value of dairy products.</li> </ul>



Worksheets

Analyse different milk products in the *Marketing milk* worksheet.

Most farmers have a contract to sell their milk to a processing factory, but some farmers produce and market their own milk and milk products to increase their share of the profits. This means they are selling direct to the public or retailers and save on costs throughout the production.

## Value-adding

Value-adding involves processing milk into a different product before selling. It usually costs more (due to the additional production steps) but farmers can charge more for the end product. Value-added products are often in higher demand because they are considered more appealing products. Some examples include:

- creating new products such as cheese or butter
- modifying existing products such as skimmed or flavoured milk
- creating more convenient packaging such as single-serve milk cartons.



**Figure 10.31** Flavoured milk products

Getty Images/Bloomberg



## LET'S ENGAGE

## CREATING A VALUE-ADDED PRODUCT: BUTTER

## PURPOSE

To create your own value-added milk product

## MATERIALS

- One jar
- One cup of thick cream (cream that can be whipped)
- Cold water

## METHOD

- 1 Pour the cream into the jar.
- 2 Put lid on jar.
- 3 Vigorously shake the jar for five minutes, until a lump has formed inside. (Note: depending on how hard you shake, it might take longer than this.)
- 4 When you hear the lump, shake for another minute.

- 5 Remove remaining liquid for the jar (this liquid is called buttermilk).
- 6 Put the lump into a bowl and wash it with cold water. Drain water.
- 7 Rinse again. Congratulations, you've made some butter! Can you think of anything you could add to your butter to make an even more specialised product?

## DISCUSSION

- 1 How did you value-add a product?
- 2 Research how farmers make butter. How did this process mirror the techniques used in dairies?
- 3 Design a marketing plan for your new product. Create at least one form of advertisement (for example, a television advertisement, poster or leaflet).

## Advertising and promotion

Dairy Australia spends approximately \$3.5 million each year promoting milk, by creating adverts and campaigns highlighting the benefits of milk. 'Legendairy' is one such campaign example. The Legendairy campaign involved television advertisements featuring celebrities to promote the health benefits of milk.



Video

Deb Poole Legendairy campaign



## LET'S REVIEW

## LOOKING BACK

- 1 Explain what deregulation is and how it affected the Australian dairy market.
- 2 Describe four marketing strategies for dairy farmers.
- 3 What is value-adding?
- 4 List five examples of value-added milk products.
- 5 Describe the specifications required of milk.

## FOR YOU TO DO

- 1 Draw a marketing chain flowchart for butter.
- 2 Research the \$1 per litre milk issue. Evaluate the effect that mainstream supermarkets have on the dairy industry.
- 3 Create a television advertisement emphasising the benefits of cow's milk over alternative milks. Use Chapter 4 to help you identify your USP and target market.
- 4 Watch the Deb Poole Legendairy milk advertisement. Identify the:
  - a unique selling point
  - b target market.
- 5 Evaluate the advantages and disadvantages of the four milk marketing strategies.

## TAKING IT FURTHER

- 1 Research how milk was kept fresh when there were no refrigerators.
- 2 Create a promotional poster for flavoured milk that entices a particular age bracket to buy.



Video

Deb Poole Legendairy campaign

# Let's summarise



Practice quiz

Complete the chapter review test on NelsonNet to review what you've learnt about dairy cattle production.

## How can dairy farmers ensure high welfare and economic returns of their farm?

Dairy farming suffers from an animal welfare issue many aren't aware of: culling of male bobby calves at a young age. However, new technology such as sexed semen is becoming more readily available, allowing farmers to produce fewer male calves. In addition, farmers who choose not to kill bobby calves can charge higher prices for their product.

Conduct a class debate on the issue: 'Which is more important for a dairy farmer, animal welfare or economic returns?'

## How can dairy farmers reduce greenhouse gas emissions?

Dairy cows contribute to Australia's greenhouse gas emissions, with methane emitted from both belching and manure. Farmers are utilising new technologies such as digestors, fencing off waterways, fertilisers, and seaweed to help reduce the greenhouse gas emissions in their cows.

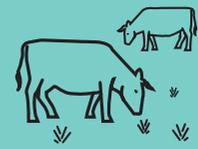
Use the table below to evaluate the effect that each of these technologies has on the farmer, and the environment.

Technology	Effect on farmer	Effect on environment
Digestors		
Fencing		
Fertiliser		
Seaweed		

## How can farmers manage the production cycle to produce high quality milk?

Each step in the production cycle is under the control of the farmer. Draw a copy of the dairy cattle production cycle and add arrows and notes to demonstrate where and how the following factors can be used to make dairy farming productive and profitable.

Timing of operations (joining, etc.)	Breed selection	EBVs	Diets and nutrition	Pasture management
Disease management	Environmental control (e.g. effluence, humidity, temperature)	Husbandry practices	Knowledge of market specifications	Understanding cattle behaviour



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# Beef cattle

## CHAPTER SUMMARY

From large-scale northern cattle stations to intensive feedlots and studs, beef production is central to Australian agriculture and identity. In this chapter, you will learn about the management and handling of cattle and debate the merits of different production systems. You will explore the ethics of live export and dehorning, and debate whether beef can be grown sustainably.

**How has beef production adapted to the harsh Australian environment?**

**How can farmers manage the production cycle to produce high-quality beef?**

## 11.1 Introduction

Beef cattle farming is one of the cornerstones of Australian agriculture, dating back to the arrival of Black Cape cattle on the First Fleet. Cattle production extends from the tropical north to the cool and temperate south, covering three-quarters of Australia's agricultural land. The majority of Australian farms carry beef cattle, some as sole enterprises and others as part of a mixed farming system with cropping and sometimes sheep.

While all Australian cattle are raised on pasture, a growing number are being fattened in feedlots. Destined for local plates and overseas markets, Australian beef is perceived as a premium source of animal protein from farms with excellent environmental standards. Australia is a small producer by world standards but is the third-largest exporter of beef. Frozen and chilled premium beef, manufacturing beef and even live cattle are sold overseas to a range of countries including Japan, the USA, Canada, Korea and Indonesia.

New Zealand beef production occurs mainly on the North Island, and usually alongside sheep farming. The dairy industry markets beef in the form of culled dairy cattle and male calves. Over 80% of all New Zealand beef is exported to a range of markets.

## 11.2 Functions and anatomy

### Functions

Beef cattle are primarily grown for the production of beef and veal. In Australia, veal is the meat from beef cattle who have been slaughtered before they reach 150 kg live weight. Depending on the cut of meat, beef is generally richer, more flavoursome and more textured than veal, which is mild, tender and delicately flavoured by comparison.

The quality and characteristics of beef depend, not only on the age of the animal, but also on the part of the **carcase** the cut comes from. Some cuts of meat – for example, rump and tenderloin – are highly valued for their quality and are sold as fillets or steaks. Other cuts are sold as manufacturing beef for the production of processed beef products including sausages, rissoles and meatballs.

**carcase** the body of the animal after removal of head, feet, hide and internal organs

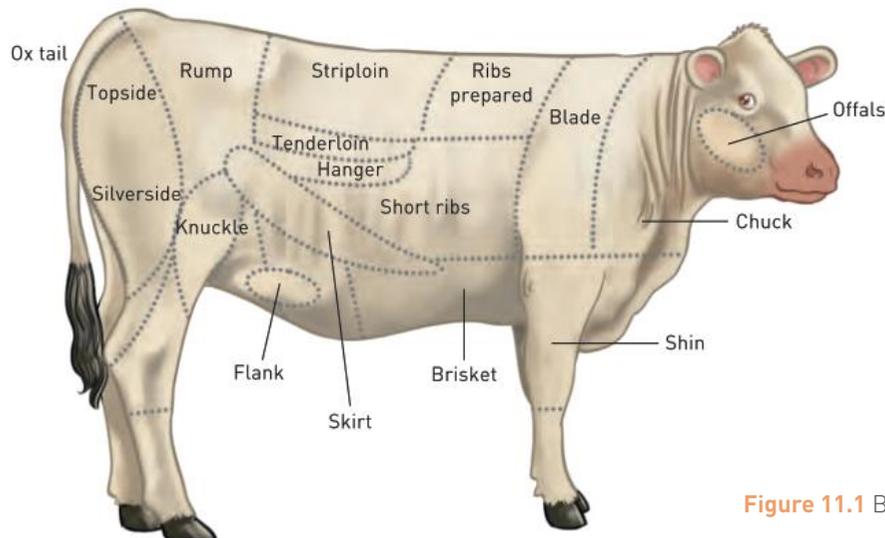


Figure 11.1 Beef carcass cuts

While meat is the main product of beef cattle, no part of the carcass is wasted. Beef by-products made from hooves, skin, bones, internal organs and other parts of an animal include leather, anti-aging cream, fertiliser, adhesives, deodorant, glass, medicines and confectionary. Some breeds of cattle are dual-purpose, producing both beef and milk.

## Beef cattle breeds

Compared with dairy breeds, beef breeds are generally more compact and blocky. Their udders are much smaller and they show greater muscling over their shoulders and rumps.

### Bos Taurus and Bos Indicus cattle

British and European breeds are known as Bos Taurus cattle and include Angus, Hereford, Shorthorns, Charolais and Limousin breeds. Bos Indicus breeds, on the other hand, are bred from Indian Zebu cattle.

Bos Taurus cattle are highly valued for their carcass traits. They produce beef that is tender and has a lot of intramuscular (within the muscle) fat called **marbling**. Marbling makes meat juicy and flavoursome. British Bos Taurus breeds, such as Hereford, Angus and Shorthorn, produce more fat than European Bos Taurus cattle. European breeds, such as Charolais, Simmental and Limousin cattle, are generally larger at maturity with leaner carcasses.

**marbling** the amount of intramuscular fat (fat within the muscle belly)

Bos Indicus cattle can be identified by the hump on their shoulders. They have adaptations to keep them cool in hot climates. Long, droopy ears and dewlaps allow efficient loss of excess body heat in tropical conditions. They are also more capable of walking long distances in search of water and pasture. Bos Indicus carcasses are generally lean with little marbling. Their meat is less tender than Bos Taurus cattle and they stress more easily with handling, further affecting their carcass quality.

### Bos Indicus x Bos Taurus breeds

Several Bos Indicus x Bos Taurus cattle breeds have been developed, including the Brangus, Braford and Santa Gertrudis.

These cattle combine the best traits of the parental breeds and overcome some of the issues of growing cattle in the subtropical and tropical regions of Australia. Braford cattle, for example, are resistant to cattle ticks and eye cancer due to their Brahman heritage. They also produce an excellent carcass due to their Hereford genes.

### Dual-purpose breeds

Some breeds are suited to both beef production and dairy production. They generally cannot compete with dairy cattle in terms of milk volumes but can offer small-scale farmers another source of income. Dexters and Shorthorns are both considered dual-purpose breeds.

#### DID YOU KNOW?

Dual purpose Dexter cattle are sometimes called 'beefy little milkers'. They are very short due to a genetic mutation that sometimes causes deformed calves.

**Table 11.1** Beef cattle breeds

Bos Taurus cattle breeds	
<b>Angus</b>	<b>Hereford</b>
 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Alamy Stock Photo/Mariana Fernandez Images</p>	 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Shutterstock.com/visual12</p>
<p><b>Figure 11.2</b> Angus cattle</p> <p>Origin: Scotland</p> <p>Traits: Medium size, black or red, polled (hornless). Excellent carcase and good marbling.</p>	<p><b>Figure 11.3</b> Hereford cattle</p> <p>Origin: Herefordshire, England</p> <p>Traits: Medium size, red and white, horned or polled. Docile and good forager.</p>
<b>Shorthorn</b>	<b>Charolais</b>
 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Alamy Stock Photo/Design Pics Inc</p>	 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Alamy Stock Photo/Wayne Hutchinson</p>
<p><b>Figure 11.4</b> Shorthorn cattle</p> <p>Origin: England</p> <p>Traits: Medium frame, red and white or roan (pictured), horned or polled, highly fertile, good milk production.</p>	<p><b>Figure 11.5</b> Charolais cattle</p> <p>Origin: France</p> <p>Traits: Large frame, well-muscled, horned or polled. Late maturing and docile.</p>
<b>Simmental</b>	<b>Limousin</b>
 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Shutterstock.com/meunierd</p>	 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">iStock.com/theasis</p>
<p><b>Figure 11.6</b> Simmental cattle</p> <p>Origin: Switzerland</p> <p>Traits: Large frame, well muscled. Good temperament and milk production.</p>	<p><b>Figure 11.7</b> Limousin cattle</p> <p>Origin: French</p> <p>Traits: Heavily muscled, excellent carcase, smaller than other European breeds.</p>
<b>Dexter</b>	<b>Murray Grey</b>
 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Alamy Stock Photo/Art Directors &amp; TRIP</p>	 <p style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Shutterstock.com/William Edge</p>
<p><b>Figure 11.8</b> Dexter cattle</p> <p>Origin: Ireland</p> <p>Traits: Dwarf breed, dual purpose.</p>	<p><b>Figure 11.9</b> Murray Grey cattle</p> <p>Origin: Australia (from Angus/Shorthorn cross)</p> <p>Traits: Medium size, silver to grey with excellent carcase.</p>

**Bos Indicus cattle breeds****Brahman**

Shutterstock.com/Johan Larson

**Figure 11.10** Brahman cattle

Origin: India  
 Traits: Medium size with hump. Intelligent but shy.

**Sahiwal**

Shutterstock.com/Elton Abreu

**Figure 11.11** Sahiwal cattle

Origin: Pakistan  
 Traits: Heat and drought tolerant, excellent milk production

**Bos Indicus x Bos Taurus cattle breeds****Brangus**

Dreamstime.com/Lifeontheinside

**Figure 11.12** Brangus cattle

Origin: USA (Brahman/Angus cross).  
 Traits: black or red, polled, tick and heat resistant. Excellent mothers with good milk production.

**Santa Gertrudis**

Alamy Stock Photo/Terry Smith Images

**Figure 11.13** Santa Gertrudis cattle

Origin: USA (from Brahman/Shorthorn cross)  
 Traits: Mainly red with small hump, excellent heat tolerance and good milk production.

**Braford**

Shutterstock.com/Shooter11

**Figure 11.14** Braford cattle

Origin: Australia (from Brahman/Hereford cross)  
 Traits: Red and white with hump, heat tolerant, high growth rates.

**Droughtmaster**

Shutterstock.com/paintings

**Figure 11.15** Droughtmaster cattle

Origin: Australia (Brahman/Shorthorn/Hereford cross)  
 Traits: Excellent mothers, quiet temperament, resistant to bloat and heat.



Worksheets

Analyse beef cattle breeds with this worksheet.

## Anatomy

### Terminology

Beef cattle are classified according to their age, sex and production use. They are also categorised according to:

- 1 dentition:** age can be estimated by examination of the lower incisors. Cattle do not possess upper incisors, and their molars grow continually and wear down with grazing. Permanent incisors erupt according to a pattern that is reasonably reliable.

- 2 *secondary sex characteristics*: the presence of features associated with sexual maturity in males, such as muscling of the neck and shoulders and development of the external genitalia, is used to help classify male cattle.

**Table 11.2** Aging cattle using dentition

Number of permanent teeth present	Breed	Average age (months)
2	Bos Taurus	24
	Bos Indicus	26
4	Bos Taurus	31
	Bos Indicus	33
6	Bos Taurus	38
	Bos Indicus	41
8	Bos Taurus	46
	Bos Indicus	51

**Table 11.3** Beef cattle terminology

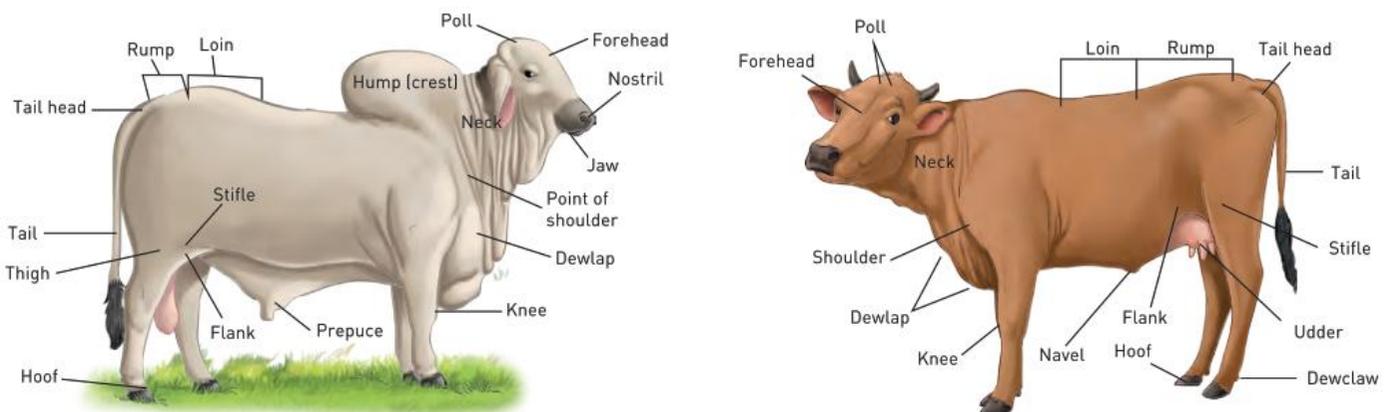
Term	Definition
Bull	Male with intact testes, capable of reproduction, used for breeding
Calf	Young animal with no permanent incisor teeth or secondary sex characteristics
Carcase	Body after removal of head, feet, hide and internal organs
Cow	Mature female with permanent teeth, used for breeding
Finisher	Cattle that have reached market weight and are ready for processing
Heifer	Young female that has not yet produced a calf
Steer	Male that has been castrated (had testes removed), with no secondary sex characteristics
Vealer	Young animal under 150 kg live weight that has been weaned for no more than seven days
Weaner	Young animal that has been weaned from milk and placed on pasture
Yearling	12–18 months old with no permanent teeth and no secondary sex characteristics



Worksheets

Review what you know about anatomy with the worksheet on NelsonNet.

### Parts of a bull and cow



**Figure 11.16** Anatomy of a beef bull and cow



## LET'S REVIEW

### LOOKING BACK

- 1 Define the terms: marbling, vealer, calf, bull, steer, heifer and cow.
- 2 Outline the main differences between beef and veal.
- 3 Identify five products derived from beef cattle, apart from meat.
- 4 Name and describe two *Bos Indicus* and two *Bos Taurus* breeds of beef cattle.

### FOR YOU TO DO

- 1 Assess the use of *Bos Indicus* and *Bos Indicus* x *Bos Taurus* cattle for tropical beef production.
- 2 **a** Examine the dentition of cattle at the school agriculture plot or a local farm to estimate their age.  
**b** Research other methods of determining the age of cattle.
- 3 **a** Assess the local climate and make a list of breeds you think would be best suited to your location.  
**b** Investigate breeds of cattle in your local area. Are these similar to the ones you predicted?

### TAKING IT FURTHER

- 1 Draw an outline of a beef steer on the white board or on a large sheet of butcher's paper and colour it in to show the location of various cuts of meat. Use the True Aussie beef website to learn more about cuts of meat from beef carcasses.
- 2 In groups, create a set of trading cards for beef breeds. Include an image, origin, characteristics and unusual facts.



Web link

True Aussie beef

## 11.3 Production

### Cycle

The production cycle of beef cattle is based on the reproductive cycle of the cow. Cows are joined to bulls for a period of 6–12 weeks. This allows farmers to time when calves are born, ensuring cows have access to the best feed possible to maximise their milk production.

After a gestation (pregnancy) period of 283 days, calves are born. Producers aim to achieve a 96% calving rate (96 calves born live for every 100 cows joined) within a calving period of nine weeks. Achieving Target 969, as this rule is known, is an indication of a productive and profitable beef enterprise.

Within two months of calving, the cows have been joined once again to a bull. In some very large farms in the northern part of Australia, bulls may be left with cows all year round. Calves are weaned off their mothers between four and nine months of age. Vealer calves are sent for processing at this age. Other calves are then generally reared on pasture. This period of time is called backgrounding and is an important part of the beef production cycle as good nutrition during backgrounding ensures beef calves grow well and produce an acceptable carcass. Calves may be sold as yearlings at 12 months, they may be finished on pasture or they may be sent to a feedlot for **finishing**.

**finishing** a period before slaughter when animals are fed high energy and/or protein feeds to improve weight gain and carcass quality

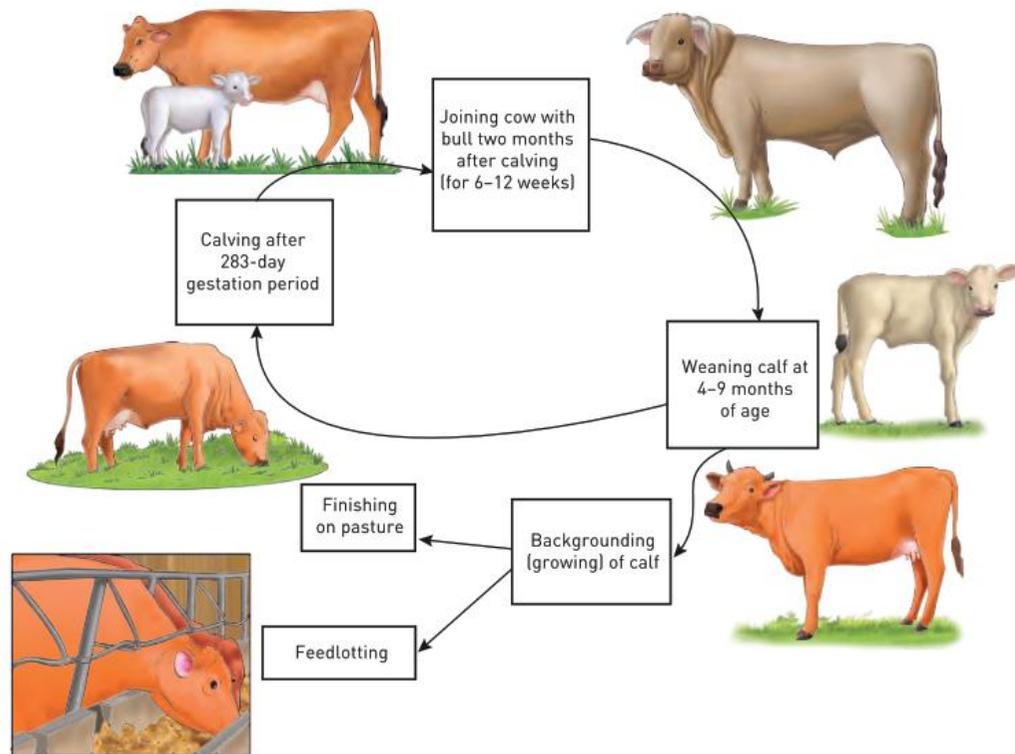


Figure 11.17 Production cycle for beef cattle

## Systems

### Grass-fed production

Most beef cattle in Australia and New Zealand are grass-fed. Grass-fed production is an extensive system involving keeping animals at relatively low **stocking rates**. Farmers who graze livestock are called graziers.

Grass-fed beef production is often part of a mixed farming enterprise, with the production of crops such as cereal grains and oilseeds occurring in rotation with beef production. These mixed farms are more common in the southern parts of Australia, with beef cattle grazing pasture and on the stubble from harvested crops and forage crops grown specifically for grazing. Cattle are also sometimes grazed strategically on crops that will later be harvested for human consumption.

### Feedlotting

Feedlots are intensive production systems. Cattle are kept at high stocking rates in yards of up to 6000 m<sup>2</sup> with mechanical or hand feeding and watering. These enterprises are generally found in areas of grain production and good water access. Cattle finished in feedlots are referred to as grain-fed.

Around 2% of Australian beef cattle are housed in feedlot systems at any point in time. Australian feedlot cattle are raised in grass-fed systems and then finished in feedlots for an average period of 50–120 days.



Figure 11.18 Feedlot production

**stocking rate** the average area available to each animal in a production system, usually expressed as the number of animals per hectare

## Northern and southern production systems

Northern Australian cattle enterprises are generally very large with low stocking rates. These grass-fed systems are dominated by the heat-tolerant *Bos Indicus* breeds, with animals foraging over vast distances. Cattle are either exported live to Asian markets or transported south for feedlotting before supplying other markets such as the Australian domestic market or American 'hamburger meat' market.

Southern production systems usually involve *Bos Taurus* breeds. These systems are often more intensive than northern production systems and have higher stocking rates. Cattle are backgrounded on pasture and sometimes finished in feedlots. Southern beef farms supply the domestic and high-value export markets with superior-quality beef.

## Organic

Organic beef is produced in grass-fed systems on certified farms. Cattle must not be treated with any pesticides, hormones, antibiotics or other non-certified chemicals. They must also not be fed genetically modified feeds.

### AG IN FOCUS

#### ALEXANDRIA STATION

##### Identify

Located on the Barkly Tableland in the Northern Territory, Alexandria Station is Australia's second-largest farm, covering over 1.6 million hectares and running around 70 000 head of cattle.

##### Understand

Alexandria Station is owned by the Northern Australian Pastoral Company, which originally ran Shorthorns



© The North Australian Pastoral Company Pty Ltd

Figure 11.19 Alexandria Station

on the property, selecting the longest legged bulls for breeding to produce animals that could range long distances for food and water. Shorthorns are good mothers but struggle in the northern conditions. High calf losses and the impact of cattle ticks convinced the owners to introduce Brahman cattle to the property. Alexandria composite cattle – a variety based on crossbreeding between the original Shorthorns and the Brahmans – are processed for domestic and export sales of chilled beef.

The station has two outposts and employs over 50 staff to perform a number of roles including stock handling, catering, driving road trains, flying planes and helicopters, checking water supplies and working in offices.

##### Discussion

- 1 Describe the production system used on Alexandria Station.
- 2 Why did Shorthorn cattle struggle in Alexandria?
- 3 Identify two features of Brahman cattle that are advantageous for this production system.

- 4 Stocking rate is calculated in the following way:

$$\text{Stocking rate (animals/hectare)} = \frac{\text{Number of stock}}{\text{Land area (hectares)}}$$

- a Calculate the stocking rate for Alexandria Station.
  - b Mt Fyans in Dundonnell, Victoria, runs 5000 Angus cattle on 5900 hectares. Calculate the stocking rate for Mt Fyans and compare it with that of Alexandria Station.
  - c Each cow in a feedlot has, on average, approximately 25 m<sup>2</sup>. Convert this to a stocking rate (remember, one hectare = 10 000 m<sup>2</sup>).
  - d Deduct some of the factors that might be responsible for the difference in stocking rates between Alexandria, Mt Fyans and an average feedlot.
- 5 Investigate what life would be like on a northern Australian cattle station. Imagine your life as a teenager, and write a report on:
- a chores you would be required to do (including farm work)
  - b schooling
  - c connections with friends and the local community
  - d prospects and opportunities after school.



## LET'S REVIEW

### LOOKING BACK

- 1 How long are cows and bulls joined for in southern and northern production systems?
- 2 State the length of gestation of cows and the age of weaning of calves.
- 3 What is backgrounding and why is it important?
- 4 Identify two differences between:
  - a grass-fed and grain-fed production
  - b northern and southern production systems.

### FOR YOU TO DO

- 1 Assess the costs associated with grass-fed and grain-fed cattle production. Consider feeding, management, environmental impacts and infrastructure (all of the necessary buildings, roads and other structures).
- 2 Conduct a poll of students' parents and guardians to determine their attitudes to grass-fed and grain-fed beef. Design questions to determine:
  - a As consumers, are they aware of the production systems these cattle are grown in?
  - b Do they have any concerns about environmental impacts or animal welfare?
  - c Is there a perceived difference in quality and price between the two types of beef?

### TAKING IT FURTHER

- 1 Use Google Earth to locate the following properties. Explore them and compare their location, vegetative cover, topography, proximity to towns and markets, and any infrastructure.
  - a Alexandria Station, Northern Territory
  - b Mt Fyan, Victoria
  - c Sandlwood Feedlot, Irvingvale, Queensland.
  - d Beaumont Station, Central Otago, New Zealand

## 11.4 Management

### Environmental management

#### Distribution

Beef cattle are farmed over more than half of Australia's landmass. Queensland boasts the highest proportion of the national herd. Feedlots are found mainly in south-eastern Queensland and the Riverina and Northern Tablelands districts of New South Wales.

#### Climate

Beef farming occurs over a wide range of climates in Australia. Enterprises in the northern tropical region must contend with highly variable monsoonal rainfall, while coastal production is affected by humidity and heat. Extensive grass-fed systems must adapt to the climate of a particular location. Climatic management includes choice of cattle breeds, appropriate stocking rates and grazing management.

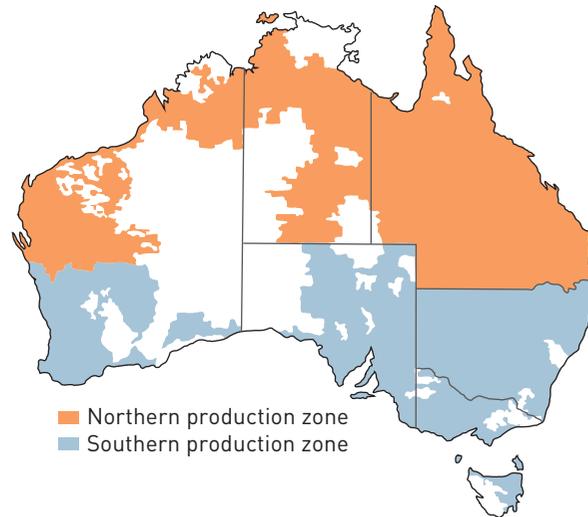


Figure 11.20 Distribution of beef cattle in Australia



Worksheets

Investigate the climate of two different beef production areas in Australia and analyse how climate affects production with the *Comparing climates* worksheet.

#### Environmental management of feedlots

Cattle in feedlots can suffer from excessive heat load, or heat stress. This can cause decreased growth rates, organ failure and death. Excessive heat load is a particular risk for cattle that have been transported to feedlots from milder climates. Apart from high temperatures, feedlots must also manage humidity, airflow and the build-up of noxious gases.

Shades and sprinklers can be used to cool cattle. Sprinklers must be set to deliver large droplets that cause evaporative cooling, rather than mist, which can stay suspended in the air, increasing humidity. Airflow can be difficult to manage. Large fans used in orchards to reduce frost damage have been suggested as an option for summer. Helicopters and light aircraft have also been used to improve airflow around feedlots.



Shutterstock.com/Jen Watson

#### Pasture management

Pasture is a mix of grasses, legumes and herbs that are managed by a farmer for feeding grazing animals. Australian and New Zealand cattle rely on pasture or other green feed for at least part of their lives. Feedlot cattle are fed grain for a short period of time but spend most of their life grazing on pasture.

Figure 11.21 Native pasture supporting beef cattle

### Improved pastures

Improved pastures, composed of highly nutritious introduced grasses, clovers and other plants, are dealt with in our discussion of dairy production in Chapter 10. These pasture types play an important role in beef production, especially in coastal and irrigation areas where sufficient water is available to support them.

### Native pastures

Native pastures are found throughout the northern production area and in some parts of the southern production area.

They exist as grasslands or woodlands, and contain a mix of grasses, lilies, daisies, sedges, rushes and herbs that have adapted to the harsh Australian conditions over millions of years. Native pastures vary depending on the location and climate. Many now contain introduced species of grass, legumes and herbs.

Kangaroo, Mitchell and Weeping grass are three native grasses that can be used for grazing beef cattle. Careful management of native grasses relies on identifying the species that are present and understanding their patterns of growth and reproduction.



Figure 11.22 Kangaroo grass

Shutterstock.com/Young Swee Ming



Worksheets

Collect native grass species and explore whether they can be used for grazing livestock with the practical NelsonNet worksheet.

Table 11.4 Advantages and disadvantages of native pastures

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Many are perennial species, so do not require sowing each season</li> <li>• Deeper, denser roots reduce erosion and can combat salinity</li> <li>• Drought and heat tolerant</li> <li>• Disease resistant</li> <li>• Higher native biodiversity</li> <li>• Very water efficient</li> <li>• Require few inputs (fertiliser, water etc.)</li> <li>• Good source of drought feed</li> </ul>	<ul style="list-style-type: none"> <li>• Generally less nutritious than introduced species</li> <li>• Less palatable (tasty)</li> <li>• Not as responsive to irrigation or fertiliser</li> <li>• Can be easily overgrazed</li> <li>• More difficult to establish in a pasture</li> <li>• Support relatively low stocking rates</li> </ul>

## Enterprise management

### Cattle handling

#### Cattle behaviour

Safe cattle handling is only possible when cattle behaviour is understood. Cattle are herd animals and will mob together. This makes mustering herds easy but can make drafting animals into smaller groups more difficult. Isolated animals are likely to panic and can be particularly dangerous: never place yourself between an isolated animal and its mob.

Cattle have a very wide field of vision, but only a small part at the front

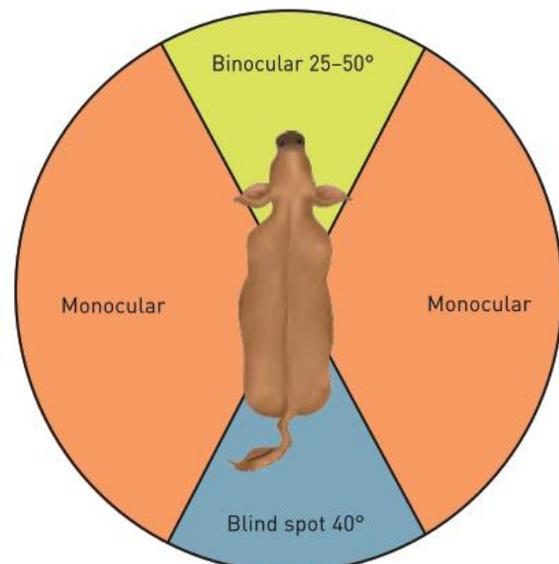


Figure 11.23 Cattle field of vision



Data scenario

Investigate how the behaviour and temperament of cattle affects weight gain.



Worksheets

Find out more about cattle behaviour with this worksheet.

of the animal is **binocular**. Cattle are unable to judge distances with their **monocular** range of vision and need to be given extra time to locate and focus on gates and fences.

### Flight zone and point of balance

The flight zone is a perimeter around an animal. If a handler moves inside this perimeter, the animal will move away. Flight zone size is different between different animals and can even change for individual animals according to circumstances. If the animal is stressed its flight zone will generally be larger.

Handlers can use the flight zone to move cattle. When the handler steps into and out of the flight zone, cattle will be encouraged to move without being stressed or pressured. Mobs of cattle also have a collective flight zone that can be used in the same way for mustering.

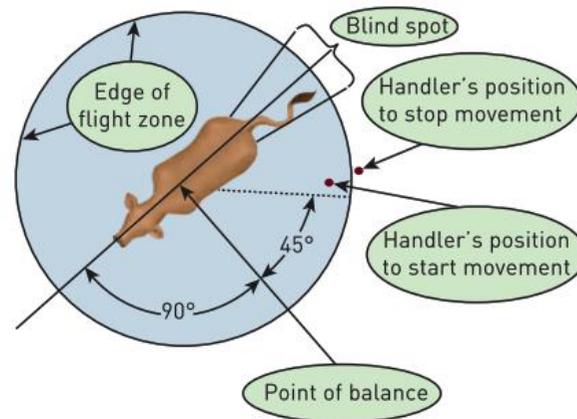
Point of balance refers to a line drawn perpendicular to the shoulder. Cattle will move backwards if a handler stands in front of the point of balance, and forwards if they are approached from behind the point of balance. Handlers can make cattle move forwards or backwards by walking parallel to the cattle, past their point of balance.

### Cattle yards and facilities

At a minimum, a cattle yard should include:

- 1 a *holding yard* for containing a mob
- 2 a *crush*, a device for restraining cattle, used for drenching, vaccinating, castrating, tagging, pregnancy testing and other husbandry activities
- 3 a *race*, a narrow laneway leading to the crush
- 4 a *forcing pen*, a smaller area that can be used to force cattle into the race
- 5 a *ramp* for loading and unloading livestock.

Safe handling relies on operators being aware of how to use these facilities correctly. Ideally, cattle should be able to be worked through yards without handlers needing to be in the same pen or yard as the animals.



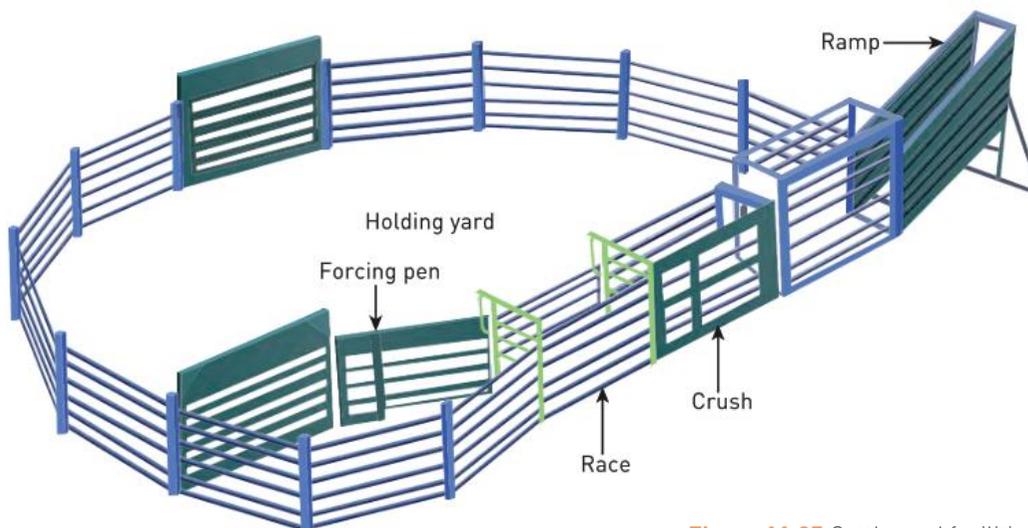
**Figure 11.24** Flight zone and point of balance for beef cattle

**binocular** vision or sight using both eyes, allowing for depth perception

**monocular** vision or sight using one eye or lens



Make sure you know how to safely handle cattle with the *Cattle yards and husbandry* worksheet.



**Figure 11.25** Cattle yard facilities



## LET'S DISCUSS

- 1 What kinds of materials have you seen used in cattle yards? Which materials do you think are the safest and most durable?



## LET'S ENGAGE



Template

Risk assessment template



Video

Cattle handling

## HANDLING CATTLE

### PURPOSE

To observe best practice cattle handling techniques, create a risk assessment for handling cattle at school and then practise using flight zones, point of balance and parallel movement to work cattle through yards

### RISK ASSESSMENT



Use the online template to create a risk assessment for this activity. View the videolink for details on safe cattle handling.

### MATERIALS

- Internet access
- Cattle and yards (if none at school, use videolink and visit a local farm if possible)

### METHOD

- 1 Before handling cattle, watch the Animals in Schools Best Practice Cattle Handling video.
- 2 Take notes on the following topics covered in the video:
  - a preparation for mustering and handling

- b safety during handling
- c the importance of communication
- d features of good yard design
- e using parallel movement.

- 3 Draw a diagram of the school cattle yards or yards at a local farm.
- 4 Write a risk assessment for handling cattle in these yards using the online template.
- 5 Under the supervision of your teacher, muster cattle and move them through cattle yards. Use point of balance, parallel movement and flight zones.

### DISCUSSION

- 1 Identify any features of your cattle yards that need to be modified to ensure safe handling.
- 2 Did your risk assessment take into account different types of cattle? How might your handling techniques change for bulls, calves or pregnant cows?
- 3 Research the work of Temple Grandin in designing cattle-friendly yards and promoting humane livestock handling.

## Basic husbandry

Many basic husbandry procedures are carried out on beef cattle. Some of these are discussed in more detail in Chapter 10.

**Table 11.5** Beef husbandry procedures

Procedure	Description
Castration	Removal of testes from males to produce steers
Vaccination	Protection against diseases including clostridial diseases
Tagging	Compulsory NLIS tags placed in ears for identification
Drenching	Oral or topical (on the skin) dosing with anti-parasitic medication
Dehorning	Removal of horn buds or tissue



Procedure	Description
Artificial insemination	Semen introduced through cervix into the uterus of breeding cows to achieve pregnancy
Pregnancy testing	Rectal examination to detect empty (non-pregnant) or gravid (pregnant) uterus
Weighing	Monitoring weight gains using scales installed in crush
Weaning	Removal (drafting) of calves from mothers

Some of these procedures are carried out at calf marking. This occurs when calves are around six months old and includes castration, vaccination, tagging and drenching. Weaning can occur at the same time or later.

## Digestion and nutrition

Refer to Chapter 10 Dairy cattle for a detailed explanation of cattle digestion. Cows are ruminant animals and possess a modified digestive system that has evolved to allow them to digest tough plant materials such as lignin and cellulose. They do this via a symbiotic relationship with the microbes – bacteria, fungi and protozoa – that live in the rumen and reticulum. These first two stomachs are the site of **microbial fermentation**, the products of which provide cattle with energy, protein and some vitamins.

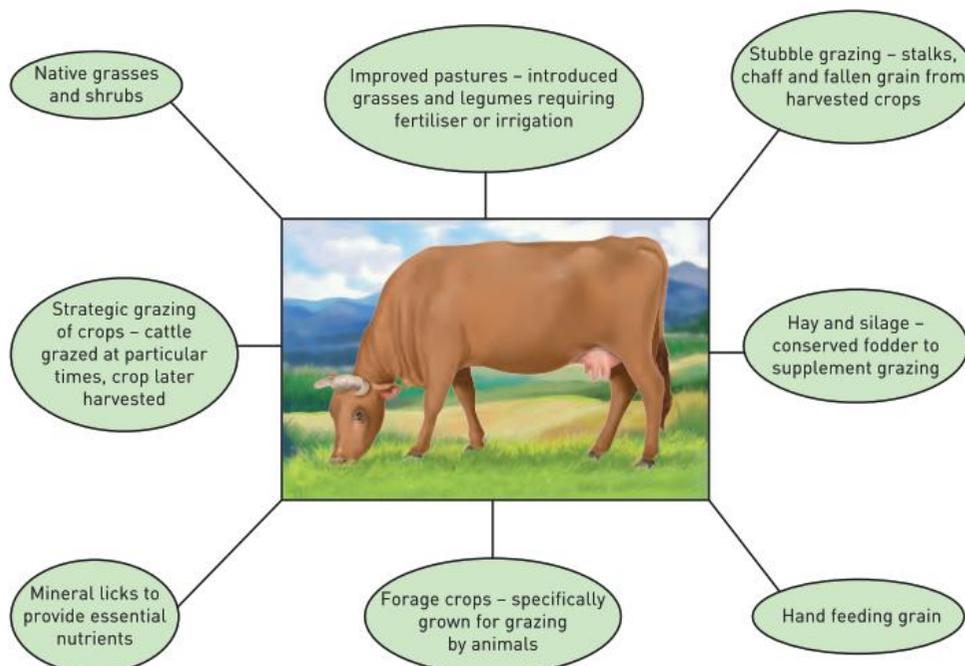
Beef cattle diets depend on the production system, stage of production and available feeds. Feeds can be classified as either roughages or concentrates. Roughages include pasture, hay, forage crops and silage. Concentrates – including cereal grains and high-protein meals – are used extensively in feedlot production as a source of energy and protein. Grass-fed cattle are often finished on concentrates.

**microbial fermentation**  
the breakdown of feedstuffs by microbes, in the absence of oxygen

## Grass-fed nutritional management

Depending on seasonal conditions and the availability of other feed, pasture-based cattle may be fed any combination of feeds shown in Figure 11.26. Pasture is the cheapest and easiest feed. Knowledge of the quantity and quality of pasture in a paddock is an important management tool.

Pasture quality varies with the type of pasture plants and their stage of growth. Early season growth may appear to be less productive, but is usually much more nutritious than later season mature grasses and seed heads.



**Figure 11.26** Feeding options for grass-fed beef cattle



## LET'S ENGAGE



WebLink

Meat & Livestock  
Australia stocking rate  
calculator

# ASSESSING PASTURE YIELD AND DETERMINING STOCKING RATES

## PURPOSE

Dry matter yield is a measure of how much pasture is available in a paddock. It is calculated in kilograms per hectare.

## RISK ASSESSMENT



Take care when using secateurs to avoid injury. Ensure a mug of water is used in microwave to avoid fires. Drying samples may be hot.

## MATERIALS

- Wire coathanger quadrat (bent to form a square)
- Scissors or secateurs
- Bag for collection
- Microwave
- Microwave-safe plastic container
- Microwave-safe mug full of water
- Electronic scales

## METHOD

- 1 Collect 25 random samples from the paddock by throwing the quadrat. Harvest all the grass within the quadrat and place in the bag. The quadrat should measure approximately 20 cm x 20 cm, so 25 samples will equal 1m<sup>2</sup>.
- 2 Cut the samples up into 3–4 cm long pieces.

- 3 Place batches of the sample in the open container in microwave next to the full cup of water.
- 4 Heat for 1–2 minutes, then carefully toss sample. Keep heating until dry.
- 5 Repeat with rest of sample.
- 6 Weigh entire dry sample and calculate dry matter (DM) yield per hectare:

$$\text{DM (kg/ha)} = \text{Weight of dry sample (kg)} \times 10\,000$$

- 7 Use the MLA Stocking Rate calculator to determine the stocking rate for:
  - a 200 kg steers
  - b lactating cows

Assume a pasture growth rate of 10 kg DM/ha per day.

## DISCUSSION

- 1 Explain why 25 random samples were collected rather than just one.
- 2 Use the MLA calculator to determine the relationship between duration of grazing and stocking rate.
- 3 Explain why the stocking rate for steers is different to that for lactating cows.
- 4 What are some of the limitations of this system for working out stocking rates? What factors does it not take into account?

## Finishing and feedlotting cattle

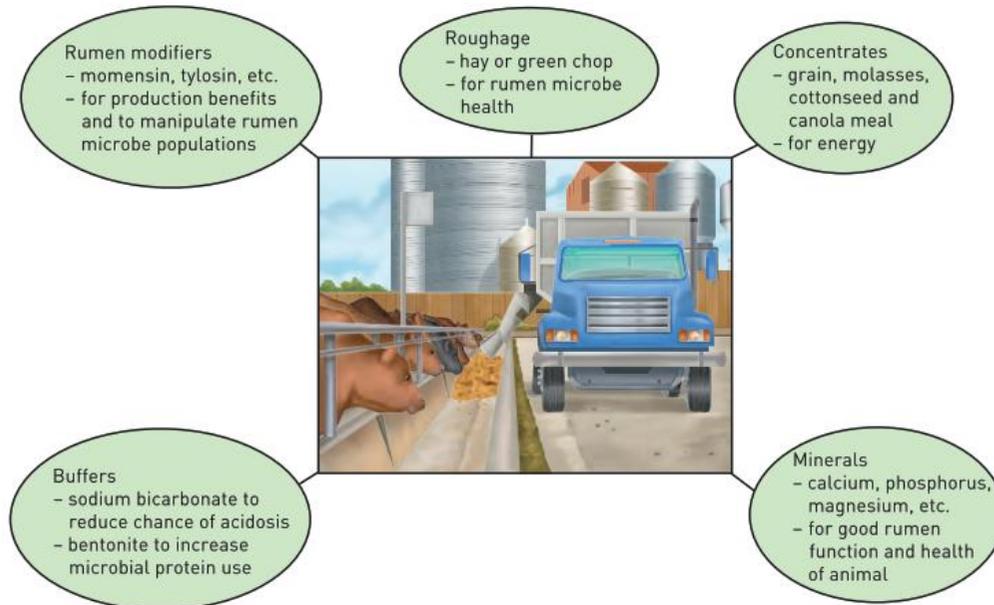
Some cattle are finished on forage crops or good quality hay, but many – including cattle in feedlots – are finished on a grain-based diet. Grains such as wheat, sorghum, triticale and barley are combined with lupins, cottonseed or canola meal and hay or silage, then supplemented with minerals and other additives to meet the exact nutritional needs of cattle for particular markets. Grass-fed cattle must be changed over slowly onto grain-based diets because a sudden change to a grain diet can cause grain poisoning or acidosis, and death.

Hormone growth promotants are implants placed under the skin of cattle to improve how efficiently they convert food into body weight. They are used in feedlots to help cattle reach target weights quicker.

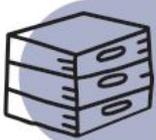


Data scenario

Investigate the effect of hormone growth promotants with the data scenario.



**Figure 11.27** Components of a feedlot ration



## LET'S EXPERIMENT

### COMPARING FINISHING RATIONS

#### AIM

To compare the effect of different rations on the growth of steers

#### HYPOTHESIS

Which diet do you think will produce the highest growth rates?

#### RISK ASSESSMENT

Refer to the Risk Assessment created in the cattle handling activity.



- Grains, pellets and hay can produce dust and allergens.
- Mix feed in a ventilated area.

#### MATERIALS

This experiment relies on access to beef steers. If cattle are not available, use an online ration calculator to estimate results for this experiment:

- Minimum of two head of cattle, preferably of the same sex, age and breed
- Concentrates and roughages, as needed depending on rations
- Weigh scales or measuring tape

#### METHOD

- 1 Weigh cattle using live weight scales or estimate the weight by measuring the circumference of the chest just behind the front legs. Use an online table to convert this length to a weight estimate.
- 2 Divide the cattle into two treatment groups. Each group will be fed a different grain-based diet. Choose locally available affordable ingredients. Formulate diets that contain:
  - 20% roughage (this can be supplied by pasture or access to good quality hay)
  - 80% grain or other concentrates (oats, sorghum, dried distillers grain, pellets, etc.).
- 3 Formulate rations for each group:
  - a Calculate the weight of concentrates for each animal. We will be feeding 2% of the animal's body weight as concentrates each day:

$$\text{Weight of concentrates (kg)} = \text{Live weight} \times 0.02$$



Weblink

Weight by girth calculator



Weblink

Beef ration calculator





Web link

Feed value of selected foodstuffs

- b** Start by only feeding half of this weight, then gradually increase to the full amount. Split the feed into a morning and afternoon ration if possible.

### RESULTS

- 1 Weigh cattle at the same time of day before feeding each week and record your results in a table.
- 2 If more than one animal was used per treatment group, calculate the mean for each group.
- 3 Draw stacked line graphs of weight gain over time for each diet.

### DISCUSSION

- 1 Interpret your results. Which diet resulted in the highest weight gain?

- 2 Was this a valid experiment? How could we improve its validity? Explore the elements of good experimental design in Chapter 5.
- 3 What advice would you give to beef farmers based on the results of this experiment?
- 4 Determine the content of energy and protein in the formulated rations. Visit Agriculture Victoria to learn about the feed value of selected foodstuffs.

### CONCLUSION

Was your hypothesis correct, incorrect or partially correct?

## Reproduction

The bovine reproductive system and reproductive technologies are described in detail in Chapter 10 Dairy cattle. In this section we will be learning about selective breeding and the beef seedstock market.

### Beef seedstock

Seedstock are breeding cattle registered with a breed association. They are used for breeding on cattle studs, also known as seedstock operations. Seedstock bulls have documented pedigrees and their production traits are recorded as estimated breeding values (EBVs) through BREEDPLAN, the Australian beef cattle EBV database.

EBVs are a numerical way of comparing the traits of a particular animal to that of the breed average. Weight gain, fertility and carcase characteristics are some of the production traits recorded as EBVs. BREEDPLAN keeps records for all beef breeds in Australia.

Commercial producers can choose to buy semen from seedstock bulls based on EBVs. Seedstock operators also sell bulls, cows, heifers and embryos.



Worksheets

Understand EBVs with the NelsonNet worksheet.



Web link

Explore BREEDPLAN to find registered cattle from the school or nearby stud.

## AG IN FOCUS

### LOWLINE SEEDSTOCK

#### Identify

Lowlines originated from a 1974 NSW Department of Agriculture experiment on growth rates in Angus cattle. The resultant cattle are now a recognised breed.

#### Understand

While stud and commercial beef producers generally select stock for fast growth rates, researchers were curious about the value of slow growing cattle. They hypothesised that selecting for slower growth would lead to smaller breeding cows that would eat less feed and could be stocked at higher rates.

Angus cattle were divided into three groups to examine the effect of growth rate on carcase traits, productivity and fertility:

- 1 lowlines, with slower growth rates
- 2 highlines, with faster growth rates
- 3 control, randomly selected from the same population.

Herds were set up in Trangie and then Glenn Innes and Hamilton as numbers increased. By the end of the experiment, the lowlines (so named because theirs was the low line on the growth rate chart) were 30% smaller than the highline calves and were less efficient and fertile than the control group. They were highly valued by small beef producers, and when the experiment finished, the herd was sold off, each animal possessing a Trangie, Glenn Innes or Hamilton number. Lowlines are generally docile and easy to handle.



Katie Fenlon

**Figure 11.28** Blackberry the bull: great-grandson of Trangie K121 and Glenn Innes N355

## Discussion

- 1 Name and describe the three treatment groups for the Lowline experiment.
- 2 What advantage did researchers think the slow growing cattle might have over faster growing animals?
- 3 Evaluate lowlines as a breed for school agriculture plots.
- 4 Investigate the breeding of lowlines using the weblink provided.



Weblink

Read a summary of the Trangie research



Weblink

Australian Lowline Cattle Association

## Outbreeding and inbreeding

Inbreeding involves the mating of two closely related individuals. This is sometimes performed to increase the likelihood of a valuable trait being passed on to the offspring. Breeders attempting to improve the genetics of their stock may sometimes breed daughters to sires (fathers) or grandsires (grandfathers) in a system called linebreeding.

Inbreeding can increase the risk of diseases caused by recessive genetic traits. Arthrogryposis Multiplex or curly calf syndrome is a genetic disease of Angus cattle where calves are stillborn with twisted spines. Calves must inherit two copies of the mutated gene to develop the syndrome. Carrier cattle possess one copy of the mutant gene, which they can pass on to their offspring. Inbreeding can increase the chance of a calf inheriting two copies of this gene and therefore being affected.

Outbreeding is any breeding strategy where unrelated animals from different breeds or populations are mated. Crossbreeding is the most common form of outbreeding in beef production. A common rule of crossbreeding is to select cows for country (the environment and conditions) and bulls for the market (desired characteristics of the carcase).

The offspring of crossbreeding are known as hybrids and possess hybrid vigour, performing better than the average of the parents in measures of performance, hardiness and health. For their first pregnancies Hereford heifers are often mated to Angus bulls. The offspring is a calf with distinctive facial markings and a lower birth weight than a pure Hereford. The small size of the crossbred calf causes fewer calving problems, but these Black Baldies, as they are known, have good growth rates and produce high quality carcasses.



Shutterstock.com/Martin Belli

Figure 11.29 Black Baldy calf

## Identification

### NLIS and data collection

The National Livestock Identification System (NLIS) is a system of electronic tagging and tracing of livestock to track stock movements, control disease outbreaks, ensure food safety and provide the market with information needed for quality assurance of carcasses.

When moving, selling or buying livestock, a National Vendor Declaration must be completed. This documents which properties the animal will be travelling between, its NLIS number and relevant information relating to biosecurity and **withholding periods**.

Electronic NLIS tags are placed in the right ear or rumen of animals. A wand or panel reader is used to record the tag number. Databases of NLIS tags can be used to keep track of:

- 1 production data such as weight gain
- 2 reproduction data including pregnancy scanning data, breeding history and BREEDPLAN traits
- 3 health records, such as vaccination and drenching information.



Shutterstock.com/DummyPhotoAcksText

Figure 11.30 NLIS tag examples and placement

## Records and financial management

### Calendar of operations

A calendar of operations is an organisational tool that allows farmers to plan out all the activities occurring on a beef property over the year. When using this tool, farm managers can plan for the purchase of inputs and labour requirements in advance. A calendar of operations for a NSW south coast grass-fed beef operation is shown in Figure 11.31.



Worksheets

Practise interpreting NLIS tags with this practical worksheet.

### withholding period

the minimum period of time from when a chemical was applied to when an area can be accessed, or a plant or animal can be processed and/or consumed

Month	Calendar of operations		
January		Silage making	Drench for liver fluke Monitor for pinkeye
February	Pregnancy testing Sell 18-month-old steers and empty breeder cows	Fertilise pastures	
March	Wean, drench, vaccinate calves		
April			Drench for worms and fluke
May		Graze oats / supplementary feed	
June	Select replacement heifers		
July	Calving		
August			
September	Purchase new bulls, sell cull heifers		Vaccinate bulls and cows
October	Joining		
November		Silage making	Calf marking (castrate, dehorn, NLIS tagging, vaccinate)
December			Vaccinate for pinkeye

**Figure 11.31** Calendar of operations for a beef property

## AG IN FOCUS

### GROSS MARGINS FOR NATIVE AND IMPROVED PASTURES

#### Identify

Gross margins can be used to compare farming enterprises or marketing options. They can also be used to make decisions about how to run a particular enterprise. For example, is it more profitable to run cattle on native pastures or invest in improved pastures?



## Understand

Table 11.6 shows a gross margin budget for a 250-hectare, 100-cow enterprise producing yearling steers and heifers on unimproved native pasture. Table 11.7 shows the gross margin budget for a different 100-cow enterprise run on 173 hectares of improved pasture.

**Table 11.6** Gross margin budget for beef cattle on 250 ha of native pasture

Income			
	No. of head	Income (\$/head)	Budget (No. of head x Income)
Yearling steers	30	832	24960
Yearling heifers	15	533	7995
Cull for age bull	1	810	810
Cull for age cows	12	331	3972
Total income			\$
Variable expenses			
	Cost (\$)		
Vet costs	2061		
Pasture management	0		
Sales costs	4020		
Variable costs			\$
Gross margin (GM) = Total income - Variable costs =			\$
Gross margin per hectare = GM/250 =			\$
Gross margin per cow = GM/100 =			\$

**Table 11.7** Gross margin budget for beef cattle on 172 ha of improved pasture

Income			
	No. of head	Income (\$/head)	Budget (No. of head x Income)
Yearling steers	30	958	
Yearling heifers	15	603	
Cull for age bull	1	1020	
Cull for age cows	12	561	
Total income			\$
Variable expenses			
	Cost (\$)		
Vet costs	2003		
Pasture management	10081		
Sales costs	4080		
Variable costs			\$
Gross margin (GM) = Total income - Variable costs =			\$
Gross margin per hectare = GM/173 =			\$
Gross margin per cow = GM/100 =			\$

## Discussion

- 1 Identify differences between the properties in income and costs. Can you account for these differences?
- 2 Calculate:
  - a the budgeted incomes for yearling steers, yearling heifer and cull cows for the improved pasture property by multiplying the income per head by the number of head of stock for each category.
  - b total incomes for both properties.
  - c variable costs for both properties.
- 3 Now calculate the gross margins by using the formula in the table. Gross margins can be expressed in several ways. You will be calculating three versions of gross margin budgets and using them to compare the properties:
  - a Calculate simple gross margins by subtracting variable costs from total income for each property.
  - b Gross margin per hectare tells us how profitable an enterprise is per hectare. Use the formula in the table to calculate this.
  - c Gross margin per cow allows us to compare profitability per head of livestock. Use the formula in the table to calculate this for both properties.
- 4 Use your calculations to evaluate the profitability of native pasture-based enterprises compared to improved pastured systems.



## LET'S REVIEW

### LOOKING BACK

- 1 Describe the distribution of the northern and southern production areas.
- 2 Explain what EHL is and identify two ways it can be prevented in feedlots.
- 3 Identify three native grasses.
- 4 Give three examples of how flight zone and point of balance can be used to move cattle safely.
- 5 Identify three operations included in the calendar of operations in Figure 11.31 and explain the importance of each one.

### FOR YOU TO DO

- 1 Decide whether the following costs are fixed or variable: seed, interest payments on tractor, fertiliser, land rates, drench, vet fees, transport to abattoir and internet access.
- 2 Use Tables 11.6 and 11.7 to compare native and improved pastures.
  - a Which pasture system would be best suited to a seedstock stud on irrigated land? Why?
  - b Which is more suited to extensive northern beef production? Why?
- 3 Construct a calendar of operations for the school cattle herd or a local beef property.
- 4 Examine cattle distribution maps at Meat and Livestock Australia. Explore the current distribution and examine recent changes.
- 5 Assess the benefits of hormone growth promotant implants in the following situations:
  - a a northern Australian grass-fed cattle station
  - b a feedlot finishing steers for market
  - c a southern grass-fed operation that exports beef to Korea and the European Union.



Weblink

Livestock distribution maps



WebLink

Stock theft report template

### > TAKING IT FURTHER

- 1 Investigate incidents of stock theft in the past 12 months.
  - a Search for news about cattle theft online.
  - b Explain the role of NLIS tags in combating stock theft.
  - c Find out what information needs to be reported to the police if stock has been stolen.
- 2 Make a scale model of cattle yards using icypole sticks, matchsticks or other materials. In your design, include a crush, ramp, holding yard, forcing pen and race.
- 3 Visit the school agriculture plot or a local farm and investigate areas where NLIS tags could be used for data collection. Choose one area or problem and write a report outlining your proposed solution and the benefits of NLIS data collection.

## 11.5 Pests and diseases

### Pests

#### Liver fluke

*Fasciola hepatica*, the liver fluke, causes disease in a range of species including cattle, sheep and humans. Mature flukes lay eggs in the bile duct of an infected animal, which are then passed out onto pasture in the faeces. There the eggs hatch and the flukes spend part of their life cycle in freshwater snails. Tadpole-like larvae are then released and eaten by cattle or sheep during grazing. The flukes then burrow through the wall of the intestine into the abdominal cavity and make their way to the liver. After penetrating the liver capsule, they migrate to the bile duct and lay eggs, completing the cycle.

The fluke lifecycle depends on the presence of freshwater snail hosts and a suitably damp environment. The parasite is a problem in areas where rainfall exceeds 600 mm a year or where irrigation is used on pasture.

Fasciolitis, the disease caused by the fluke, can present as a sudden onset, severe outbreak in stock causing rapid death. It can also be chronic, with affected animals suffering from anaemia, fluid accumulation, and yellowing of the skin and mucous membranes caused by liver failure. Management of fluke involves controlling the environment to reduce fluke numbers and stock ingestion, and the use of **flukicides** to treat infections.

**flukicide** an insecticide used to kill or reduce the numbers of flukes



### LET'S DISCUSS

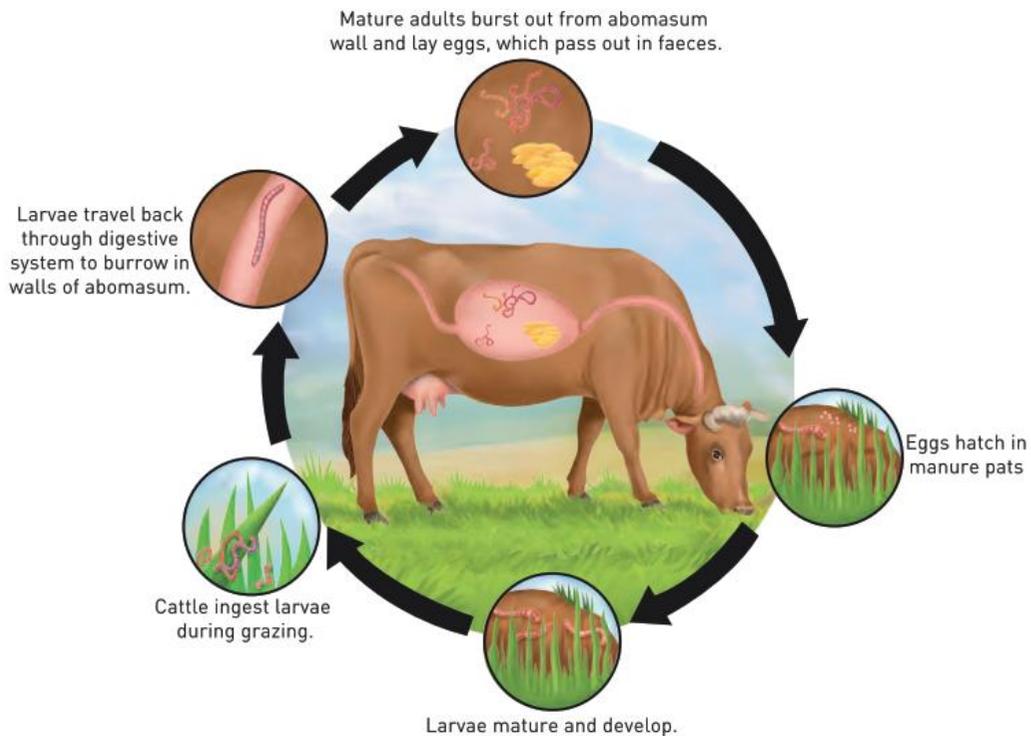
- 1 How could beef farmers control the environment to prevent fluke infestations?

#### Brown stomach worms

Ostertagia, or brown stomach worms, cause disease in young newly weaned stock grazing infected pastures. Cows are also susceptible around the time of calving. Damage to the gut wall is caused by larvae that burrow into the glands of the abomasum, or fourth stomach, then burst

out as adults. Eggs are then laid and passed out in faeces, where they hatch and are eaten by grazing cattle.

Drenches are medications that are given either orally or applied to an animal's skin. They contain chemicals that kill or inhibit particular stages in the lifecycle of roundworms. Drenched cattle should be moved onto clean, uninfected or low-risk pastures.



**Figure 11.32** Lifecycle of brown stomach worms

## Diseases

### Grain poisoning

Grain poisoning is also called grain acidosis, or overload. It occurs when cattle are introduced suddenly to grain diets, as can occur in feedlots, during drought feeding or accidentally. Grain is rapidly fermented in the rumen, releasing lactic acid and reducing the rumen pH. This can cause depression, diarrhoea, dehydration and bloating. Severe grain acidosis can lead to organ failure and death.



### LET'S DISCUSS

- 1 Why would accidental grain overload be a risk of mixed farming enterprises?
- 2 What precautions should these farms take to reduce the risk of grain overload?



Worksheets

Find out about *Black disease in beef cattle* and how to prevent it with this worksheet.

Introduction of grain in diets needs to be done slowly over a period of a few weeks for the rumen microbes to adjust. Feedlot cattle are initially fed a starter diet consisting of more roughage and less grain, before being placed on finisher diets containing a higher proportion of grain. Supplements such as monensin and bicarbonate of soda can also be given to reduce the likelihood of grain poisoning.

### Clostridial diseases

Clostridial diseases are caused by several different Clostridial bacteria, and include blackleg, pulpy kidney, malignant oedema, Black disease, tetanus and botulism. Clostridial spores – infective, reproductive particles – are found in soil and sometimes in the tissues of healthy animals. The spores can multiply and cause disease after accidental injury, castration or other husbandry practices, and even in association with liver fluke infestations. Affected animals are usually young, although pregnant cows are also susceptible.

Prevention of these diseases involves vaccination. Five-in-one vaccines offer protection from five clostridial diseases and should be administered to calves at six weeks of age, followed by a booster six weeks later. Adults should receive yearly boosters.



## LET'S REVIEW

### LOOKING BACK

- 1 Outline the signs of infection with liver fluke.
- 2 Identify the two factors that must be present for liver fluke transmission.
- 3 How do brown stomach worms cause damage to the gut?
- 4 Describe two situations where cattle may have a sudden change to a grain-based diet.
- 5 How are clostridial diseases prevented?

### FOR YOU TO DO

- 1 Draw the life cycle of a liver fluke. Use the brown stomach worm lifecycle as a guide.
- 2 Young stock and calving females are at a high risk of contracting clostridial diseases. Consider the factors that might be related to this increased risk and identify strategies to help control these risks.

### TAKING IT FURTHER

- 1 Create a poster informing cattle farmers about the dangers of grain acidosis, signs of acidosis and prevention methods.
- 2 Design a pamphlet for beef farmers on clostridial diseases and vaccinations. Include the following:
  - a an outline of the five diseases covered by the 5-in-1 vaccine
  - b an explanation of how vaccines work
  - c a vaccine schedule for beef cattle.

## 11.6 Social and ethical issues

### Dehorning

Cattle with horns are more likely to cause damage to carcasses during handling and transportation. They also pose a risk to human handlers. Dehorning of calves is a common practice but can be seen as cruel in terms of animal welfare. Dehorning is a painful procedure that should be carried out in accordance with the Australian Animal Welfare Standards and Guidelines for Cattle in a way that minimises pain and stress as far as possible.

According to the guidelines, dehorning should be performed as young as possible, preferably before the horn buds attach to the skull. It should be carried out by skilled operators using appropriate equipment, ideally on a cool dry day. Pain relief medications should be administered to older calves.

In the long term, breeding for polled or hornless cattle will allow farmers to cease dehorning practices. This can be difficult and time consuming, but advances such as the polled gene marker developed by the CSIRO are helping farmers breed hornless cattle.



Alamy Stock Photo/Wayne Hutchinson

**Figure 11.33** Gas dehorners heat up and destroy horn bud tissue

### AG IN FOCUS

#### LIVE EXPORT OF CATTLE

##### Identify

Live export is a significant market for northern Australian cattle producers. Animal welfare concerns led to a temporary shutdown of exports in 2011 and the introduction of new regulations to ensure humane transport and processing.

##### Understand

The major destinations for Australian live cattle export are Indonesia, Vietnam and China. Live cattle exports provide growing populations in Indonesia and other countries with an affordable source of animal protein. Cattle can be slaughtered using halal methods suitable for Indonesia's 80% Muslim population. The majority of Indonesians do not have electricity, so live slaughter and the daily sale of fresh meat at 'wet markets' eliminates the need for refrigeration.

Ethical concerns regarding live export centre on the conditions during transport and the slaughter methods. Tendon slashing and other inhumane practices in abattoirs have been filmed and reported on in the media, prompting public outcry.

New regulations mean ships must comply with strict guidelines for space, ventilation, drainage and the provision of food and water. Indonesian abattoirs and feedlots must also meet strict standards for animal welfare.

Activists are calling for an end to the live export trade. Northern producers maintain that there is no domestic market for these *Bos Indicus* cattle because Australian consumers prefer European breed carcasses. If they were to be processed and sold in Australia, they would need to be trucked very long distances to market, resulting in high costs and stress for the animals. Farmers also argue that, if Australia stops supplying cattle, other countries with less strict animal welfare rules may start exporting more.

Cattle could be slaughtered in Australia and beef exported chilled and boxed, but there are limited abattoir facilities in northern Australia and high transport and labour costs would make the beef unaffordable to many Indonesians.

### Discussion

- 1 Identify some of the barriers northern producers face in selling their cattle to Australian consumers.
- 2 Why are live export cattle from Australia important to Indonesian society?
- 3 Outline some of the ethical arguments against live export.
- 4 Should Australia continue to export live cattle? Justify your answer.



## LET'S REVIEW

### LOOKING BACK

- 1 Why are beef cattle dehorned?
- 2 Outline some standards that beef farmers must adhere to when dehorning their cattle.
- 3 Identify the main markets for Australian live export of cattle.
- 4 Outline one method that can be used to prevent farmers from having to dehorn their cattle in the long term.

### FOR YOU TO DO

- 1 Review the CSIRO Hornless Cattle Ag in Focus case study in Chapter 5. Assess the impact of this innovation on animal welfare in the beef industry.
- 2 Research the ethical implications of one other animal husbandry activity (for example, castration or branding).
  - a Explain why this procedure is carried out.
  - b Outline the animal welfare issues related to this practice.
  - c Report on animal welfare standards to which producers must adhere.
- 3 Many consumers believe that locally produced beef is more ethical than mass-produced beef sold in supermarkets. Conduct a class debate on the ethics of locally grown versus supermarket beef.

### TAKING IT FURTHER

- 1 What would ethical beef production look like? Consider the ethical issues discussed in this chapter and investigate others of your own choosing. Use what you have learned to design an ethical beef farm. Make a model or draw a diagram of your farm, and write an accompanying report explaining the ethics of beef production on this property.



WebLink

Animal Welfare Standards  
for Cattle

## 11.7 Sustainability

### Sustainable practices and methods

#### Grazing strategies

Several different types of grazing strategies can be employed when maintaining sustainable practices on a beef cattle farm.

##### Set stocking

Set stocking, also known as continuous grazing, involves cattle being left on the one pasture for prolonged periods of time. Stocking rates are usually low compared with what can be achieved with other grazing strategies. This is because the paddock doesn't get a rest and the pasture often needs to feed the cattle year-round. Supplementary feeding of cattle with hay, silage or other feeds is often needed over winter. Overgrazing can lead to loss of ground cover and erosion, while the soil in camp areas can become compacted.

##### Rotational grazing

Cattle are rotated regularly through smaller paddocks. Higher overall stocking rates can be used because, after a short period of intense grazing, pasture is given a long rest period. More fencing and watering points are needed, and cattle must be moved, sometimes as frequently as every 36 hours depending on the size of the paddocks. Cattle are unlikely to overgraze particular plants or areas, and compaction and erosion are also reduced.

Rotational grazing also helps with the control of parasites. Worm eggs hatch and are infective when there are no cattle on that paddock. By the time cattle return, many larvae are dead.

##### Tactical grazing

A combination of rotational and continuous grazing can also be used. Cattle can be rotated off particular paddocks at certain times of the year to allow important pasture species to recover and set seed.

### Sustainable technology

#### Virtual fencing

Rotational grazing is more environmentally sustainable than continuous grazing but requires more fencing. With virtual fencing, cattle are fitted with solar-powered collars. Global positioning system coordinates are uploaded to the collars to set up a boundary. When cattle stray close to a boundary, sound is emitted as a warning then a small electric shock is administered if the cattle proceed further. After two to three shocks, cattle are trained and will retreat on the warning noise.

Fences can be moved by redrawing coordinates on a phone or device. Cattle can be moved from one boundary area to the next without the farmer needing to manually move them. Virtual fencing collars also allow farmers to monitor the location and movement of their cattle.



Worksheets

Compare the sustainability of kangaroo farming and beef production with this worksheet.



## LET'S DISCUSS

- 1 What other advantages would be associated with farmers being able to monitor the location and movement of their cattle?

## Sustainable decision-making

### Using land appropriately

#### AG IN FOCUS

### FEEDLOTING OR FINISHING ON PASTURE?

#### Identify

Which system is more sustainable: feedlotting or feeding pasture? The answer is far from simple.

#### Understand

Grass-fed beef is marketed as being more sustainable, natural and environmentally friendly. This is especially the case with beef raised in rotational grazing systems. Feedlots, in comparison, are sometimes seen as crowded, unnatural and a source of pollution due to effluent, gases, noise and dust.

Feedlot cattle produce 38% less greenhouse gas emissions than grass-fed cattle. This is, in part, due to their carefully prepared diets and higher growth rates. Feedlot cattle reach **target weights** and are processed sooner. As the global population increases, feedlot beef production has the potential to feed more people more efficiently.

Compared with grass-fed cattle, feedlot cattle have been found to be more stressed with lower disease resistance. They are also more prone to digestive upsets such as grain poisoning. Surprisingly, grass-fed cattle have higher mortality (death) rates. This may be due to the constant monitoring and veterinary care of feedlots.

Manure from grass-fed cattle improves soil structure, provides dung beetles, worms and soil microbes with a source of food, and fertilises pasture plants. Effluent from feedlots must be captured and contained. If not processed and held properly, it can lead to water pollution and the spread of disease. Some feedlots collect solid wastes and use them to produce fertiliser, which they then sell.

#### Discussion

- 1 How are grass-fed and feedlot beef systems viewed by the public?
- 2 Grass-fed systems require more land than feedlot systems to produce the same amount of beef. Is this a fair comparison? In your answer consider the following:
  - a the classes of land that can be used to produce grass-fed beef.
  - b land use to produce grain for feedlots.
- 3 Consider the short-term and long-term arguments for grass-fed and feedlotted cattle. Consider economic, social, animal welfare, environmental and other reasons.
- 4 Evaluate feedlots as a sustainable alternative to grass-fed beef production.

**target weight** the live weight an animal needs to reach to be sold to a particular market



## LET'S REVIEW

### LOOKING BACK

- 1 Define the terms: set stocking, rotational grazing and tactical grazing.
- 2 Outline how virtual fences work.
- 3 Explain the difference between grass-fed and feedlotted cattle.

### FOR YOU TO DO

- 1 Evaluate rotational grazing as a sustainable alternative to set stocking.
- 2 Discuss the advantages of virtual fencing.
- 3 Investigate electric fences and their role in rotational grazing.

### TAKING IT FURTHER

- 1 Identify the school farm or a nearby property on Google Earth. Print an A3 colour image and trace around the boundary fence. Attach an A3 transparency sheet to the image and complete the following activities:
  - a Class the land from 1 to 8 using the weblink provided.
  - b Design a key and use permanent coloured markers to divide the property up according to classes.
  - c Redesign the farm based on land classes. Any Class 1 land should be used for cropping, while Classes 7–8 should be fenced off for no or minimal grazing.
  - d Decide on agricultural enterprises that would suit each land class and the local conditions and plan them on your map.



Weblink

Land capability

## 11.8 Marketing

### The market

Beef production accounted for 20.6% of Australia's entire farm value in 2018–19. Grass-fed beef continues to dominate production, accounting for 68% of the market.

Australian consumers eat, on average, 26 kg per person annually. Australian beef consumption has fallen over the past decades as chicken and pork have become more popular.

Of the 2.24 million tonnes of beef and veal produced on Australian farms, half was exported to a total of 78 countries, at a value of \$8 billion. Japan, the USA, South Korea, China and Indonesia are the most significant purchasers of Australian beef. New Zealand exports 80% of its beef. China and the USA are New Zealand's main trading partners.

Each export market has different requirements for beef. Japanese consumers have traditionally sought highly marbled beef from Wagyu cattle. Recently, there has been an increase in demand for *akami* or lean beef among younger Japanese consumers. Manufacturing beef from northern Australian producers is sold to the USA, while the Indonesian market mainly consists of live cattle that are then slaughtered for the halal market.

### Beef marketing chain

The marketing chain depends on which market the cattle are being sold in. At the abattoir cattle are stunned, slaughtered and then suspended from their hindlegs to bleed. The skin, head and internal organs are then removed before the carcass is sectioned.

### Specifications

Market specifications are the key characteristics of the product that determine its value to consumers and the price paid to producers. Specifications can relate to quantity (how much) or quality (how good).

A number of markets are available for selling beef, and each has its own requirements. For example, marbling is highly valued in Japan. Cattle that are destined for the Japanese export market are generally slaughtered at an older age and higher weight to ensure the meat has adequate fat. Breeds that naturally have more marbling in their beef, such as Wagyu, are preferred. In contrast, Australian consumers prefer lean meat so cattle are processed at an earlier age.

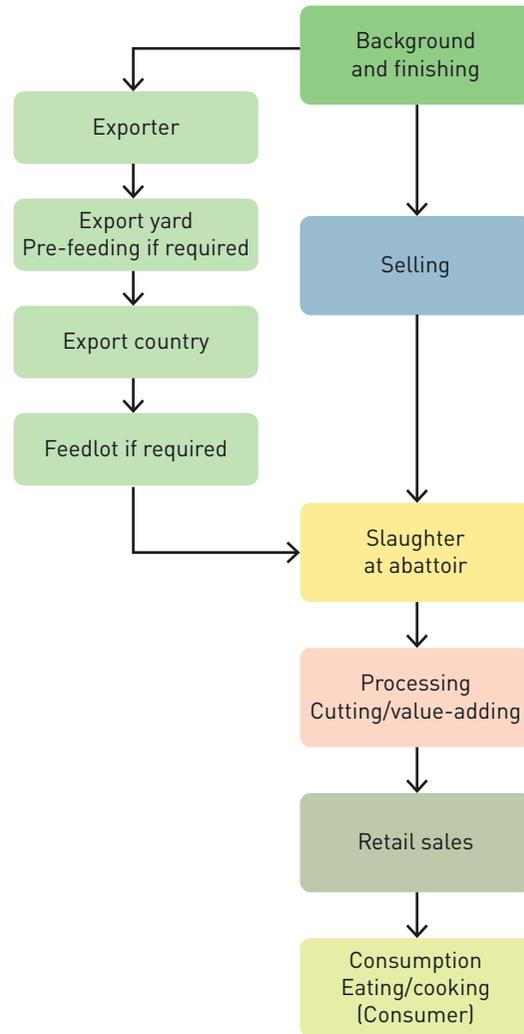


Figure 11.34 Marketing chain for beef

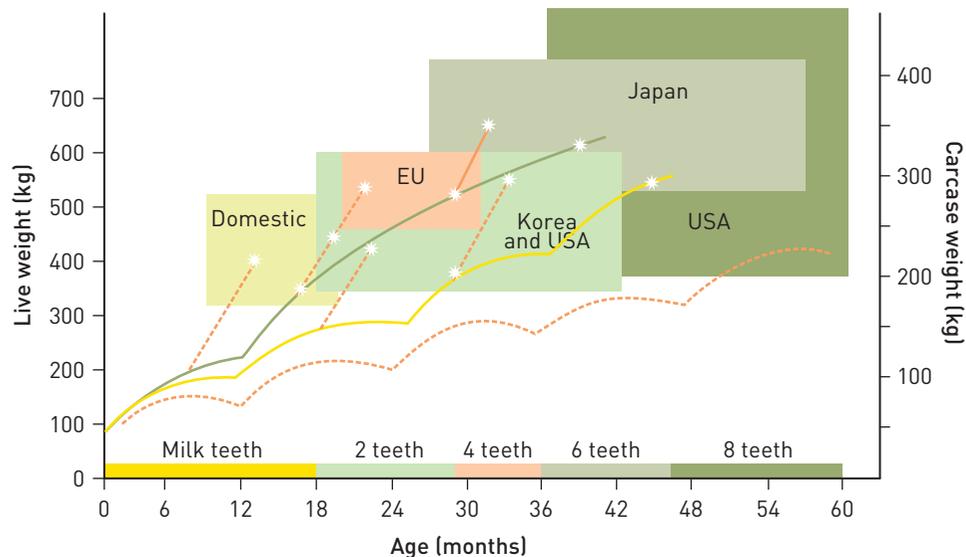


Figure 11.35 Weight and age requirements for domestic and export beef markets



## LET'S DISCUSS

- 1 How does choosing a market affect management practices on beef farms? Consider all the factors displayed in Figure 11.35 in your discussion.

There are many market specifications for beef, some of which are shown in Table 11.8.

**Table 11.8** Market specifications for beef cattle

Market specification	Definition and how it is measured
Live weight (kg)	Weight of live animal. Can be used to estimate carcass weight
Hot carcass weight (kg)	The weight of a carcass within two hours of slaughter
Age (dentition)	Number of adult teeth gives an estimate of animal's age
P8 fat depth	Depth of fat at P8 site on the rump. Used to estimate fat cover of whole carcass.
Meat or carcass pH	Stress and incorrect chilling can lead to high pH and dark cutting, tough meat
Marbling	A measure of intramuscular fat. Marbling makes meat tasty and juicy.
Tropical breed content	Height of hump relates to Bos Indicus genes. The higher the hump, the poorer the quality of meat, on average.

### DID YOU KNOW?

Hoof and Hook or Steer Competitions are a great way to get involved with the beef industry and learn how to manage cattle to meet market specifications.



### LET'S ENGAGE

## LIVE ASSESSMENT OF BEEF CATTLE

### PURPOSE

Most of the market specifications in Table 11.8 are measured during carcass grading in the abattoir. There are several methods to estimate carcass traits while the animal is alive, including condition scoring, fat and muscle scoring, and estimating carcass weights using dressing percentages.

### RISK ASSESSMENT

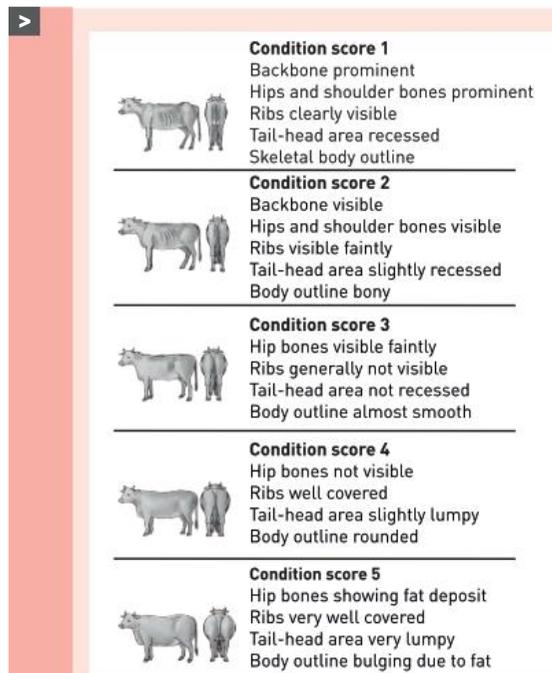


Refer to the risk assessment you created for cattle handling in the previous Let's Engage activity. Complete these activities under the supervision of your teacher.

### MATERIALS

- Beef cattle (if cattle are not available, use photos or videos of cattle and proceed to the discussion after completing the first step in the method).
- Condition scoring illustration
- Live weight scales (if available) or long measuring tape





**Figure 11.36** Condition scoring of beef cattle

#### METHOD

- 1 With cattle in the paddock or holding yard, observe an animal from a distance and compare it to the condition scoring system. Consult with other students to determine its condition score.
- 2 Weigh cattle on scales or use the method for estimation outlined in this chapter's experiment.
- 3 Estimate the dressing percentage of the cattle. This is the percentage of live weight that is due to the carcass. Most

beef cattle have dressing percentages between 58–62%. Some breeds are at the higher end of this range (for example, Angus and Limousin), and some are lower (for example, Herefords and Simmentals). Heifers have lower dressing percentages than steers. Estimate the dressing percentage for your cattle and complete the following calculation:

$$\begin{aligned} &\text{Estimated carcass weight (kg)} \\ &= \text{Live weight (kg)} \times \text{Dressing percentage} \end{aligned}$$

#### DISCUSSION

- 1 How consistent were the results of the condition scoring? Did students get similar results?
- 2 Assess the importance of practice and skill in assessing condition scores and estimating carcass weights.
- 3 What other factors might influence an animal's condition score and weight?
- 4 Cattle need to be well muscled but reasonably lean (not too fat) for the domestic market. What would be an optimum condition score for beef cattle ready for market? Consider fat coverage and muscling.
- 5 From your findings, what recommendations would you make about managing these cattle? Consider nutrition, husbandry procedures, breeding and genetics.

## Marketing strategies

Beef cattle can be sold in several ways, some of which are shown in Table 11.9. The marketing strategy chosen will depend on location and the chosen market. Some beef enterprises are vertically integrated. For example, feedlot producers may also own a feed mill and abattoir.

**Table 11.9** Marketing strategies for beef cattle

Marketing strategies	Role in beef marketing
Saleyards	Cattle are transported to saleyards with lots of other cattle and are sold to the highest bidder.
Over the hook	Sold directly to the abattoir with a price paid based on carcass weight.
Online	Cattle are sold via auction or set price. Buyer is then responsible for arranging transportation.
Forward contracts	Producer agrees to supply a certain number of cattle at a particular time and price. The producer must ensure any agreed market specifications are met.
Paddock sales	Buyer inspects cattle on seller's property and arranges transportation to their own property or processing facility.



Shutterstock.com/Lakeview Images

**Figure 11.37** Cattle saleyard

## Halal and kosher meat

Halal beef production is an emerging market in Australia and an important export market. The word *halal* is Arabic for ‘permitted’ and halal beef is slaughtered and processed in a way that complies with the Islamic faith. Meat must be certified by the Australian Federation of Islamic Councils to be sold as halal.

Kosher beef is slaughtered and processed according to Jewish laws under the supervision of licenced rabbis (religious figures similar to priests). Only the forequarters of beef carcasses are considered kosher. Meat and dairy products cannot be cooked or eaten together.



### LET'S DISCUSS

- 1 Are halal or kosher foods available in your local area?

## INDUSTRY IN FOCUS

### SALEYARD MANAGER

#### Identify

Saleyard managers run livestock saleyards. They coordinate the arrival and unloading of cattle and sheep, ensuring that NLIS paperwork is complete and correct. They oversee the care of livestock until sale, and coordinate the activities of agents, buyers and sellers on auction day.

Depending on the size of the saleyard, sales may happen once a month or multiple times each week. Saleyard managers must sight national vendor declarations for every animal and ensure all transfers of ownership are legal. Saleyard managers sometimes receive help from the police who often attend sales to detect and catch cattle and sheep thieves. National vendor declarations must also be inspected to make sure livestock have not been treated with medicines or chemicals that have a withholding period.

Saleyard managers are responsible for the biosecurity of the yards and animals. Saleyards are the perfect place for an outbreak and quick transmission of potentially disastrous diseases such as foot-and-mouth disease. Managers must have a good understanding of animal disease and prevention because as stressed animals in saleyards have the potential to transmit infections. They must also make sure the saleyard complies with environmental regulations, especially relating to effluent and water use.

### Discussion

- 1 Outline some of the roles of a saleyard manager.
- 2 What skills would a saleyard manager need to fulfil these roles?
- 3 Identify some of the potential problems that may arise in a saleyard.
- 4 Online sales are an alternative to saleyards. Evaluate the effectiveness of saleyards and online sales as methods for selling beef cattle.

### Value-adding

Carcass cuts can be value-added by processing and packaging. Value-added beef products include stir fry strips, marinated meat, beef jerky and pre-prepared frozen meals. By-products are made from internal organs, hides, bones, fat and other tissues. Gelatin, found in jelly and marshmallows, is made from bones and skin. Fats and oils are used to produce margarine, soaps and lipsticks, while intestines are used for natural casing of sausages.

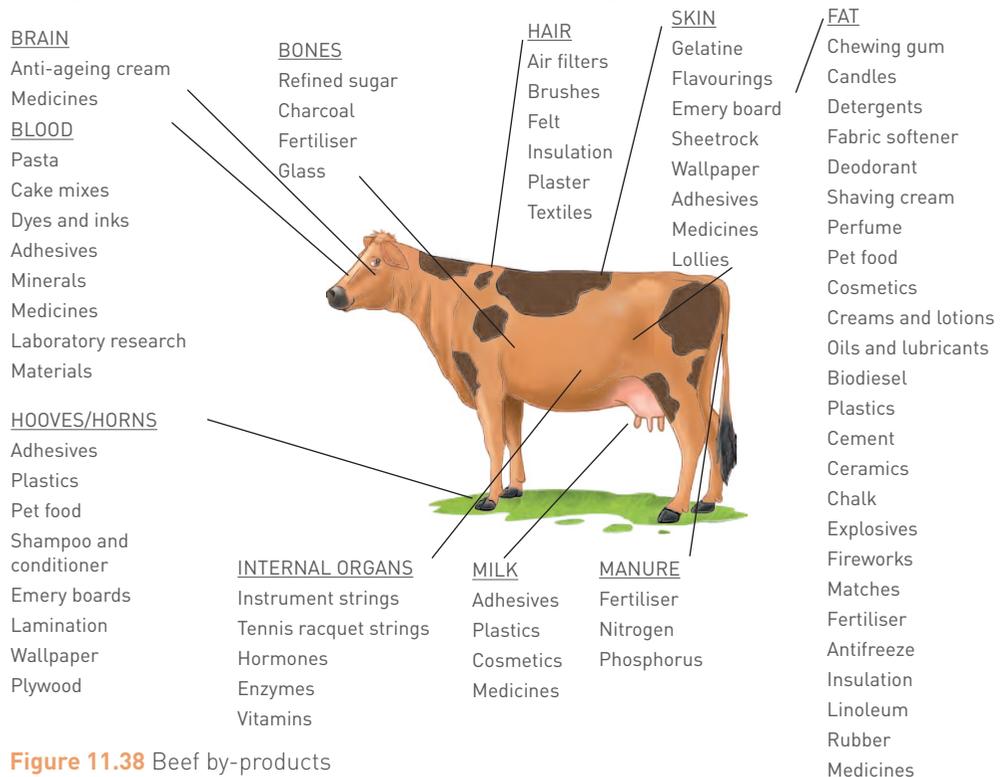


Figure 11.38 Beef by-products



## LET'S REVIEW

### LOOKING BACK

- 1 Identify Australia and New Zealand's main export markets for beef.
- 2 Describe changes in demand for beef in Japan.
- 3 Identify three market specifications and explain why they are important.
- 4 Explain how beef farms can be vertically integrated.

### FOR YOU TO DO

- 1 From Figure 11.35, determine the maximum live weight, age and number of adult teeth for each of the following markets:
  - a domestic
  - b the USA
  - c Japan.
- 2 Explore data on Australia's and New Zealand's beef industries at the Australian Bureau of Statistics and Beef + Lamb NZ.
- 3 Investigate one export market and write a report outlining the type of beef purchased and the volume of sales. Use the MLA Market Snapshots link on NelsonNet.
- 4 Investigate a current promotional campaign for beef.
  - a Identify the target audience for this campaign.
  - b Describe the campaign. What is the message and how is it being delivered?
  - c Assess the effectiveness of this campaign. Do you think it is an effective way of increasing consumer awareness of and demand for beef?

### TAKING IT FURTHER

- 1 Create a marketing chain for one value-added product such as leather or beef jerky.
- 2 Research the Wagyu breed and create a presentation on its origin, characteristics and uses in beef production.
- 3 Conduct a survey of local butchers to determine:
  - a their marketing and supply chain
  - b their attitudes about the importance of market specifications
  - c whether they produce value-added products.



Weblink

ABS



Weblink

Beef NZ



Weblink

MLA Market Snapshots

# Let's summarise



Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about beef cattle production.

## How has beef production adapted to the harsh Australian environment?

Cattle production occurs in a number of climatic zones and on a variety of soil and pasture types. Production looks very different in the north of Australia compared to the south. Feeding systems vary from large, open rangelands of native pasture and woodland to intensive feedlots with grain feeding of cattle. Breed choice and crossbreeding have resulted in animals that are adapted to the diseases and climate of a particular region. Technology is used to monitor and manage cattle in remote locations as well as in intensive feedlots.

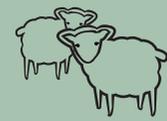
Copy and complete the following table by adding examples of how Australian beef production has adapted to Australian conditions.

	Feeding and nutrition	Breeding and genetics	Technology
Northern production			
Southern production			
Feedlots			

## How can farmers manage the production cycle to produce high-quality beef?

Each step in the production cycle is under the control of the farm manager. Draw a copy of the beef cattle production cycle and add arrows and notes to it to demonstrate where and how the following factors can be used to make beef farming productive and profitable.

Timing of operations (joining, castrating, etc.)	Breed selection	EBVs	Finishing diets	Pasture management
Disease management	Environmental control (e.g. effluent, humidity, temperature)	Husbandry practices	Knowledge of market specifications	Understanding cattle behaviour



# Sheep

## CHAPTER SUMMARY

Australia is known worldwide for the quality of its wool. Sheep production is based around prime lamb production, wool production, speciality carpet wool production and sheep milk production. In this chapter you will learn about the physiology of sheep and what nutrition is needed at different stages of their lifecycle. You will also investigate the power of consumer demands and see how sheep farmers react and adapt to animal welfare issues, such as mulesing.

**What makes Australian sheep production unique and successful?**

**How does Australian sheep production address consumer concerns?**

## 12.1 Introduction

Currently Australia has 72 million sheep, with a total gross value of Australian sheep meat to the economy of \$4.7 billion in 2018–19. The sheep industry is comprised of approximately 31 100 farms accounting for 8% of the world's sheep meat production. The Australian sheep industry is dominated by wool production, with sheep feedlots and prime lamb production growing in importance. Sheep milk production is small-scale but plays a relevant role in niche markets.

Sheep farming is another animal enterprise that, like dairy and beef farming, contributes heavily to Australia's greenhouse gas emissions. Sheep farmers are therefore becoming more sustainable in their practices, monitoring and reducing use of chemicals, reducing stock numbers, planting and protecting trees, encouraging biodiversity and ensuring the resources and the land will sustain future generations.



Worksheets

Create a sheep production glossary to help you remember all the terms as you study this chapter.

## 12.2 Functions and anatomy

### Functions

#### Wool production

Wool is a natural fibre grown by sheep, the same way as human hair. Wool contains wavy clusters, or **staples**, of fibres. Sheep are **shorn** annually to harvest and process the wool. Wool is a versatile product, able to be made into items such as woollen blankets, fire fighter uniforms, insulation, suits, thermal underwear, carpets and much more.

Australia produces 25% of the world's **greasy wool** and is one of the leading general wool producers. Wool is produced in all states except the Northern Territory. The wool is shorn once or sometimes twice a year and then sold to be processed.

Wool is categorised as superfine, ultrafine, superfine, fine, medium and broad according to its **micron** measurement. The fibre diameter is the characteristic that determines the quality and value of wool. The smaller the number, the finer the wool.

**DID YOU KNOW?**

Wool fibre is measured in micrometres: 1 micron = 1 millionth of a metre.

**Table 12.1** Merino wool micron grades

Microns	Grading
14.5 and less	Extrafine
14.6–15.5	Ultrafine
15.6–18.5	Superfine
18.5–22.5	Medium
Greater than 22.5	Broad

Extrafine and ultrafine is the finest wool in the world and is used to make fabric of very high value, targeting the high-end fashion market. This wool is also blended with silk and **cashmere** to produce a high-quality fabric.

**staple** a cluster of wool fibres

**shearing/shorn** the process of removing the wool from the sheep

**greasy wool** wool shorn straight from the sheep

**micron** the measurement used to describe the fibre diameter of wool

**cashmere** the quality wool fibre produced by goats

## Carpet wool

Carpet wool can be classified as pure wool or wool blend (mixed with other natural or synthetic fibres). Wool for carpet production includes:

- specialty carpet wool (only four breeds in Australia can produce this wool)
- basic and filler wools: course fibres from crossbred sheep such as Romney sheep.

Australia imports 90% of its carpet wool, mainly from NZ.

## Meat production

Australia is the second-largest sheep producer in the world and the world's largest exporter of sheep meat, both lamb and **mutton**. Prime lamb producers use either pure breeds or **crossbred** sheep in their breeding programs. With the increased demand for lamb and unpredictable wool prices in recent decades, there has been a trend towards dual purpose merino sheep, grown for both wool and meat production.

## Sheep milk

Sheep milk in Australia and New Zealand is a niche market with only a very small number of farms milking sheep, predominantly to produce cheese. Sheep milk contains more protein and fat than traditional cow's milk. Antara Ag, New Zealand, milk 20 000 sheep with the cheese produced sold locally and milk powder exported to China.

## Breeds of sheep

There are more than 20 different breeds of sheep in Australia. While merinos are the most common breed, predominately used for wool production, there are numerous other breeds used for meat, carpet wool and milk. Some of these breeds are **dual-purpose**. A sheep may also be **purebred** or crossbred. Crossbreeding is conducted to improve the quality of the lambs, gaining the best characteristics from the two breeds used.

Crossbreeds are important in prime lamb production (you can find out more about prime lamb production in Chapter 12.3 Production).

**Table 12.2** Breeds of sheep in Australia

Merino	Romney
 <p><b>Figure 12.1</b> Merino sheep</p> <p>Purpose: Wool production Traits: Most common breed, wool fibre of less than 24 microns</p>	 <p><b>Figure 12.2</b> Romney sheep</p> <p>Purpose: Carpet wool, breeding to produce other carpet wool breeds and prime lambs Traits: Wool fibre of 30–40 microns</p>

**mutton** meat from sheep that are over 12 months old and have incisors in wear (it takes about a month for them to show wear)

**crossbred** the product of crossing two different breeds

**dual-purpose** sheep used for two different purposes, such as meat and wool production

**purebred** an animal with parents of the same breed

**terminal sire** used over different breeds of crossbred ewes with the aim to improve carcass traits

**poll** an animal born naturally with no horns

**> Poll Dorset**



Alamy Stock Photo/Nigel Cattlin

**Figure 12.3** Poll Dorset sheep

Purpose: Dual-purpose, short wool, meat-producing sheep. Used as a **terminal sire** for prime lamb production.  
 Traits: Bred in Australia to eliminate horns from the Dorset Horn.

**Texel**



Alamy Stock Photo/GFC Collection

**Figure 12.4** Texel sheep

Purpose: Meat  
 Traits: Heavily muscled (produces a lean carcass), lambs finish early (ready for market before other breeds)

**Suffolk** **Dorper**



Shutterstock.com/Plotitsyna NiNa

**Figure 12.5** Suffolk sheep

Purpose: Dual-purpose: meat and short wool. Rams used as terminal sire for crossbreeding.  
 Traits: Rams have high sex drives and ewes have high fertility.



Shutterstock.com/Andre Klopfer

**Figure 12.6** Dorper sheep

Purpose: Meat  
 Origin: South Africa  
 Traits: Suited to dry regions. No shearing required, produces lean carcasses.

**Border Leicester** **Friesian/East Friesland**



Video

Find out about Australia's newest breed of sheep, the 'Lamb Master', with this video.



Alamy Stock Photo/Nigel Cattlin

**Figure 12.7** Border Leicester sheep

Purpose: Dual-purpose, wool and meat. Rams used for cross-breeding with merinos.  
 Origin: British



Shutterstock.com/Bildagentur Zoonar GmbH

**Figure 12.8** Friesian sheep

Purpose: Multi-purpose, meat, carpet wool and milk  
 Traits: Ewes produce 500–600 litres of milk per lactation cycle (210–230 days)

## Anatomy

Many terms can be used to refer to sheep of different ages and at different stages of the production cycle (Table 12.3).

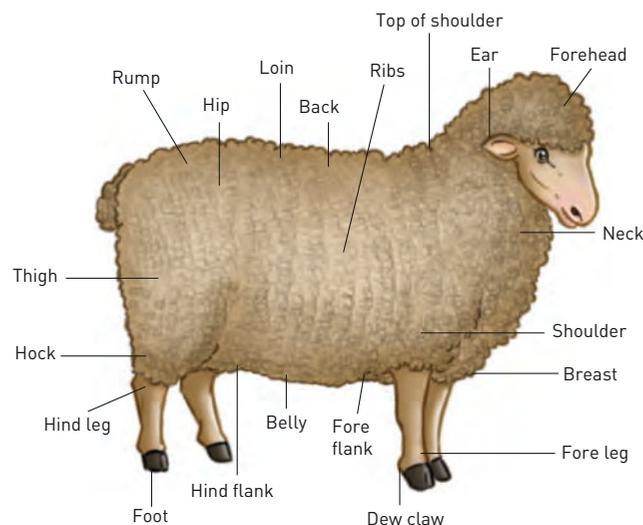
**Table 12.3** Sheep terminology

Term	Definition
Lamb	A young sheep under 12 months of age or that does not have any permanent incisor teeth in wear
Ewe	A mature female sheep
Maiden ewe	A female that hasn't yet lambed
Ram	A mature male sheep with intact testes
Weaner	A lamb that has recently been weaned (removed from its mother)
Wether	A castrated male sheep
Hogget	A sheep of either sex with no more than two permanent (adult) teeth
Terminal sire	A ram that is joined to crossbred ewes to produce prime lambs for meat production

### Parts of a sheep

Farmers need to be aware of the anatomy of sheep, to visually assess them when purchasing, judging, or when choosing the best animals for breeding. Farmers also need to be able to correctly age sheep because the age of a sheep influences market prices. Sheep are aged by examination of their teeth. Their milk teeth are gradually replaced by adult teeth or permanent incisors. Sheep have lower incisors but no upper incisors and instead have a hard, smooth dental pad. Figure 12.10 can be used to assist when aging the sheep. A simple guide to age is to divide the number of adult teeth by two. For example, a sheep with two teeth is one year old.

However, remember that different breeds of sheep can vary and therefore aging is approximate only.



**Figure 12.9** Parts of a ewe



### LET'S DISCUSS

- 1 In general, lamb is a more expensive meat than mutton. Why do you think consumers prefer lamb over mutton?
- 2 How might inaccurate ageing of sheep affect sheep farmers?



Worksheets

Assess your school's sheep flock with the practical NelsonNet worksheet.



Worksheets

Review your knowledge about sheep anatomy.

Lamb's teeth (0–12 months)	8 milk teeth	
12 months or 2 teeth	2 adult teeth, 6 milk teeth	
24 months or 4 teeth	4 adult teeth, 4 milk teeth	
36 months or 6 teeth	6 adult teeth, 2 milk teeth	
40 months or 8 teeth	Full mouth – 8 adult teeth	

**Figure 12.10** How to age a sheep by its teeth



## LET'S REVIEW

### LOOKING BACK

- 1 Describe four different breeds of sheep.
- 2 What is the current sheep population in Australia?
- 3 Identify four main products of sheep production.
- 4 Outline one key feature that is important when assessing sheep.

### FOR YOU TO DO

- 1 Research two breeds that have been developed in Australia, such as the Australian White sheep or Cormo.
  - a Why were these breeds developed?
  - b What are their main features?
  - c What other countries would you recommend these breeds for, considering the facts you've learned in parts a and b?
- 2 Investigate the new breeds of sheep that have been brought into Australia and create a website detailing your findings. You can use free software such as Wordpress, Wix or Weebly to create your website.
- 3 Discuss the main desirable features in:
  - a a high-quality wool-producing sheep
  - b a prime lamb-producing sheep
  - c a carpet wool-producing sheep
  - d a milking sheep.

### TAKING IT FURTHER

- 1 Compare sheep milk production in Australia and New Zealand with cow milk production. Create a report highlighting the differences you found.
- 2 Research the Carpetmaster and Elliotdale and the role these breeds play in the carpet wool industry in Australia and New Zealand.



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Australian White sheep



Weblink

Cormo sheep

# 12.3 Production

## Production cycle

Wool and meat have different production cycles. For wool, ewes and rams are bred and the resulting lambs are either kept for wool or sold.

Shearing occurs at least once per year, but the timing of shearing is dependent on individual enterprise factors. Shearing should not occur within two weeks of joining or in late pregnancy. Other husbandry practices carried out during the production cycle are discussed in the 12.4 Management section.

Prime lamb production involves careful crossbreeding systems. Border Leicester and Suffolk rams are used to produce two generations of meat sheep, with the second generation being referred to as prime lambs.

In Figure 12.13, Suffolk rams are referred to as terminal sires because they represent the final step in the breeding system, with both ewe and ram lambs being used for meat production.

Merino and first-cross ewes are also shorn, providing an additional source of income to prime lamb enterprises.

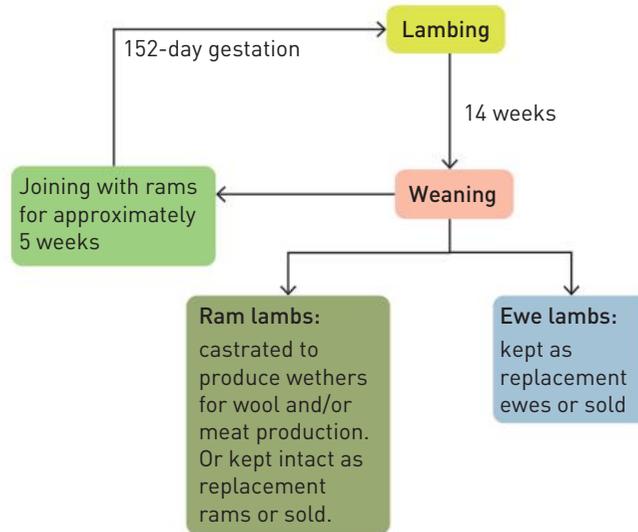


Figure 12.11 Simple production cycle of a merino ewe

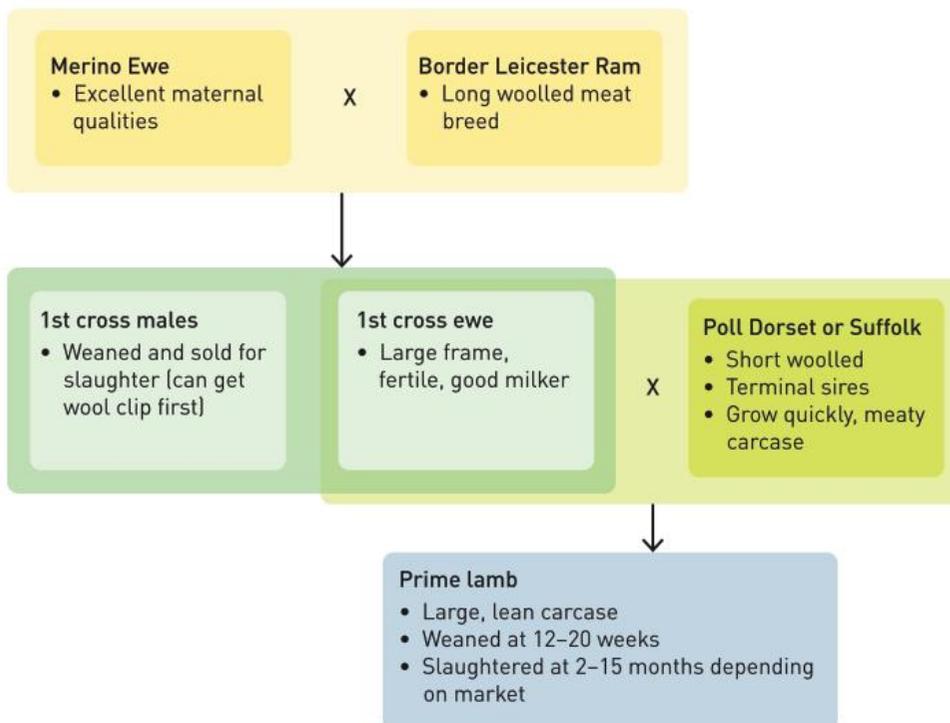


Figure 12.12 Example of a prime lamb production cycle

## Systems

There are different farming systems associated with wool, lamb, carpet and milk production.

### Commercial sheep production systems

Sheep systems can be focused on wool or lamb production, a combination of the two, or in conjunction with other farming enterprises such as wheat. Commercial enterprise, wool production and prime lamb production are examples of extensive farming.

### Wool systems

In commercial wool systems, the main product is wool. Wool growing tends to occur in the sheep-wheat belt of the eastern states. The merino sheep is the main breed used to produce the wool. Wool production tends to be extensively run, with sheep grazing on native and improved pastures.

### Prime lamb systems

In prime lamb production systems, the focus is on producing quality sheep meat using purebred sheep or crossbreeding with terminal sires to meet market specifications. Prime lamb production can be combined with other enterprises such as wool production, wheat production or beef cattle. Prime lamb production is a mix of extensive production, such as breeding sheep being grazed on a mix of improved pastures or native pastures, and lamb feedlots, which are intensive operations with the lambs being fed on high-grain rations in small paddock enclosures.

#### Lamb feedlots

The lambs are fed in intensive systems to maximise their growth and finish them quicker than in pasture. When weaned, lambs are placed into a feedlot where they are fed a strict ration. Feedlotting lambs is a management strategy to ensure farmers can achieve a consistent supply of quality lambs that have the ideal fat score and weight. Feedlotting gives farmers the flexibility and confidence to ensure lambs are ready to be sold despite the pasture quality and the climatic conditions.



Alamy Stock Photo/Richard Ellis

**Figure 12.13** In commercial lamb feedlots, lambs are fattened quickly in high stocking densities.

### Stud sheep systems

Stud systems aim to breed superior sheep that can be purchased by commercial producers to improve the quality of their breeding stock. The stud system prepares rams that can be purchased at regional stud sales, privately, or through on-property ram sales.

### Sheep dairies

Sheep milk is an emerging industry, with 13 commercial farms milking 5500 sheep in Australia. The main breeds used are the Awassi, Friesian and breeds crossed with prime lamb or carpet wool producers. The milk is mainly used to produce yoghurt and cheese. New Zealand has

only a small number of sheep dairies, but also has the largest sheep dairy in the world, milking approximately 10 000 East Friesian and Poll Dorset cross ewes. Sheep dairies are examples of intensive farming enterprises, with high **stocking densities** in small areas.

**stocking density** in a given area; for example, per m<sup>2</sup>, per hectare, per km<sup>2</sup>

## AG IN FOCUS

### ANTARA AG SHEEP DAIRY

#### Identify

Antara Ag is a sheep dairy located in Southland, New Zealand, which currently milks 10 000 sheep over three properties. Antara milks Poll Dorset/Friesian crosses that produce better quality milk than purebred Friesians.

#### Understand

Despite having a small sheep dairy industry, New Zealand is home to the largest sheep dairy in the world: Antara Ag Farms. The dairies currently have 14 000 ewes and are milking 10 000 of these.

Compared with cow milk production, sheep milk production has had less development and research, meaning it is difficult to find and develop breeding programs that can improve milk production or quality. As with cow dairies, highly nutritious pastures are required to produce high-quality milk, and therefore, sheep milk producers find themselves competing for both land and customers with cattle farmers. The owner of Antara Ag is looking at using similar production techniques to dairy farmers, such as pasture management, to ensure high production levels. However, with the similar benefits from following dairy production models also come the problems: male lambs are an unwanted waste product of production and sold to any market that is found.

#### Discussion

- 1 What problems do sheep dairies face?
- 2 What breed(s) do Antara Ag use, and why?
- 3 Discuss the similarities and differences between sheep and cow dairies.
- 4 Discuss how genetics will affect future sheep dairy production.



Weblink

Antara Ag Farms



## LET'S REVIEW

### LOOKING BACK

- 1 What is the difference between intensive and extensive farming? Use examples of sheep production systems to show your understanding.
- 2 Outline the differences between the types of sheep production systems.
- 3 What is feedlotting?
- 4 Outline the benefits of a feedlot system.

### FOR YOU TO DO

- 1 Draw a production cycle for:
  - a a wool-producing merino
  - b a prime lamb.
- 2 Research how carpet wool production occurs.
- 3 Discuss the effect on farmers from producing both meat and wool on their farm. Consider the following factors in your answer: finances, ethics and management.



### > TAKING IT FURTHER

- 1 Research the sheep–wheat belt. Create a poster that shows:
  - a where the sheep–wheat belt is located
  - b what the sheep–wheat belt is
  - c reasons why sheep production is concentrated in this area.
- 2 Would you recommend a feedlot system for wool production? Discuss why or why not.

## 12.4 Management

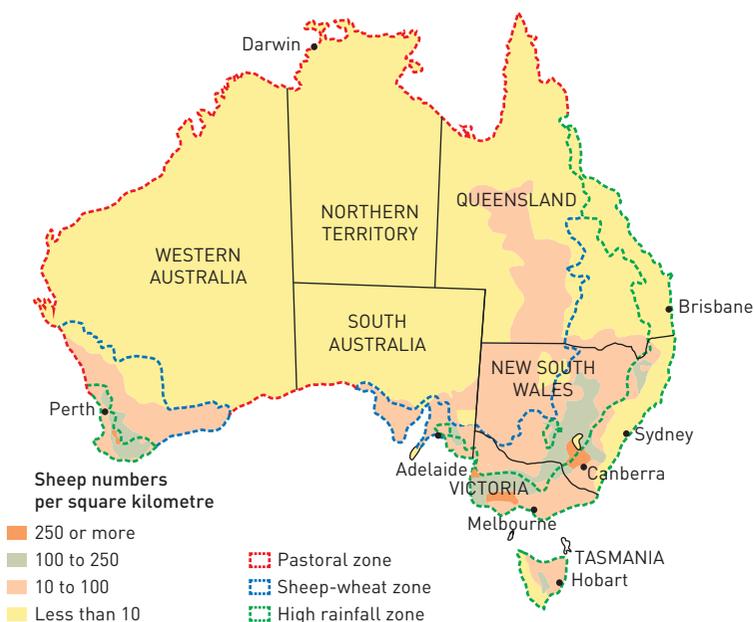
### Environmental management

#### Distribution of enterprises

#### DID YOU KNOW?

Australia has a ratio of three sheep per person while New Zealand has a ratio of six sheep per person. In the 1980s, the ratio was 20 sheep per person.

Australian broadacre zones and regions, <http://apps.daff.gov.au/agsurf/regions.html>, Department of Agriculture and Water Resources. CC-BY-3.0-AU licence.



**Figure 12.14** The location of sheep in Australia

There are 72 million sheep in Australia across all sheep production systems. Sheep are largely farmed in the sheep–wheat belt, which mainly lies across the eastern states of NSW and Victoria, and in southern WA.

More intensive production occurs within the sheep–wheat belt, where higher rainfall allows higher stocking densities. In the pastoral zone, there are more extensive grazing sheep enterprises, where sheep can graze across large areas of less productive land.

#### Climate

Wool production occurs in both the high and low rainfall zones. Prime lamb production is restricted to areas of good rainfall or irrigation and improved pasture. Merino wool production extends into the pastoral zone, because merinos are not suited to the coast due to the humidity.



### LET'S DISCUSS

- 1 Queensland is 27 times the size of Tasmania and yet both states have the same number of sheep. Why do you think this is?

# Enterprise management

## Breeding

### Choosing stock

Australian Sheep Breeding Values (ASBV) are a collection of production data that is recorded and used in the selection process for breeding stock. The ASBVs estimate the breeding value of an animal based on pedigree and performance and are a projection of how the offspring will perform. The type of data collected includes birth weight, weaning weight, post-weaning weight, fat depth, eye muscle depth, wool weight, fibre diameter and worm egg counts. Farmers can use this information to decide on the type of rams or ewes to purchase to improve their flocks. For example, for prime lamb production a farmer may be interested in improved weaning weights to be able to produce offspring that grow faster and on average heavier, reaching target weights in a shorter time. This can be a financial gain because the farmer will earn more money per lamb. In wool production, selecting a ram that has a high greasy wool figure can produce lambs that will cut more wool, leading to an increase in the total amount of wool produced, resulting in possible higher financial return.

### The breeding cycle

Sheep are pregnant for five months, or approximately 150 days. A ewe will come onto **oestrous** every 17 days (although this can vary depending on individual animals and breeds.) A ewe will be on heat for 12–36 hours, and during this time she will stand for the ram to join her.

Some sheep are seasonal breeders, which means they are affected by a change in day length. British long wool and meat breed sheep (for example, the Border Leicester) are seasonal breeders, coming into heat when the daylength decreases. Other breeds (such as Dorsets and merinos) are not affected by season and can be joined all year round.

### Joining

Ewes are mated with rams during **joining** season. Before this occurs, the ewes are often fed extra feed to increase the chance of them having twins and triplets. This management technique of extra feeding is called ‘flushing’ and causes the ewes to ovulate more eggs.

Ewes are joined with the rams for approximately five weeks, or two oestrus cycles. This gives the ewes two chances to fall pregnant. On average, two rams are needed for every 100 ewes in a flock. This ratio is known as the ram percentage. More rams (up to 3%) might be needed for maiden ewes, but too many rams can lead to aggression and fighting.

## Pregnancy management

Ultrasound scanning is a management tool that enables the farmer to identify pregnant ewes. The farmer can then separate their ewes into different mobs. For example, a farmer will manage the ewes carrying twins differently to ensure these ewes are fed a higher plane of nutrition compared with the ewes carrying singletons. The **dry** ewes can also be separated and sold or given less feed and run as a wool-only mob.

Ongoing ewe management is important to ensure high lambing percentages. Ewes need to avoid stressful situations such as sudden changes in diet or large paddock movements and maintain condition score of 3 throughout the pregnancy.

## Lambing

Lambs can be classified as autumn or spring lambs. This is dependent on the timing of joining and lambing. Ewes can be moved into lambing paddocks close to the homestead for ease of monitoring.



Video

Watch a video about how merino farmers are using DNA profiling to assist with breeding.



Weblink

Australian Sheep Breeding Values

**oestrus** another term for heat; when a sheep can get pregnant



Worksheets

Learn about how farmers are using new technology to assist with breeding with the *JIVET* worksheet.

**joining** the process of placing the males (rams) in with the females (ewes)



Data scenario

Explore how rams and ewes grow differently with the data scenario.

**dry** not pregnant or lactating



Weblink

Visit the Meat and Livestock Australia website to investigate how timing of lambing affects the target market for the product.

Lambing percentage is a calculation of how many lambs are born to the number of ewes that were joined. The higher the lambing percentage, the more lambs have been born and survived.

The weaning rate is a calculation of the number of lambs that have been weaned compared with the number of lambs born.



## LET'S DISCUSS

- 1 Why might we have a high lambing percentage, but low weaning rate?
- 2 How could farmers increase both of these?

### Marking activities

Lamb marking should occur when lambs are between 2–12 weeks of age. At lamb marking time, the farmer will conduct several activities, such as:

- *mulesing (only if necessary)*: lambs have wool-bearing skin from the crotch area removed for prevention of flystrike
- *tail docking*: the removal of the tail. This process can be carried out using three methods: rubber rings, knife or a gas knife. The code of practice guidelines can be referred to for the age of the lambs and location for conducting tail docking. Tail docking is only required in certain breeds of sheep that are prone to flystrike (tail docking is used to prevent flystrike).
- *ear tagging*: a form of identification of the sheep. Ear tagging is part of the National Livestock Identification System (NLIS) and all sheep must be tagged with an NLIS tag. This tag will have the Property Identification Code for the farm along with a number to individually identify each sheep.
- *ear marking*: ear marking, or notching, is mandatory in some states. This is where a notch is placed in the animal's ear. Each farm has their own notch that will identify the farm.
- *castration*: the process of removing the testicles from ram lambs. This can be carried out using two methods: cutting using a suitable sharp knife or placing rubber rings according to the code of practice guidelines.
- *vaccination*: lambs are given an injection to protect against certain diseases. The lambs are given an initial vaccination, then a booster follow-up four weeks later.

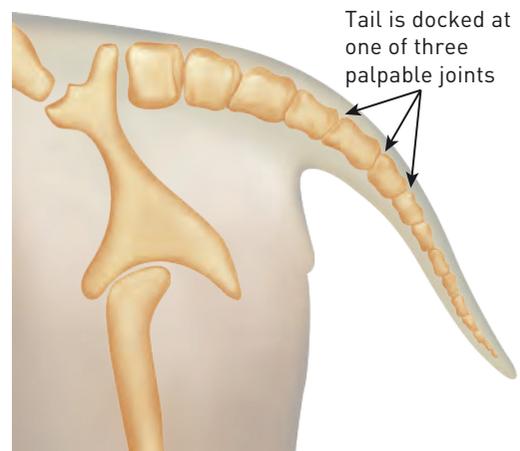


Figure 12.15 Tail docking procedure



Figure 12.16 Sheep with distinctive 'notches' taken out of its ear



WebLink

Code of Practice for lamb marking

Shutterstock.com/Margo Harrison

There is a code of practice that farmers can use that sets out guidelines to ensure the well-being of the livestock.

## Weaning

Weaning is the permanent removal of the lamb from their mother's milk. Weaning occurs between three and five months of age. This will vary depending on the season and the individual farm. Management of lambs at weaning is important for the survival of the weaners and to ensure continued growth and weight gain. Weaner management includes introducing lambs to supplement feed before weaning. They are given the second vaccination booster at weaning and farmers ensure they have a minimum condition score of 2.



### LET'S ENGAGE

## MONITOR WEIGHT GAIN OF LAMBS

### PURPOSE

To monitor the weight gain of lambs from birth to weaning

### RISK ASSESSMENT



Conduct a risk assessment using the template on NelsonNet.

### MATERIALS

- Scales
- Lambs
- Record sheet
- Condition score sheet
- App (optional) – see Method step 1

### METHOD

- 1 Before beginning the process of weighing, research which apps are available to assist in recording weight gains. Download the one you think will work best.
- 2 Weigh each lamb when born and record their weights in the app, and on paper.

- 3 Weigh each lamb every week until weaning.
- 4 If possible, weigh the lambs for an extra four weeks after weaning.

### DISCUSSION

- 1 Draw a graph of the weight gain for each lamb (or if you don't have too many lambs, you could draw a stacked line graph, recording all their weights on the one graph).
- 2 Was there a difference in weight gain between the lambs? If so, can you discern any patterns (for example, related to the sex of the lambs)?
- 3 Did the lambs suffer a setback in weight gain at weaning? If so, can you explain why this might have happened.
- 4 Compare the difference in using the app to record the weights on paper. Which was easiest?
- 5 What management strategies could a farmer implement to ensure lambs did not suffer a setback at weaning?



Template

Risk assessment template



Weblink

Sheep management apps

## Feed and nutrition

Sheep are ruminant animals, meaning they have four stomachs: the rumen, reticulum, omasum, and abomasum (you can find out about the function of these four stomachs and other facts about rumination in Chapter 10 Dairy cattle). Ruminants use microbes to digest tough plant materials that other animals with a single stomach cannot use.

Sheep require a balanced diet that contains energy, protein, vitamins and minerals. They get these nutrients through pasture or supplemental feed. You can read more about the advantages and disadvantages of improved and native pastures in Chapters 10 and 11.

Is it important that sheep drink between 2.5 and 12 litres of water per day.

The feed ration will depend on the size and type of animal, and the level and type of production. For example:

- larger sheep require more feed than smaller sheep
- pregnant sheep and ewes producing milk require more energy than dry animals
- young lambs and growing sheep require more protein than fully grown sheep
- wethers producing wool require a maintenance ration with suitable energy levels to maintain their body condition

If sheep are on a poor plane of nutrition or a poor quality feed ration, it can cause weight loss, low fertility, high mortality, increased risk of disease and poor wool growth.

Supplementary feeding is supporting the sheep with additional feed when pastures are dry and lacking suitable nutrients. Supplementary feeding aims to meet an increase in nutritional needs due to changes in the lifecycle of the sheep (such as pregnancy), increase the growth of lambs and weaners, and increase fertility.

## DID YOU KNOW?

Sheep drink up to six times as much water as a human should drink each day.



Web link

The DPI feed cost calculator aids in helping design a suitable feed ration that is affordable

**Table 12.4** A simple ration formula

Nutrient	Percentage	Examples
Energy	70%	Cereal: wheat, barley, oats
Protein	25%	Pulses: legumes, lupins, chickpeas
Vitamins and minerals	5%	Iron, calcium
Roughage	<b>Ad lib</b>	Hay or silage

**ad lib** available to feed all the time

## Lamb feedlotting

In feedlots, lambs are fed a high-quality feed ration to optimise the growth of the lambs and meet target markets in a short time. The amount of feed will depend on the starting weight of the lamb, the type of ration, the growth rate of the lamb and the target market. Lambs should be gradually introduced to the feed ration: starting with 100% hay, and over a 14-day period gradually changing to the grain feed. If lambs are moved to grain too quickly, they can suffer from grain poisoning (you can find out more about grain poisoning in Chapter 11 Beef cattle).

**Table 12.5** Guide to introducing grain concentrates

Days	Concentrate %	Hay %
All lambs on feed	0	100
2-4	20	80
5-7	40	60
8-10	50	50
11-13	60	40
14 plus	70-85	15-30



Data scenario

Explore the effect of feed rationing and pasture on weight gain with the data scenario on NelsonNet.

**Table 12.6** Examples of introducing grain quantities

Days	Quantity per lamb
Until all lambs on feed	Only hay
2-4	100 g
5-7	250 g
8-10	400 g
10-13	550 g
14 plus	700 g



## LET'S ENGAGE

## CALCULATE THE COST OF A FEED RATION

### PURPOSE

To understand the costs involved in developing feed rations

### MATERIALS

- Access the DPI website using the NelsonNet weblink

### METHOD

- 1 Use the link above to design a feed ration for sheep at your school farm. If your farm doesn't house sheep, design a feed ration for one of the following:
  - a a pregnant ewe
  - b a prime lamb in a feedlot
  - c a stud ram.

Remember, first identify the needs of your sheep.

- 2 Visit the local produce stores or research prices on line to ascertain the different costs of feeds.
- 3 Outline the costs of a feed ration for the school sheep or your case study sheep.

### DISCUSSION

- 1 How much did the feed ration cost?
- 2 Can you identify the proteins and energy feeds in the feed ration?
- 3 How can the feed ration be modified to reduce the cost?
- 4 Now try designing a feed ration for different type of sheep (such as one of the other examples in Question 1). Discuss how and why the rations differ.



Weblink

DPI feed cost calculator

## General husbandry

### Drenching

Drenching is where animals are given a substance, orally or through injection, to control internal parasites such as Barber's pole worm or brown stomach worm. Alternatively, pour-on drench can be used to control both internal and external parasites, including lice. The entire mob of sheep is drenched based on the dose for the heaviest sheep. This avoids under-dosing any sheep, which could lead to worms becoming resistant to the drench more quickly. Overdosing is not a problem because drenches are very safe.



## LET'S ENGAGE

## CALIBRATE A DRENCH GUN AND DRENCH

### PURPOSE

To calibrate and check a drench gun and then drench the school sheep flock

### RISK ASSESSMENT



Gloves should always be worn when handling chemicals. Sheep should be approached carefully.

### MATERIALS

- School sheep
- Management equipment
- Sheep race
- Pens
- Drench
- Drench gun
- Measuring cylinder

### METHOD

- 1 Identify the heaviest animal in the flock. If the flock has a big variation, split the flock so that similar animals are penned together.
- 2 Read the label and identify how much drench to administer.
- 3 Set the drench gun to the required amount, according to the heaviest animal.
- 4 Using water, draw water up into the drench gun and squirt into a measuring cylinder 10 times.
- 5 Check the volume of water. For example, if 10 mL is required, there should be 100 mL in the measuring cylinder. Adjust the drench gun accordingly.



Template

Risk assessment template

- 6 Move the sheep into the race.
- 7 Draw up the appropriate dose of drench.



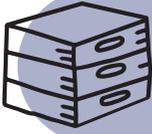
Alamy Stock Photo/Tim Scrivener

Figure 12.17 Drenching a sheep

- 8 Open the mouth, place the drench gun nozzle into the mouth and gently squeeze the gun to deliver the entire dose.
- 9 Move on to the next sheep, and continue until all the flock is drenched.
- 10 Return the flock to the paddock.
- 11 Rinse and clean the equipment and allow to dry.

### DISCUSSION

- 1 Why should you drench according to the amount for the heaviest sheep?
- 2 What is the impact of not drenching correctly?



## LET'S EXPERIMENT

## TESTING THE EFFECT OF MINERAL SUPPLEMENTS ON SHEEP PRODUCTION

### PURPOSE

In this experiment you will test the effect of a mineral drench on the weight gain of sheep.

A variety of liquid mineral drenches are available for sheep. Many are designed to modify the rumen environment and provide trace elements, improving the efficiency with which the sheep convert feed into weight gain. Investigate the availability of these supplements at the local produce store, or contact local farms to see what they are using. Most mineral drenches are long-acting, requiring only one dose for the duration of this experiment.

### HYPOTHESIS

Now that you have investigated and learned about the drench you will use, what effect do you think it will have on weight gain?

### RISK ASSESSMENT



Use the template on NelsonNet to write a risk assessment for this activity. Ensure you address the safe and humane handling of livestock (see the NSW Animals In Schools website for details)

### MATERIALS

- Four or more dry (not pregnant or lactating) sheep, preferably of the same breed, age, sex and production status. Weaners would be ideal.
- Mineral drench
- Drenching gun
- Live weight scales

### METHOD

- 1 Sheep should be in good health before conducting this experiment and should be kept as a mob on the same pasture or rations.
- 2 Randomly allocate half of the sheep to a control group and half to a treatment group. Record NLIS tag numbers for each group.



Template

Risk assessment template



Weblink

NSW Animals in Schools

- 3 Weigh sheep and record weights.
- 4 Calibrate the drenching gun according to the previous Let's Engage activity in this chapter.
- 5 Follow the instructions on the mineral drench to administer a single dose to each sheep in the treatment group.
- 6 Weigh sheep weekly for six weeks.

### RESULTS

- 1 Construct a table and record your results.
- 2 Draw a stacked line graph of live weight over time for the two groups.
- 3 Draw a column graph of total weight gain for each group during the experiment.

### DISCUSSION

- 1 Interpret your results.
- 2 Apart from weight gain, what other data could you collect to determine the effectiveness of this product?
- 3 Was the experiment valid? What factors were difficult to control?
- 4 How could you improve the design of this experiment?
- 5 Would you recommend this supplement to sheep producers? Justify your answer.

## Jetting

Jetting is the application of chemicals to the skin and wool of sheep either by hand with a jetting wand or in an automatic jetting race. Sheep are soaked in the chemical to treat lice in long wool sheep. Jetting is also a useful tool in the protection of sheep during high-risk periods for fly strike.

## Foot paring

Foot paring is trimming the hoof and monitoring the health of the feet. Foot paring enables a close inspection of the hoof as well as ensuring the animal is walking correctly. Hoof inspection is vital to ensure there are no signs of infection, wounds or abscesses.

## Faecal egg counts

Farmers regularly collect faecal samples from sheep and then send them away to have worm egg counts conducted. Conducting regular worm counts allows farmers to monitor the worm burden of the flock. The worm count identifies the type of worm present and the extent of the worm burden. This helps to identify highly susceptible sheep (which can then be culled from the flock), identify when drenching is necessary and monitor the effectiveness of the drenches being used.

## Shearing

Shearing is the process of removing wool from a sheep. Shearing times will vary depending on the region, type of enterprise and breed of sheep. Some wool production enterprises shear every eight months. The main reason for the shorter time between shearing is so the staple length is better able to meet market specifications. The longer a farmer waits until shearing, the more the wool grows and therefore the longer the length of the staples.

Crutching is the removal of wool from around the tail and between the rear legs. This process occurs during times when flystrike is a high risk and usually halfway between the shearing times.



Video

Find out more about technology being used in wool production with the *Landline* episode.



Video

Explore the process of milking a sheep.

## Records and financial management



Worksheets

Create a calendar of operations for a sheep farm with this NelsonNet worksheet.

### AG IN FOCUS

#### NATTAI VALLEY POLL DORSETS

##### Identify

A farmer operates a small Poll Dorset flock in the Sydney Basin region of Sydney, producing 190 lambs per year from a flock of 100 ewes on 20 hectares of land.

##### Understand

The farmer processes the lambs locally, packages the meat and then sells the meat at the local produce market, held every second Saturday. The farmer lambs in both autumn and winter. The lambs are weaned at three months of age and then placed in a feedlot for two to three months to finish them. Drenching and vaccination occurs regularly throughout the year. Shearing occurs at the start of November, along with footparing. Processing of the lambs occurs every two months, with the lambs being processed at a local abattoir.

The farmer spends the following variable costs during production:

##### Variable costs

Pasture maintenance and improvement	\$38/hectare
Supplementary feed for lambs	5 kg/sheep per week for 12 weeks \$0.15/kg
Adult sheep health (including lice treatment and scanning of ewes)	\$5.30/ewe
Lamb health (including marking and vaccination)	\$5.00/lamb
Shearing costs	\$7.00/ewe
Livestock selling costs	\$2.00/lamb

The farmer then sells the lambs for \$130 per lamb, at six months of age.

##### Discussion

- 1 Develop a calendar of operations for the farm. (Use Chapter 4 Agricultural business to assist you.)
- 2 Calculate the lambing percentage rate.
- 3 Calculate the stocking rate.
- 4 Calculate the gross margin per hectare for the Nattai Valley Poll Dorsets.
- 5 The farmer cannot decide whether they should move to a wool production business. You need to determine the profitability of a wool production enterprise and compare this with the farmer's current lamb production, to determine which is the most economically viable business.

The farmer will keep 100 ewes, which produce 190 lambs. The farmer plans to keep 90 lambs for future wool production and sell the other 100. The lambs sell for \$70 at four months of age. Meanwhile 5 kg of wool is produced from each sheep. This sells at \$13 per kg.

You discover the variable costs for a wool production enterprise are:

Pasture	\$38/hectare
Supplementary feed for lambs	2.5 kg/sheep/week for 12 weeks \$0.15/kg
Adult sheep health (including lice treatment, and scanning of ewes)	\$5.30/ewe
Lamb sheep health (including marking and vaccination)	\$5.00/lamb
Crutching of all sheep	\$1.50/sheep
Shearing costs	\$7.00/ewe
Wool selling costs	\$9.00/sheep
Livestock selling costs	\$2.00/lamb

- a Calculate the gross margin per hectare of the wool production enterprise.
  - b Which enterprise would you recommend to the farmer?
- 6 Would you make any recommendations to the farmer, regarding when they are conducting their activities?



## LET'S REVIEW

### LOOKING BACK

- 1 What type of digestive system does a sheep have?
- 2 What does the term 'flushing' mean?
- 3 How does pregnancy scanning aid the management of pregnant ewes?
- 4 Outline the management activities that can be carried out on a farm.
- 5 What activities are carried out at lamb marking?
- 6 What is an Australian Sheep Breeding Value and how does it help farmers?

### FOR YOU TO DO

- 1 Consider the animal welfare concerns around lamb marking activities.
  - a Research the pain relief that is available to farmers when conducting lamb marking activities.
  - b Prepare an article for the school newspaper or website outlining the issue and solutions available to reduce pain for the lambs.
- 2 Create a calendar of operations for a wool production system and sheep milk dairy. Compare the differences between the two systems.
- 3 Discuss the differences in nutrients required for different types of sheep.

### TAKING IT FURTHER

- 1 Research other breeds that increase in oestrous activity as day length shortens.
- 2 Download the Lambing Planner app. Investigate what the app can do, and then prepare a business case outlining whether the school should use it or not.
- 3 Evaluate the suitability of eastern Queensland as a location for a new wool production sheep farm.



Weblink  
Lambing Planner

## 12.5 Pests and diseases

### Pests

#### INDUSTRY IN FOCUS

#### PARASITOLOGIST

##### Identify

As the name suggests, a parasitologist studies parasites such as gastrointestinal worms (Barber's pole worm), flies, lice, ticks and many more. They study the life cycle, genetics, reproduction, infestation and biology of a wide variety of parasites. Parasitologists have many different roles. Some of these roles include conducting faecal worm egg counts, maintaining parasite colonies for trials, conducting drug trials on differing scales, conducting larval differentiation tests, authoring scientific reports and many other fascinating things.

There are many opportunities in the field of parasitology. You can work for the government in the Department of Primary Industries, for a multinational pharmaceutical company such as Novartis, or you could become a researcher at a university. Because there is a wide variety of jobs available to a parasitologist, there are many different settings that they could be working in such as a laboratory or out in the field.

To become a parasitologist you need to study an animal science degree. To help you get into this degree, in senior school it is best to study biology, chemistry, mathematics and agriculture.

##### Discussion

- 1 What does a parasitologist study?
- 2 List some activities that a parasitologist might undertake.
- 3 Research two parasites that affect sheep and discuss the signs of the parasitic infestation.
- 4 Research three organisations that a parasitologist could work for and outline what the organisation does (for example, a government department, pharmaceutical company and private research group).



Worksheets

Learn about Barber's pole worm with the NelsonNet worksheet.

### Blowfly strike

Sheep blowfly strike is caused by *Lucilia cuprina*, the Australian blowfly, which lays flesh-eating maggots predominantly in the breech areas of sheep. They can also lay eggs in the pizzle areas of rams and wethers, along with any wounded area. All wool sheep can be affected. There are a number of risk factors for flystrike, including the presence of fleece rot, dags and skin wrinkles. These conditions are ideal for maggots to grow and develop, meaning wool sheep have an increased risk of flystrike. Blowfly strike can be easily spotted: wool may become matted and smelly and sheep become agitated. In severe cases, sheep become weak, anaemic and suffer from toxæmia (toxins in blood), resulting in death or culling.

Flystrike treatment focuses on prevention methods such as mulesing young lambs, breeding resistant sheep, tail docking to the industry recommended length, shearing or crutching at high risk times for flystrike, reducing scours through monitoring and controlling worm burdens and culling sheep that are highly susceptible to flystrike.

## Integrated pest management

Integrated pest management (IPM) programs can be developed to manage sheep pests such as blowfly strike.

**Table 12.7** IPM strategies for managing blowfly strike

Strategy	Examples
Cultural	<ul style="list-style-type: none"> <li>Scheduling the time of lambing to avoid blowfly strike season (flies don't like cold weather)</li> <li>Crutching before fly season to reduce dags and faecal or urine staining</li> </ul>
Physical	<ul style="list-style-type: none"> <li>Conducting regular worm counts</li> <li>Conduct health checks on the sheep</li> <li>Fly traps (to encourage blowflies to enter a specific area)</li> </ul>
Biological	<ul style="list-style-type: none"> <li>Live bacteria released on sheep fleece to attack fly larvae</li> </ul>
Genetic	<ul style="list-style-type: none"> <li>Breeding plain-bodied (non-wrinkled) sheep with bare breeches and resistance to fleece rot</li> </ul>
Chemical	<ul style="list-style-type: none"> <li>Treating sheep with chemicals via jetting</li> <li>Chemicals should be considered carefully to limit pests developing chemical resistance</li> </ul>

## Diseases

### Pregnancy toxaemia

Pregnancy toxaemia occurs in pregnant ewes, with those carrying multiple lambs more likely to suffer. It is a result of a dramatic reduction in blood glucose levels. The disease usually occurs in the last weeks of pregnancy, when ewes may not be receiving the required nutrition. The affected ewe will display signs of drowsiness, separate from the mob, and will not graze or eat. Treatment requires immediate advice from a veterinarian and should include an intravenous glucose solution every 6–12 hours.

### Grass tetany

Grass tetany a fatal disease associated with low magnesium levels and is caused by poor adsorption of magnesium or when the intake of quality lush feed is limited. The disease can be seen in sheep that are under high physical stress or have had a sudden change in lush feed.

Usually the animals are found dead. Sheep will show signs of being agitated, sitting on the brisket with head bent towards the flank. Prevention is the key with grass tetany. Avoid sudden changes in feed or a sudden increase in lush green pastures, reduce stress with improved low stress handling methods, and use suitable magnesium supplements to help prevent the disease.

### Controlling diseases in sheep

Some specific strategies to prevent disease involve:

- quarantine*: ensuring newly arrived sheep are quarantined and allowed to empty out before being placed with other sheep
- management*: providing an appropriate plane of nutrition, careful pasture management and appropriate husbandry procedures
- vaccinations*: injecting sheep with a vaccine to protect against certain diseases. They are given an initial dose, then a follow-up dose four to six weeks after, along with an annual booster.



Worksheets

Conduct a faecal egg count of your sheep flock with the practical NelsonNet worksheets.



## LET'S REVIEW

### LOOKING BACK

- 1 What is the difference between a pest and a disease?
- 2 Outline the signs of Barber's pole worm in sheep.
- 3 Describe two diseases sheep can suffer from.
- 4 Define the term IPM.
- 5 Outline how an IPM program can assist farmers to control pests.

### FOR YOU TO DO

- 1 The Nattai Valley case study farm has developed a problem with Barber's pole worm. As a result, several ewes and lambs have become sick and some lambs have died.
  - a Research IPM programs.
  - b Using the Wormboss website, design an IPM program strategy for the Nattai Valley Farm that could assist in dealing with the problem.
- 2 Discuss the reasoning behind use of IPM – why are chemicals only used strategically?
- 3 Design an informative leaflet for farmers to help them control one pest or disease found in sheep production.



Weblink

Wormboss



Weblink

How does chemical resistance occur?

### TAKING IT FURTHER

- 1 Worm resistance is an increasing problem in sheep flocks. Traditional methods have been to drench the sheep every three to four months. This has led to a chemical resistance in the worms, especially in areas of high rainfall and small farms, predominantly with Barber's pole worm.
  - a Explain how chemical resistance occurs. (You can use the NelsonNet weblink to help you, or review Chapter 3 Farm resources and technology.)
  - b Discuss how conducting worm counts assists farmers to minimise the resistance issue.
- 2 Explain the factors that contribute to paddock contamination.
- 3 Research Johne's disease and prepare a fact sheet for farmers to help them identify, control, prevent and treat the disease.

## 12.6 Social and ethical issues

### Mulesing

Mulesing is carried out to reduce the incidence of flystrike. It involves cutting skin from a lamb's breech area to remove the wrinkles and create a bare patch of skin. The breech area is susceptible to flystrike because the area is moist with urine and clumps of faeces forming dags.

Flystrike costs the industry over \$280 million per year. The increased time and cost devoted to the care and prevention of flystrike affects the overall profitability of the industry.

Many consumers view the process as barbaric, with little consideration for the welfare of the lambs. There has been a consumer backlash and lack of understanding of the process,



Alamy Stock Photo/Russotwins

**Figure 12.18** Mulesing involves the removal of skin from around the breech.



Video

Find out more about the impact of mulesing on Australian farmers with the *Landline* episode.

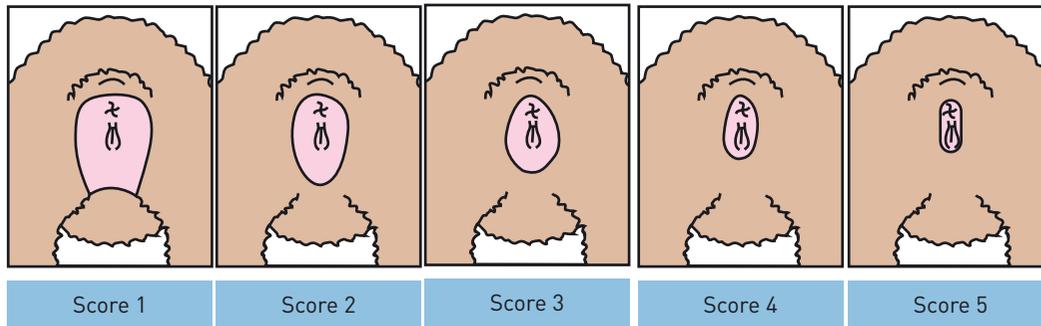


Weblink

Research the Australian Wool Innovation group and their approach to flystrike

resulting in the sheep industry spending research and development money to investigate alternative methods to mulesing and pain relief to be used when mulesing.

Australian Wool Innovation has been working with farmers to create a new treatment approach for managing flystrike, based on best practice and animal welfare improvements, with the long-term aim to remove the need for mulesing.



**Figure 12.19** Mulesing score chart used to help farmers breed flystrike-resistant sheep

In the short term, they aim to change the way mulesing is performed, with a focus on pain relief for the lambs by:

- using intradermal agents to modify the breech area of the sheep. The agent is injected 1 mm into the skin, causing the skin to contract without an open wound.
- welfare-approved surgery with trained technicians and using pain relief. However, the pain-relief spray, which contains a mix of antiseptic and anaesthetic, is only being used by 60% of farmers.

In the long term, they intend to reduce the need for mulesing by:

- improving non-invasive management strategies such as controlling scours and worms, correct tail length, jetting, timing of shearing and crutching, and improved nutrition.
- breeding flystrike-resistant sheep. Australian Wool Innovation is working to develop trait score charts to help farmers identify and select sheep with a high resistance to flystrike. Breeders are able to use the chart, which provides a consistent language among the wool producers.



## LET'S REVIEW

### LOOKING BACK

- 1 What is mulesing?
- 2 Why is mulesing carried out on sheep?
- 3 Outline some of the alternatives that are suggested instead of mulesing.

### FOR YOU TO DO

- 1 Conduct a class debate on the issue of mulesing: one side should be the farmers, the other side the animal welfare activists.
- 2 Mulesing results in short-term acute pain for the lambs, yet prevents a condition that causes pain, stress and possible death at a later stage. Considering this statement, evaluate whether mulesing is an acceptable practice.



Weblink

Alternatives to mulesing





Weblink

Scientists search for bare  
bum sheep gene

### > TAKING IT FURTHER

- 1 Read the article at the NelsonNet weblink and discuss genetic engineering of bare bum sheep. What effect would the bare bum sheep have on the wool industry?
- 2 Investigate other issues within the industry such as:
  - a castration of male lambs to increase weight gain and reduce aggression
  - b tail docking of lambs.

Prepare an article for the school newspaper debating one of these issues.

## 12.7 Sustainability

### Sustainable practices and methods

Historical unsustainable practices have included activities such as overstocking, continuous grazing of pastures, clearing of trees and the use of arsenic-based sheep dips.

#### Sheep dips

Chemicals such as organophosphates, and organochlorides like DDT (Dichlorodiphenyltrichloroethane) and dieldrin used to be used to control external parasites, through a plunge or spray dip. DDT has now been banned due to the impact it had on the environment and the wildlife living within it. Traces of the chemical have been found in marine life (such as whales and dolphins) and birds, and even resulted in eggshell thinning of the peregrine falcon. Although effective in the control and elimination of agricultural pests, it caused **bioaccumulation** within ecosystems in many environments. Arsenic-based sheep dips have been one cause of bioaccumulation. Toxic levels of arsenic have been found around old sheep dip sites, meaning these locations must be fenced off and not used for agricultural production. Arsenic and other chemicals, such as DDT, can leach into waterways, contaminating water sources and resulting in this bioaccumulation. In areas where these old dips and jetting systems are located, traces of the chemical are still present in the ground 30 years later.

#### Riparian zones

Riparian zones are areas alongside waterways, rivers, creeks and wetlands that can occur within a farm. These areas are sensitive and easily damaged by the livestock. The livestock can destroy the diverse vegetation, cause erosion of banks and upset the balance of the ecology in the water.

Managing riparian zones has several short-term impacts on a farmer. Management of these zones is costly. Farmers may need to construct fencing and install water troughs to stop livestock damaging the wetland area. Revegetating riparian zones requires an investment in labour and time, as well as the cost of purchasing plant stock. Revegetating means that the farmer gives up land to do so. In the long term, this means they have less farmland to graze livestock on.



iStock.com/prill

**Figure 12.20** Riparian zones can become damaged by livestock grazing and compaction.

**bioaccumulation** the increase in concentration of a chemical in organisms as we move up the food chain

On the other hand, managing riparian zones can increase **return on investment** in the long term. By managing riparian zones, a farmer ensures that their farmland is productive for years to come, providing them long-term economic security. Riparian zones also improve water quality, because there is less chemical contamination, less faecal run off and decreased erosion from compaction along the water ways.

### Shelter belts

Shelter belts form a line of protection for the sheep, particularly lambs, and ensure greater lamb survival. Trees block birds such as eagles, that will swoop in and kill the lambs. Shelter belts provide protection from extreme weather and reduce the likelihood of lambs dying from exposure. Shelter belts also invite other animals to the area, increasing biodiversity in a time where biodiversity is rapidly declining.

## Sustainable technology

### Genetics research to reduce methane emissions

Alongside dairy and beef cattle, sheep are a ruminant animal contributing to greenhouse gas emissions.

#### DID YOU KNOW?

In Australia, all sheep emit the same amount of methane as all beef cattle (about 30% of all livestock emissions each).

When ruminant animals digest their food, gases such as methane are created that need release by burping or through manure. Genetic research can help reduce the amount of methane released by sheep. Researchers in New Zealand are breeding low-emitting sheep that are able to release 10% less methane than their counterparts. The low-emitting sheep also have greater feed conversion efficiency: they have smaller stomachs, requiring less feed yet still put on the same amount of weight, an added bonus to the farmer.

#### DID YOU KNOW?

In New Zealand, livestock emissions are their biggest contributor to greenhouse gas emissions.



Weblink

Read more about the research to genetically reduce methane emissions in sheep

## Sustainable decision-making

### AG IN FOCUS

#### FLINDERS RANGES, SOUTH AUSTRALIA

##### Identify

The Flinders Ranges is an example of the impact of unsustainable farming practices.

##### Understand

When Europeans settled in the region, farmers were given allotments of land and then stocked their farms, without a clear understanding of the region, the plant species or the impact of grazing stock on these areas. After a combination of overstocking, lack of knowledge and drought times, the area has been significantly affected. The high stocking rates were suitable in the short term, with high wool prices allowing farmers to earn



**return on investment** the income received after paying for something

high profits. However, the long-term damage resulted in massive soil degradation of the entire region.

In addition, the high stocking densities caused compaction of the soil. Water and nutrients struggle to flow through the soil, and plant roots can't get through. Native species were replaced with annual shallow-rooted pasture species that were not suited to the harsh conditions. Shallow roots and loss of groundcover led to soil erosion. Other erosion issues have developed, such as gully erosion, when water runs along the surface instead of into the soil and creates a gully.

Stocking rates are now being controlled, with farmers working together with local environmental groups to develop and implement strategies that allow the native species to regenerate, stock numbers to be limited and fencing off and replanting sensitive areas. For example, farmers are reintroducing native grasses to the area, as native plants are able to handle the climate and soil better.

### Discussion

- 1 Discuss the short- and long-term impacts of the European settlers' farming practices in the Flinders Ranges.
- 2 How do changes in stocking rates affect the environment?
- 3 Discuss grazing management recommendations, considering what you learned in this case study.
- 4 You are researching new, sustainable opportunities for sheep farmers. You hear about native weeping grass, a high-protein grass. Research this grass and consider whether it could be used by Australian sheep farmers. Prepare a report discussing the question: Is native weeping grass a sustainable and economically viable alternative pasture species for sheep farmer? Your report should include:
  - a a description of weeping grass
  - b how sheep farmers could use it
  - c the short-term impacts of using native weeping grass
  - d the long-term impacts of using native weeping grass
  - e an answer to the question.

## 12.8 Marketing

### Wool production

#### The market

Australia is the world leader in wool production, producing approximately 380 million kg of wool in 2018–19. Australia exports much of its wool, with the export wool industry valued at \$4.251 billion in 2018–19. The biggest customer for Australian wool is China with wool also exported to countries such as India and Italy.

#### Market specifications

Wool undergoes both subjective and objective measurements to price it. Samples are taken before the sale for measurement of specifications such as:

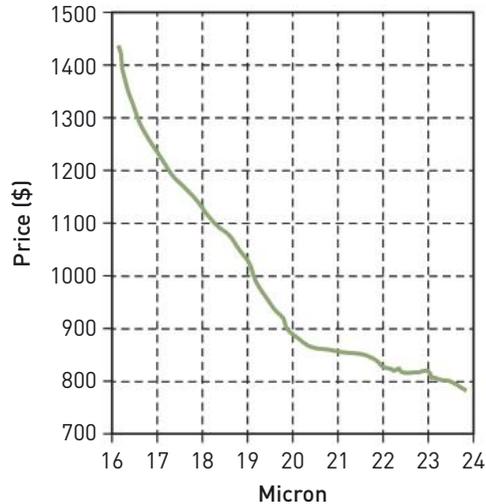
- *diameter*: the sale price depends on the diameter (measured in microns) of the sale lot. The chart below shows the relationship between micron measurement and the price.



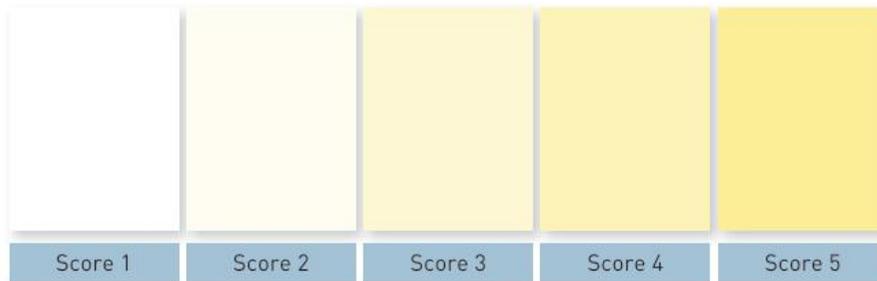
Worksheets

Explore the market specifications for wool with the NelsonNet worksheet.

- *length*: the ideal length of the staple is 85–90 mm. Discounts are given if the staple is outside the required specifications. The staple length determines the end use of the wool, either knitting or weaving. The longer staples tend to be used for weaving.
- *strength*: the measure of the force required to break the wool. The measurement is in Newtons per kilotex. The strength is important in the processing of the wool because staple strength relates to the fibre and breakage wastage during the combing. The price improves as the staple strength increases.
- *vegetable matter content*: a standard pre-sale test to identify the vegetable matter content in the wool. The more vegetable matter present means that the wool will require additional treatment known as carbonising to remove the vegetable matter. This process is costly and can damage the staples.
- *colour*: graded for colour using the score card below. The wool is then graded as being scourable or unscourable.



**Figure 12.21** As the micron increases, the price decreases.



**Figure 12.22** Wool colour chart



## LET'S ENGAGE

### DOES WOOL BURN?

#### PURPOSE

To test the flammability of wool in comparison with other fabrics

#### RISK ASSESSMENT



Use the template to conduct a risk assessment before completing this activity.

#### MATERIALS

- Different samples of fabric
  - Synthetic
  - Cotton
  - Wool
  - Wool blends

- Heat mat
- Bunsen burner
- Tongs
- Water bottle
- Goggles

#### METHOD

- 1 Take a sample of fabric, hold with the tongs.
- 2 Ignite the sample using the Bunsen burner. Hold over the heat mat.
- 3 Observe how the fabric burns.
- 4 Use the water bottle to spray water onto the burning fabric to put the fire out.
- 5 Repeat with each sample.
- 6 Record your observations.



Risk assessment template

**DISCUSSIONS**

- 1 How did wool react to being burned?
- 2 How did the other fabrics react to being burned?
- 3 Consider the implications of the flammability of the fabric to the end use.
- 4 Relate the properties and characteristics of wool to its many uses.

## Marketing strategies

### Live auction

Most wool is sold through the open auction system. A wool sample is displayed, with pre-sale certificates, for the buyers to inspect. The buyers determine which pots they will bid for. The lots are then sold to the highest bidder.

### Private sales

Woolgrowers can sell direct or combine their wool clip with other growers to sell direct to a processing mill.

### Electronic

Wool can be sold online through a system similar to the live auction, but the buyers do not inspect the wool samples. The pre-sale certificates are available for the buyers on request.

### Value-adding

Value-adding is any process or service that adds or enhances the value of a product and can occur anywhere along the market chain. Value-adding allows the farmers to become price makers not price takers. Some examples of value-added products are wool insulation, meat by-products like gelatine, and sheep manure.



WebLink

Explore how to buy and sell wool

## AG IN FOCUS

### WOOL INSULATION

#### Identify

Tas Natural Wool Insulation is a Tasmanian company producing wool insulation for all of Australia.

#### Understand

Wool insulation is one way of value adding to wool. Wool is a more environmentally friendly alternative to other forms of insulation (such as synthetic insulation) used in building houses. Wool is particularly durable: the fibres can be bent back more than 20000 times before breaking. This is ten times more than silk and seven times more than cotton. Wool is also able to protect against hot and cold in all climates. In Australia, humidity is often a problem. Wool insulation soaks up moisture in high humidity. This absorption of moisture then emits energy that heats up the wool, hence preventing condensation. This reduces the chance for mould or damp to grow in a house.

#### Discuss

- 1 Why is wool a good insulator?
- 2 Why is this a good value-added product idea for Australians in particular?
- 3 Create a poster advertising wool insulation. On your poster you should include a name, logo, slogan and identify the benefits of choosing wool insulation.

# Meat production

## The market

The Australian sheep meat industry was worth \$4.8 billion in 2018-19. Australia produced approximately 501 000 tonnes of lamb and 238 000 tonnes of mutton, with around 50% of the production exported. Australia is the world’s largest exporter of sheep meat and is the third largest producer of lamb and mutton.

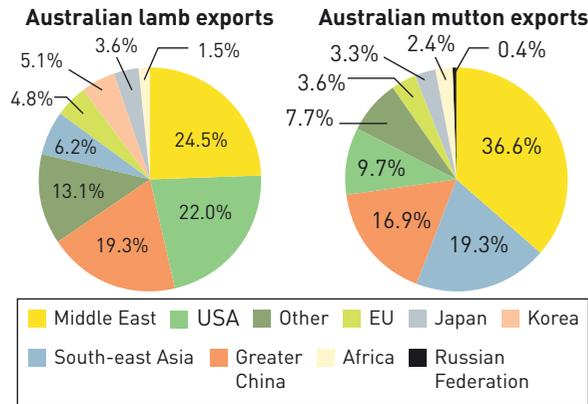


Figure 12.23 Export destinations of the Australian sheep meat industry

## Market specifications

Lamb and sheep tend to be sold in lots or consignments. The lambs are assessed for their age, breed, carcase weight, fat score, condition and overall quality. These specifications differ depending on whether the meat is destined for the domestic or export market.

Table 12.8 Specifications for lamb

Characteristics	Domestic supermarket	Domestic food service	Export to the US	Export to Middle East
Weight	18–22 kg	20–25 kg	20–30 kg	10–16 kg
Fat score	2 and 3	2 and 3	2 to 4	2
Comments	Second cross	Lean meat preferred	Prime lamb cuts	NA



Weblink

Explore the specifications for other types of sheep meat



## LET'S DISCUSS

- 1 Prime lamb production used to be called fat lamb production. Consumers did not like this name. Why do you think this is?

## Marketing strategies

There are various methods of selling sheep, including those listed in Table 12.9.

Table 12.9 Methods of selling sheep meat

Method	Description
Saleyard	<ul style="list-style-type: none"> <li>• Sheep transported to central saleyard</li> <li>• Sold to highest bidder</li> <li>• Price will vary depending on quantity of sheep and buyers, and quality of sheep</li> </ul>
Paddock sale/private sale	<ul style="list-style-type: none"> <li>• Sheep inspected on-farm by buyers</li> <li>• Farmer negotiates own price</li> <li>• Sheep remain on property until transported to abattoir, feedlot or buyers farm</li> </ul>
Over the hook	<ul style="list-style-type: none"> <li>• Delivered to abattoir, ownership changes at abattoir scales</li> <li>• Sheep sold when market ready (so better able to meet market specifications)</li> <li>• No stress of saleyards</li> <li>• Grid payment system</li> </ul>



Method	Description
Contract	<ul style="list-style-type: none"> <li>• Contract between buyer and seller</li> <li>• Contract supplies specific amount, price and specifications</li> <li>• Can be penalised if sellers do not meet contract</li> <li>• Results in buyers influencing management practices on a farm</li> </ul>
Auction plus	<ul style="list-style-type: none"> <li>• Online auction system</li> <li>• Sheep assessed before auction</li> <li>• Details entered online</li> <li>• Buyers peruse details and bid for sheep online</li> <li>• Transported direct to abattoir or buyer's property</li> </ul>

## Value-adding

### AG IN FOCUS

#### COWRA LAMB

##### Identify

Breakout River is a butcher located in Cowra, NSW. The business began in April 2006, and quickly became partners with Cowra Meat Processors. Breakout River uses its prime location and innovative processes to value-add to create quality lamb products.

##### Understand

Breakout River is located in Southern NSW, alongside the Lachlan River. It is situated in the Lachlan Valley, an extremely fertile part of Australia. The fertility means that the ideal pastures and fodder crops can be grown, and therefore lambs grown in this region are well-known for their quality across Australia.

Chris Cummins heads the buying team at Breakout River. He sources lambs in the Cowra region, claiming to only source the best lambs available to give to customers. At Breakout River, the lambs undergo a special chilling process that results in the company being credited with the longest shelf life of lamb in the industry. This means that although the process itself takes longer and is more complicated than others, the lamb can be sold for a higher price because customers are assured of its quality and longer shelf life. Breakout River sells to both wholesalers and individual customers.

##### Discuss

- 1 What does Breakout River do to value-add to its lamb?
- 2 How does the location of Breakout River affect its process?
- 3 What considerations would need to be made in deciding to value-add the lamb instead of selling through traditional methods such as the saleyards?



## LET'S REVIEW

### LOOKING BACK

- 1 How much wool is sold overseas?
- 2 What is the value of sheep meat to Australia?
- 3 Outline the market specifications for wool.
- 4 Identify the four markets for sheep meat.
- 5 Compare the selling methods for wool and sheep meat.



**> FOR YOU TO DO**

- 1 Survey local butchers on:
  - a how they value-add lamb
  - b what customers look for in meat
  - c how they deal with competitors.
- 2 Using the research gained from local butchers, design your own value-added lamb product. Create a marketing poster for your lamb. Use Chapter 4 Agricultural business to assist you.
- 3 How do you think increased selling of lamb online will affect local farmers?
- 4 Research how organic lamb is produced and explain why people would purchase organic meat.

**TAKING IT FURTHER**

- 1 Research why greasy wool is sold overseas and the finished product returned.
  - 2 Debate the concerns over the live sheep trade.
-

# Let's summarise



Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about sheep production.

## What makes Australian sheep production unique and successful?

Australia is one of the largest sheep producers in the world, and is the world's largest exporter of sheep and lamb products. Outline the management techniques and production systems used to make Australian sheep production unique and successful. Use the words in the table below to assist you.

Breed of sheep	Systems	Nutrition
Breeding	Husbandry	Technology

## How does Australian sheep production address consumer concerns?

Consumers are becoming more concerned with issues around animal welfare and sustainability. Create a mindmap detailing all the ways Australian sheep farmers have tried to address consumer demands regarding sustainability, animal welfare and market specifications.



# Poultry

## CHAPTER SUMMARY

Chicken eggs and meat are produced in many ways, including via cage, barn, free-range, pastured and organic systems. Chickens can be monitored throughout their growth and development within the egg by using a method called candling. Chicks are then grown in rearing sheds, with extra warmth provided by brooder lamps for the first weeks of their life. Different techniques can be used to improve growth of chicks, such as using various light colours to increase their growth rate.

Poultry production has many ethical concerns; for example, cage production doesn't allow chickens to roam naturally. As a result, free-range chickens are slowly becoming more popular, despite the increased production cost for farmers. Ethical concerns must be weighed with production concerns to ensure the most efficient and successful business for the farmer.

**How has poultry farming changed over time?**

**How can chickens be produced ethically?**

**Are chickens a sustainable alternative to other farm animals?**

## 13.1 Introduction

Poultry are domesticated birds farmed for meat, eggs or feathers. The term 'poultry' includes chickens, ducks, geese, turkeys, pigeons, quails, pheasants, and even ostriches and emus.

In Australia, emus, mutton birds and parrots were hunted and trapped by Aboriginal peoples for millennia, customary practices that still occur today. An emu caller, made from hollowed-out wood, attracts the male emu away from his nest. Although emu nests could contain up to 15 eggs, it was normal practice for hunters to leave some eggs, ensuring a sustainable emu population and harvests for future years.

The first period of Maori settlement in New Zealand is named after a now-extinct giant bird, the moa. Twelve species of moa inhabited New Zealand, the largest birds reaching 3 metres in height. These giant flightless birds were hunted alongside weka (ground hens) and kakapo (semi-flightless night parrots).

Chickens descended from the red junglefowl of India over 7000 years ago, arriving in Australia with the First Fleet in 1788. Over time, poultry became a common fixture in Australian backyards, allowing many families to be self-sufficient in their production of eggs and meat. Chickens are still the most popular poultry species in Australia today, although the nature of egg and meat farming has changed considerably.

Australia's poultry industry has become larger and more specialised. Hatcheries, breeding farms, feed mills, chicken meat growers, egg producers and marketing companies have evolved to concentrate on individual steps in the production, processing and marketing of chicken eggs and meat. Today, the poultry industry consists mainly of large-scale producers located near major towns and cities.

## 13.2 Functions and anatomy

### Functions

#### Layer birds

Layer birds produce eggs that are sold whole as table eggs or processed into egg products such as egg pulp and liquid eggs. Compared with birds used for meat production, layer birds have much lighter frames. All their energy goes into producing eggs rather than meat carcasses, with the average commercial layer bird producing around 350 eggs per year. Layer birds are selected for a number of traits, including:

- high egg production
- egg weight
- shell colour and strength
- a long laying life.

Most layer birds are **hybrids**, produced from crossing pure breeds selected for these production traits. In Australia, approximately 98% of eggs are produced by ISA Brown, Hy-Line, Hisex and other layer hybrids. Hybrids inherit the superior egg production traits from both of their parents and also display hybrid vigour, meaning they perform better than the average of their parent breeds and are usually healthy and robust. Commercial layer hybrids

**hybrid** an organism bred from crossing two different varieties, breeds or sometimes species

are produced by crossbreeding a number of generations of selectively-bred pure lines. As a result, backyard breeders cannot create new ISA Brown, Hisex or Hy-Line layer birds by simply breeding existing birds. Each hybrid layer is the result of a carefully managed and controlled breeding system owned by specific breeding companies.

### DID YOU KNOW?

The 'ISA' in ISA Brown stands for Institute de Selection Animale, the French company that developed this hybrid layer in 1978.

ISA Browns, Hy-Lines and Hisex laying hens are sex-linked hybrids. The colour of the newly hatched chicks is determined by their sex, with males hatching out yellow and females hatching brown. This makes the hatchery's job of sexing the layer chicks very easy.

### Meat birds

Just like layers, commercial meat birds are hybrids. Since the late 1990s, fertilised eggs from international poultry genetics companies have been imported into Australia to improve the production, fertility and welfare of meat chickens. The high growth rates and large carcasses of meat birds are not due to steroids, growth hormones or genetic modification, but are solely the result of careful selective breeding. Today's meat chickens are selected for:

- high meat yields
- efficient conversion of feed into weight gain (known as feed conversion efficiency)
- reproductive fitness and fertility
- leg and cardiac strength
- disease resistance.

Most Australian meat bird hybrids are produced from crosses between the Cobb and Ross breeds. Both sexes are grown and used for meat production.

### Purebreds

Popular purebreds include Australorps, Leghorns, Light Sussex and Rhode Island Reds. Some of these are dual-purpose birds, being kept for both meat and egg production.

Purebred chickens are an important source of genes for commercial layer and meat breeders. New crosses are developed from purebreds with desirable characteristics. Poultry clubs and chicken fanciers play an important role in preserving and protecting the genetic variation of chickens.



Shutterstock.com/Ivonne Wierink

Figure 13.1 ISA Brown hen



Shutterstock.com/Mriya Wildlife

Figure 13.2 Thirty-day-old meat bird

### DID YOU KNOW?

Bantam chickens are smaller breeds of chickens. Many full sized or standard breeds have a bantam version.

## Poultry by-products

Poultry by-products include feathers; down; blood, meat and bone residues from processing plants; manures; and soiled bedding or litter from housing. Manures and soiled litter are processed into fertilisers, while other by-products are rendered to produce meat and bone meal, blood meal, fats and oils. Poultry meat meal is an important source of protein in some animal feeds. Fats and oils are used by pharmaceutical and chemical companies.

Feathers and down are used for insulation and padding for pillows, doonas, sleeping bags, clothing and furniture. Feathers and down are sourced from ducks and geese, not chickens, and are imported into Australia. Birds are often plucked alive, up to four times a year. The Traceable Down Standard has been introduced to address animal welfare concerns in the feather-and-down industry. To meet the standard, producers have to conform to local animal welfare regulations and cannot engage in live plucking.

### AG IN FOCUS

#### MUTTON BIRDING IN AUSTRALIA AND NEW ZEALAND

##### Identify

Tasmanian Aboriginal peoples and the Rakuira Maori have harvested mutton bird chicks from the wild for thousands of years.

##### Understand

Mutton birds, or short-tailed shearwaters, are valued for their meat, oil, feathers and down. Chicks are harvested in April, just before they get their flight feathers and migrate to the Arctic. They are at their heaviest at this stage, and contain the most gurry, or gut oil.



Shutterstock.com/ivandon

**Figure 13.3** The short-tailed shearwater or mutton bird

Apart from being a source of food and fibre, mutton bird harvesting is also an important cultural practice. Commercial mutton bird harvesting is only carried out by local Aboriginal and Maori people, and is conducted in a sustainable fashion. Populations of birds are monitored to ensure harvesting will not have long-term impacts on mutton bird colonies. During the harvesting process, burrows are protected because birds will reuse these over a number of seasons.

Unfortunately, mutton bird populations are threatened by environmental changes and commercial fishing. Animal rights activists are opposed to the harvest of the chicks, which they view as inhumane.

##### Discussion

- 1 Why is harvesting conducted just before the chicks migrate?
- 2 Identify some uses of, and products made from, mutton birds.
- 3 Explain why mutton birding is under threat.
- 4 Discuss the practices used to manage and harvest mutton birds sustainably.



WebLink

Investigate how these birds are used by Tasmanian Aboriginal peoples and learn how to cook mutton bird.



WebLink

Read about the steps in harvesting and processing of mutton birds in New Zealand.

## Anatomy

### Poultry terms

Newly hatched chickens are called chicks. Up until one year of age, males are called cockerels, after which they are known as roosters or cock birds. Until they start laying eggs, females are known as pullets. Once they start laying they are called hens.

### Anatomy of a rooster and hen

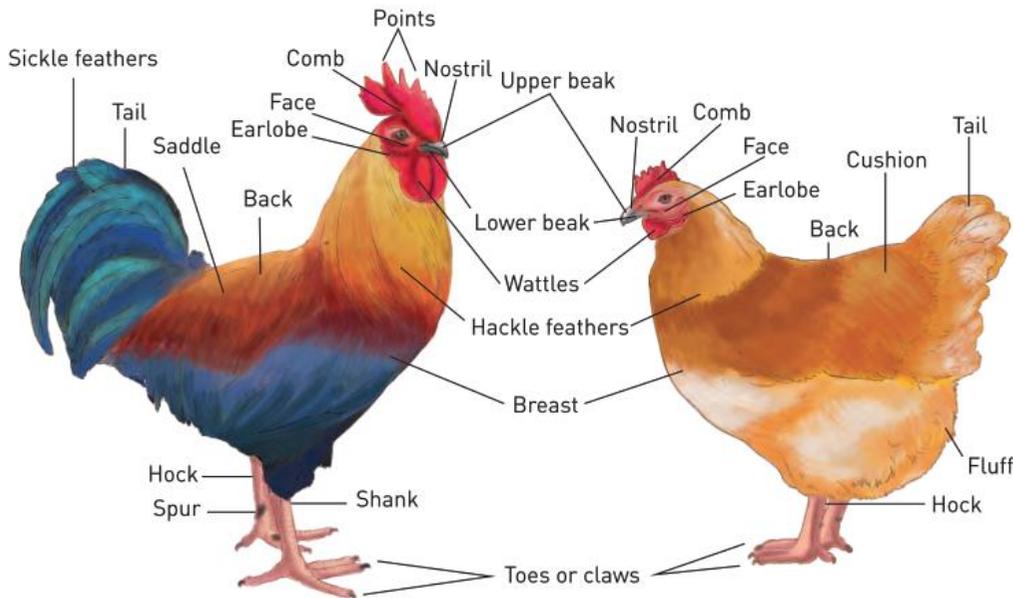


Figure 13.4 Anatomy of a rooster and hen

### Structures of an egg

Eggs consist of a hard protective shell with thousands of tiny pores to allow airflow. The central yolk has a tiny germinal disc where the chicken embryo will develop if the egg is fertilised. The yolk provides food for the developing chick and is held in place by the chalazae. The egg white, or albumen, cushions the yolk and acts as a barrier against external germs.

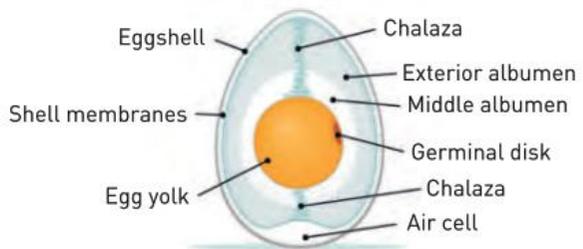


Figure 13.5 The structures of an egg

Shutterstock.com/logika600



Worksheets

Review what you know about poultry anatomy by completing the worksheet on NelsonNet.



### LET'S ENGAGE

#### WHAT IS INSIDE AN EGG?

##### PURPOSE

To examine the structures inside an egg

##### RISK ASSESSMENT



Wash hands before and after this activity.

##### MATERIALS

- Fresh eggs
- Paper plates
- Probes or icypole sticks

##### METHOD

- 1 Carefully crack an egg onto a paper plate and identify the structures shown above.

##### DISCUSSION

- 1 Draw a labelled diagram of your egg.
- 2 Construct a table detailing the structures and functions of an egg.



## LET'S REVIEW

### LOOKING BACK

- 1 Identify the two main types of poultry enterprises.
- 2 Define the following terms: hen, pullet, chick, rooster, meat bird, layer, dual-purpose bird and hybrid.
- 3 How can you tell male and female layer hybrid chicks apart?
- 4 Why are sex-linked hybrids considered better than purebreds for commercial production?
- 5 Identify five products made from chickens or other poultry species.

### FOR YOU TO DO

- 1 Examine a hen or rooster and identify the main anatomical features.
- 2 Compare layer birds and meat birds in terms of the traits used for selective breeding.
- 3 Contact your local poultry club or visit a poultry fancier to learn about the range of purebreds in your area.

### TAKING IT FURTHER

- 1 Write a report on one breed of chicken, outlining its appearance, history and uses.
- 2 Eiderdown is considered a sustainable alternative to other types of down. Investigate the eiderdown production process and discover why eiderdown is so highly regarded, and why it is much more expensive than other down.



Video

Watch a video about the eiderdown production process

# 13.3 Production

## Cycle

### Layer production cycle

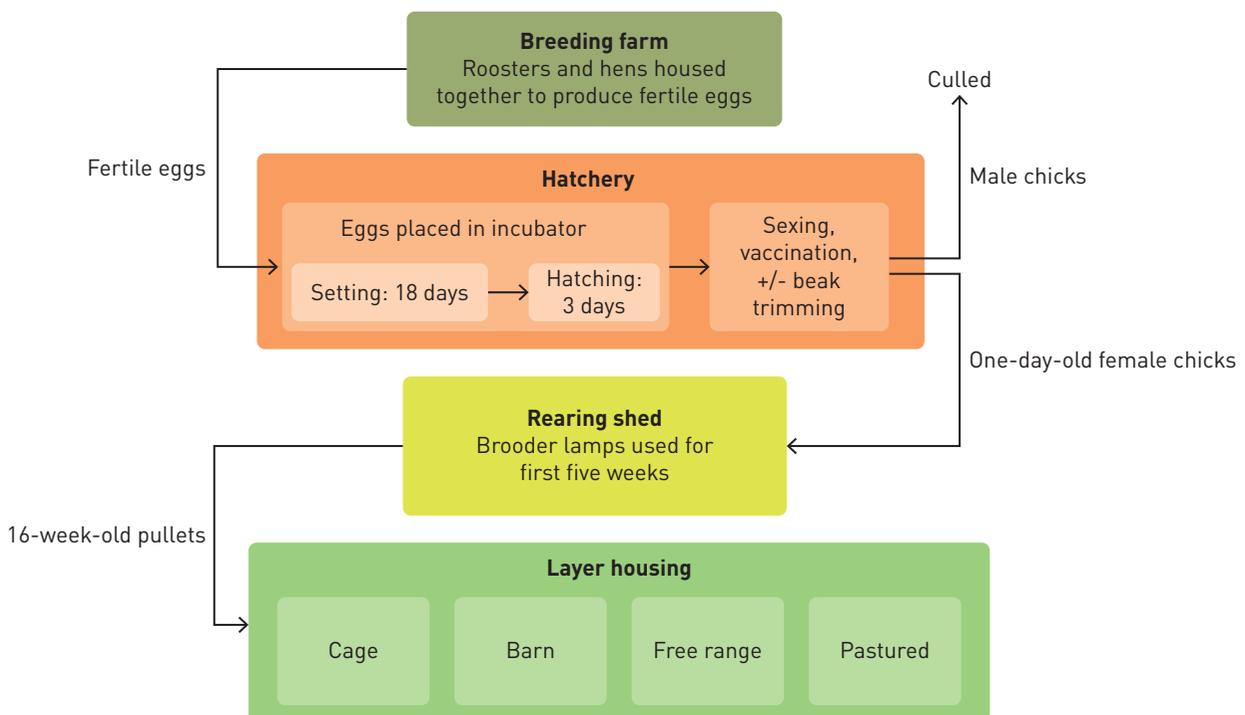


Figure 13.6 The production cycle of layer birds

## The hatchery

Hatcheries are specialised facilities for incubating eggs. Fertile eggs from breeding farms are placed in an **incubator** for 21 days. The temperature, relative humidity and airflow are controlled to provide optimum conditions for the developing chicks. Incubation is divided into two periods.

- 1 *Setting*: during the first 18 days, the eggs are turned throughout the day to stop the developing chick from sticking to the shell.
- 2 *Hatching*: for the last three days, the eggs are not turned so the chick has time to prepare for hatching.

After hatching, birds are sexed. Male chicks are separated and culled because they cannot lay eggs. The females are then vaccinated. Sometimes the chicks' beaks are trimmed to reduce injury and cannibalism.

### DID YOU KNOW?

Newly hatched chicks absorb the remains of their yolk and use this as food for up to 72 hours after hatching. They do not need food during this stage.

**incubator** a device used to optimise conditions for hatching fertile eggs



Weblink

Learn more about the egg production cycle at Australian Eggs.

## AG IN FOCUS

### MALE CHICKS AND GENE MARKERS

#### Identify

A number of new technologies are currently being developed to sex chicks while they are still in the egg.

#### Understand

The CSIRO is investigating using gene markers to separate male chicks from females before they hatch.

A gene marker is a segment of DNA for which the location is known and associated with a particular gene. The marker might be part of the gene or close to it. If the presence of the marker is detected, it means the gene is also present. Eggs can be scanned at the hatchery for the presence of a sex-related gene marker at nine days incubation. Male eggs can be identified and disposed of humanely, reducing the costs associated with incubating, handling, sexing and disposing of male chicks.

Alternatively, the male eggs can be used by pharmaceutical companies to produce vaccines. Eggs injected with viruses at 11–12 days' incubation are used to grow and multiply virus particles that are then processed into vaccines. Influenza vaccines are routinely grown in fertilised eggs.

#### Discussion

- 1 What is a gene marker and how can it help reduce the number of day-old chicks that must be disposed of?
- 2 Research how male layer eggs can be used in vaccine production.
- 3 Brainstorm as a class other potential solutions to reduce the number of male chicks being culled. Prepare a report describing one of those ideas in more detail.



Weblink

Vaccine production with eggs

**brooder** a heating device used to simulate conditions under a sitting hen

**clutch** the number of eggs laid on consecutive days

**moult** the loss and replacement of a chicken's feathers, usually associated with shortening of day length; egg production ceases until moulting has finished

**Rearing sheds**

Day-old females are transported to rearing sheds. The chicks are placed under **brooder** lamps for the first five weeks to keep them warm. After this age, they are able to regulate their body temperature.

**Layer housing**

At 16-18 weeks, the chicks (now called pullets) are transferred to layer housing. Within a few weeks they will start laying eggs. Usually a hen will lay one egg per day for three to eight days then have a break. The number of eggs a hen lays in a row is called a **clutch**.

**Culling**

After approximately ten months, the layers will **moult**, signalling the end of the first laying season. Their feathers will fall out and be replaced. Laying will cease during this period. Hens are sometimes culled at their first moult when they stop laying eggs. They can be kept for a second laying season but usually produce 10-30% fewer eggs.

**Meat production cycle**

Meat chickens are also hatched in incubators at a hatchery but are not sexed because both males and females are grown for meat. After vaccination, they are transported to growing farms where they are placed under brooder lamps.

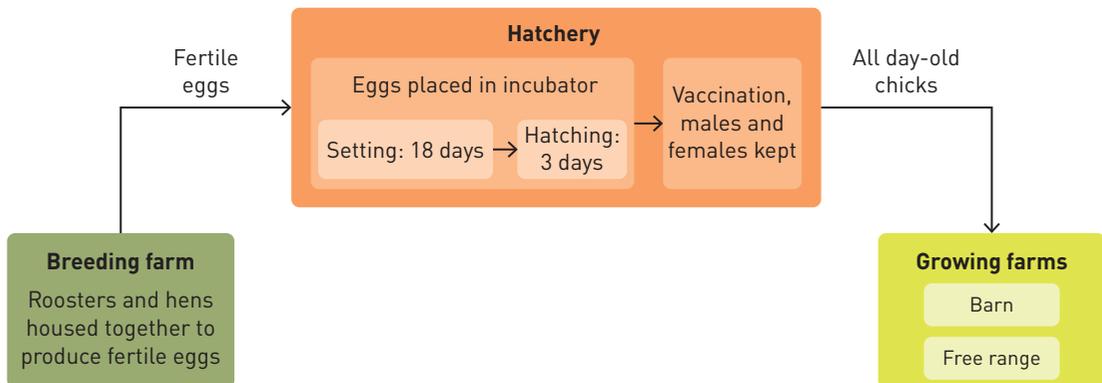
Meat chickens have been selectively bred to grow much faster than layer birds so, within 30 days, some will have already reached their target weights for processing. Ideal carcass weights depend on what the chicken is to be used for. Birds used for the production of fillets, for example, are usually left to grow larger and are processed as late as 65 days.



Shutterstock.com/branislayupadar

**Figure 13.7** Meat chicks at the hatchery

Some of the chickens are harvested at any one time in a process called 'thinning out'. Up to five batches of chickens will be harvested this way from each shed. After the last chickens have been harvested, the shed is cleaned and prepared for the next batch of meat chickens.



**Figure 13.8** The production cycle of meat birds

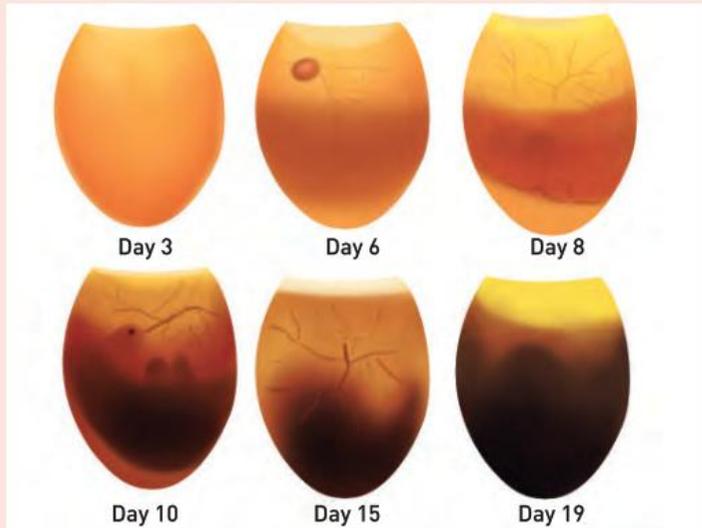


## LET'S ENGAGE

## INCUBATING AND CANDLING EGGS

### PURPOSE

To monitor the development of eggs in an incubator.



© JP Ventures LLC & Incubator Warehouse.

**Figure 13.9** Egg candling highlights the development of a chick inside the egg.

### RISK ASSESSMENT



Incubators can harbour germs that may cause disease in humans. Make sure to wash your hands before and after handling eggs.

### MATERIALS

- Fresh, fertile eggs
- Incubator
- Candling equipment OR smartphone and cardboard box

### METHOD

- 1 Use fresh (less than one week old), clean, fertile eggs that have been turned daily before incubation.
- 2 Set up the incubator according to the manufacturer's instructions.
- 3 Candle eggs before placing in incubator, then every two to three

days. Place the egg over a small hole in a cardboard box and use a smartphone flashlight to illuminate the egg from outside the box. The egg can be viewed through an eye-hole cut into the top of the box.

- 4 During the last three days, increase the humidity by placing a pan of extra water on the floor of the incubator. Remove any turning devices at this time.
- 5 At 21 days, place hatched chicks in a brooder with food and water.

### DISCUSSION

- 1 Make sketches of the changes in the eggs during development. Compare your sketches with the video, 'Development of a chick'.
- 2 Did all the eggs develop? During candling, what changes did you notice to the eggs that didn't develop?



Data scenario

Investigate the relationship between *Egg size and hatchability* by completing the data scenario on NelsonNet.



Video

Development of a chick

## Systems

Most poultry enterprises are intensive, meaning animals are kept at high stocking rates in relatively small areas.

### Layer systems

#### Cage production

Conventional cage production involves groups of between four and 20 hens housed in stacked cages inside large sheds, each containing up to 100 000 birds. Each bird must have a minimum of 550 cm<sup>2</sup> of floorspace (roughly the size of this book).

Feed and water are delivered automatically and eggs roll along the sloping floor to collection trays at the front of the cage, keeping them clean and free from damage. Manure is collected and moved along on conveyer belts to avoid soiling the cages below.

Consumer concerns about animal welfare have reduced the popularity of this production system. Although hens housed in cages are unable to express some of their natural instincts and behaviours, they have lower rates of mortality and cannibalism than other production systems. Hens housed in cages are also safe from potential predators.

Furnished cages are a new, more bird-friendly version of cage production. These cages are fitted out with perches, nesting boxes and areas for dust bathing.



Shutterstock.com/TTstudio

**Figure 13.10** Cage egg production

#### Barn production

Barn production involves up to 30 000 birds being kept indoors in large sheds. Each bird is required to have a minimum of 800 cm<sup>2</sup> of floorspace. Birds are free to roam around the shed and have access to nesting boxes in which to lay their eggs. Flooring is composed of **litter**, wire mesh or slats. Some barns also have perches.

Barn production is more expensive than cage systems, and eggs must generally be washed due to soiling. Birds are also more likely to die or suffer from injuries due to cannibalism. They are, however, safe from predators.

#### Free-range production

In free-range production, hens are kept in sheds similar to those used in barn production but given free access to outdoors during daylight hours. According to the 2018 Australian definition of free-range production, stocking rates must not exceed 10 000 birds per hectare (equivalent to each bird having 10 000 cm<sup>2</sup> of floorspace). This is high compared with international standards, where free-range systems are often limited to below 2500 birds per hectare.



Alamy Stock Photo/Adrian Sherratt

**Figure 13.11** Free-range egg production

**litter** poultry bedding material, often composed of sawdust, rice hulls or straw



WebLink

Watch free range chickens in real time with the Sunny Queen Chooktracker.

Free-range systems are more expensive than cage or barn production, and eggs must be washed due to soiling. Birds also suffer higher rates of mortality and cannibalism, and may be prone to attack from predators.

### Pastured production

In pastured production, hens are housed in purpose-built trailers or caravans and have free access to the outdoors. Stocking rates are much lower than other systems, and birds are regularly moved to new pastures. Just like free-range hens, pastured hens are able to express a full range of natural behaviours. However, this is an expensive production system and can be associated with higher rates of cannibalism and mortality. Predators are also a problem.

Electric netting is used to keep hens in and predators out, and marenna dogs are often kept as guardians to protect the flock.



**Figure 13.12** Pastured egg production with a marenna dog keeping guard

Shutterstock.com/TFoxFoto



Video

Watch the *Landline* episode about pastured egg production.

### Meat bird systems

#### Barn production

Meat birds can be housed in large sheds, similar to those used for barn production of layer birds. Up to a dozen or more sheds may be present on the one farm, with each shed measuring 150 metres or more in length. Meat bird stocking rates are calculated per kilogram of bird, which means that more young meat birds can be housed in a given space than older, larger birds. Thinning out the flock as they grow means that producers can avoid exceeding maximum stocking rates as the birds get bigger. Depending on the type of shed, meat birds can be stocked at a rate up to 40 kg/m<sup>2</sup>.



**Figure 13.13** Barn production of meat birds

Alamy Stock Photo/FLPA

**DID YOU KNOW?**

Maremmas are used as guardian dogs for chickens, lambs, goat kids and even fairy penguins!



Worksheets

Camden Park Poultry farm grows meat chickens for a large processing company. Investigate their business by completing the NelsonNet worksheet.



Data scenario

Explore how male and female meat chicks grow by investigating the data scenario *Meat bird growth rates* on NelsonNet.

#### Free-range production

Birds are allowed access to the outdoors through 'pop holes' as soon as they are old enough to withstand outside temperatures. Free-range producers generally stock their barns at a lower rate than for barn production to compensate for the increased difficulty in controlling climate in these open barns. Lower stocking rates also allow the birds to move around and find pop holes more easily.

#### Certified organic

Organic meat chickens must only receive certified organic feed. They also must not receive vaccinations (unless legally required) or certain medications, including antibiotics. Certified organic meat chickens can be raised in barn or free-range conditions.

### RSPCA-approved meat systems

Birds must be housed at a lower stocking density and must have access to perches and other enrichment objects, such as things to peck. Producers must also use approved lighting regimes and bedding materials.



## LET'S REVIEW

### LOOKING BACK

- 1 Define the following terms: brooder, incubator, clutch, moulting, thinning out and litter.
- 2 Describe three systems of layer and meat production.
- 3 Why would free-range, barn and pastured eggs require washing, but not cage eggs?
- 4 Outline how layer and meat bird stocking densities are calculated.
- 5 Why are meat birds thinned out rather than harvested all at the same time?

### FOR YOU TO DO

- 1 Construct a table to compare the following features of cage, barn, free range and pastured egg production systems: minimum space per bird, cost of production, washing eggs due to soiling, mortality (death) rates, cannibalism rates, exposure to predators and ability to express natural behaviours.
- 2 Analyse the benefits of keeping laying hens for a second season, compared with culling after moulting and breeding replacement layers.
- 3 Investigate the types of eggs available at the supermarket. For each type, make a record of: brand, price, production system and stocking density (for free-range and pastured eggs).
- 4
  - a Survey parents and teachers regarding their knowledge and attitude towards barn, free-range and organic chicken meat production. Questions could relate to which type of chicken they eat, animal welfare and the cost of chicken meat.
  - b Conduct the same survey with your peers.
  - c Compare your results. How did age affect your results?

### TAKING IT FURTHER

- 1 Visit the Australian Eggs website to find out more about different production systems.
- 2 Investigate turkey farming in New Zealand.
- 3 What other birds are farmed in Australia? Research this question, choose a bird and describe the production system. Make sure to include a flowchart detailing the system in your answer.



WebLink

Australian Eggs



WebLink

Turkey farming

## 13.4 Management

### Environmental management

#### Distribution of poultry farms

Poultry farms have traditionally been located near major towns or cities to reduce the cost of transport to markets and allow access to services such as electricity. As cities have grown, increasing land values and environmental complaints about noise and pollution have put

poultry farms under pressure. More farms are now being set up in regional areas close to grain growers, to reduce the cost of feed.

## Climate

Temperature, airflow, humidity and air quality need to be monitored and controlled. These factors can vary over short distances so it is important that the **microclimate** around the birds is measured and assessed.

How climate is managed depends on the stage of production. During incubation, temperature is kept at 37.4–37.6°C but relative humidity is increased during the hatching period. This helps to avoid chicks sticking to shells as they hatch. Similar conditions can be created in a small incubator by placing a pan of water in the base during the last three days.

During brooding, the temperature needs to be gradually reduced over the first five weeks. This can be achieved by raising brooder lights higher each week. In large sheds, brooder guards are used to keep the chicks near lights. The guards are then gradually moved further out to allow chicks access to more of the shed.

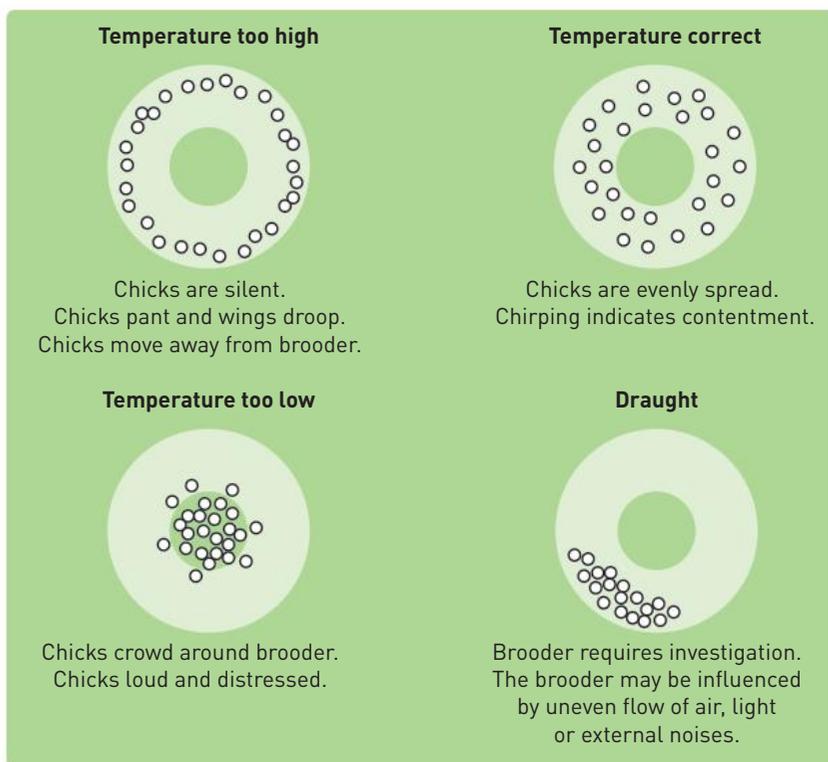
Chick behaviour can be used to assess brooder temperature. Chicks will huddle together under heat lamps if too cold, and pant and spread their wings when too hot.

**microclimate** the climate in a very small area, which can vary greatly from the overall climate of a larger area



Worksheets

Learn more about temperature requirements for chicks by completing the worksheet *Brooder temperatures for chickens and turkeys* on NelsonNet.



**Figure 13.14** Temperature-related brooder behaviours

Layer and meat chicken housing is ventilated to keep temperatures between 20–24°C. At cooler temperatures, birds will start using food energy to keep themselves warm. At higher temperatures, birds have lower weight gain, poorer shell quality and lighter egg weights. Foggers, fans and sprinklers can be used to keep temperatures down in hot weather.

Ventilation also reduces the build-up of dangerous gases such as ammonia, carbon dioxide and sulphur dioxide. Some gases are denser than air and sink to the ground. In shed situations, this can lead to dangerous conditions at bird height.

### Naturally ventilated sheds

Traditional barns and sheds have sides that are partially open with wire netting. Large curtains are raised and lowered to manipulate the temperature and ventilation rate. Roof vents and ceiling fans are also used, and the chickens are misted to increase evaporative cooling. Naturally ventilated sheds are cheaper to run and maintain, but are not as effective at maintaining optimum climatic conditions.

### Tunnel-ventilated sheds

One end of the tunnel-ventilated shed is fitted with large fans that draw air through the shed from the other end, through cooling pads. Temperature sensors adjust the fan rate as often as every three minutes. These sheds use more electricity and are more expensive to maintain. However, they are very effective at maintaining an optimum shed environment.



LET'S ENGAGE

## ASSESSING BROODER CONDITIONS

### PURPOSE

To regularly assess the microclimate inside a brooder to ensure chick health and comfort

### RISK ASSESSMENT



Brooder lights can cause burns. Take care when taking measurements near lights. Wash hands before and after this activity.

### MATERIALS

- Brooder with chicks
- Thermometer

### METHOD

- 1 Assess the temperature at various times during brooding. Choose a spot in the middle of the brooder away from direct heat.
- 2 Assess the behaviour of the chicks. Copy the table below and record your observations.

Age (days)	Temperature requirement (°C)	Temperature of brooder (°C)	Behaviour of chicks
0	34		
7	30		
14	26		
21	22		
28	20		

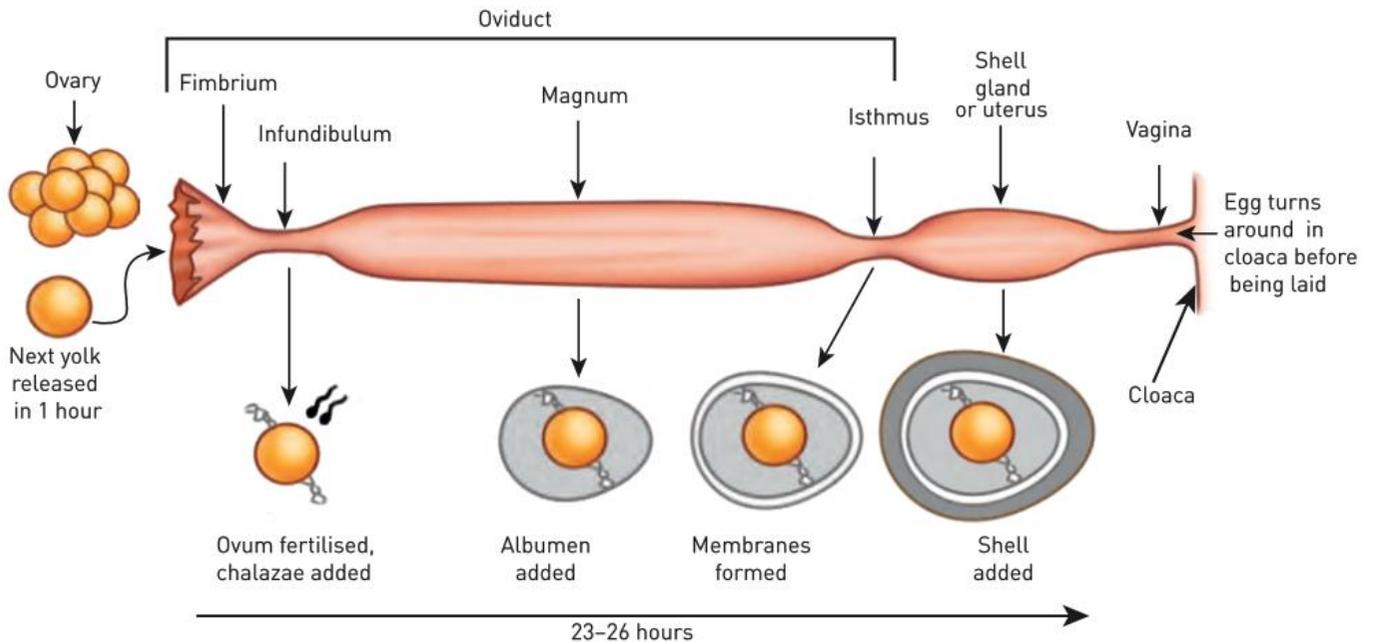
### DISCUSSION

- 1 What adjustments are needed to be made to the heat source during brooding?
- 2 Describe the behaviours of the chicks when the temperature was too warm or too cold.
- 3 How could brooder temperature be monitored in large-scale enterprises?

## Enterprise management

### Breeding and genetics

Commercial layer and meat birds are the result of several generations of careful breeding. They possess a combination of excellent production traits inherited from specifically selected parents, grandparents and great-grandparents. Hybrids look and behave in predictable ways and are very similar to each other. This is important because commercial egg producers want their eggs to be identical. Meat producers need birds that grow predictably and produce easily processed carcasses.



**Figure 13.15** The reproductive organs of a hen

Breeder farms house breeding hens and roosters together and collect eggs for incubation. Eggs are produced in the hen's reproductive tract, as shown in Figure 13.15.

#### DID YOU KNOW?

Roosters do not have a penis. Mating involves a cloacal kiss where the rooster and hen press their cloacae together to transfer sperm.

**cloaca** the body cavity of a hen or rooster containing the ends of the digestive, reproductive and urinary tracts



Worksheets

Learn more about eggs by completing the worksheet *Chicken eggs* on NelsonNet.

### AG IN FOCUS

#### BREEDING MEAT CHICKENS

##### Identify

The chickens we eat are actually the fourth generation of a breeding program that continuously supplies new meat birds.

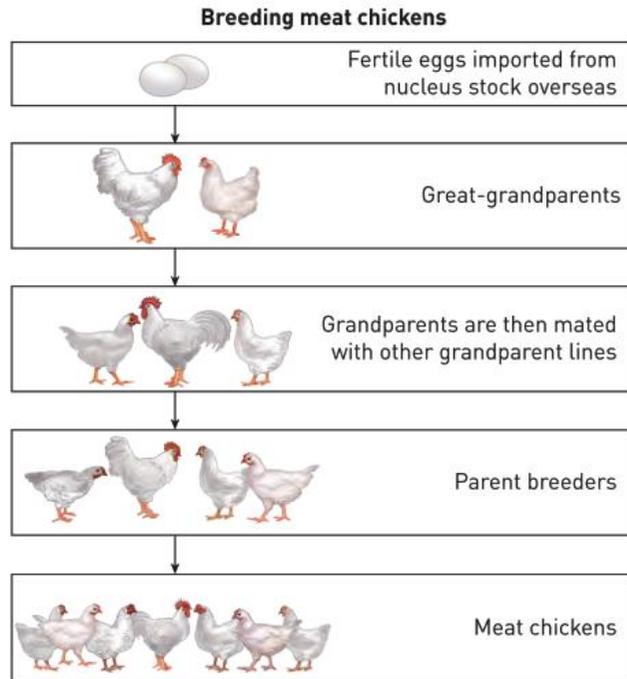
## Understand

Fertile eggs are imported from overseas and hatched to produce great-grandparent birds. These birds are very valuable and are kept in breeder farms in isolated, strategic locations around Australia.

The next generation of chicks are transferred from the hatchery to another breeding farm, and the process is repeated until the fourth generation hatch. This last generation of hybrids are raised for meat.

## Discussion

- 1 Discuss why great-grandparent breeder farms would be located in isolated, strategic locations.
- 2 Breeding birds must be kept in optimal condition. Describe some of the ways these birds would be cared for to ensure they are healthy and productive.



**Figure 13.16** The meat chicken's family tree

## Nutrition

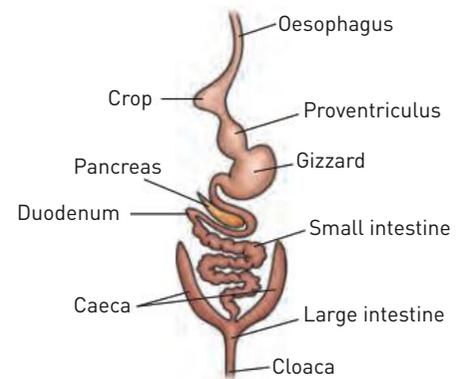
### Digestive system

Chickens must swallow their food whole because they have no teeth. The crop stores and softens food before passing it down to the proventriculus, or stomach, where acid and enzymes are used for chemical digestion. The ventriculus, or gizzard, is a strong, muscular organ that grinds the food. Grit is fed to birds to help this mechanical digestion.

The small intestine is the site of further chemical digestion and the absorption of nutrients. Water is absorbed in the large intestine, then faeces are passed out of the cloaca.

### Feeding

Birds need protein for growth and development, while carbohydrates and fats are important energy sources. Layer birds must have high levels of calcium in their diet for eggshell production. Birds housed indoors need additional vitamins and minerals because they do not have access to sunlight or green feed. Hens housed in pastured and some free-range production



**Figure 13.17** The digestive system of a bird

systems have access to a range of natural feeds, including insects and other invertebrates as well as a variety of plant material.

Poultry feed is usually based on a combination of ingredients including:

- cereal grains, such as wheat and sorghum (these are carbohydrate sources)
- protein meals, including oilseed and meat meals
- fats and oils, such as tallow and canola oil
- minerals and vitamins, including calcium and phosphorus.

The ingredients are mixed together to meet nutritional needs and are processed into pellets, crumbles or mash at feed mills. Layers and meat chickens have very different nutritional requirements.

**Table 13.1** Nutritional requirements for meat chickens

Nutrients	Starter (0–10 days)	Grower (11–24 days)	Finisher (>25 days)
Protein (%)	22–25	21–23	19–21
Energy (Kcal/kg)	3010	3175	3225
Calcium (%)	1	0.9	0.85

**Table 13.2** Nutritional requirements for layers

Nutrients	Starter (0–6 weeks)	Grower (6–15 weeks)	Point of lay (15 weeks–adult)
Protein (%)	20	17.0	16
Energy (Kcal/kg)	2860	2900	2850
Calcium (%)	1	1	2.75

## INDUSTRY IN FOCUS

### POULTRY NUTRITIONIST

#### Identify

Poultry nutritionists are animal scientists who formulate diets for birds in different production systems. Knowledge of biology, animal behaviour, biochemistry and economics is essential to this profession. Most poultry nutritionists have tertiary qualifications (a university degree, at least) in animal or agricultural science.

When formulating diets, poultry nutritionists need to take into consideration the nutritional needs of the birds, the type of stage of production and their taste preferences. Diets need to be cost effective, so an understanding of grain markets and seasonal conditions is also important. Some poultry nutritionists work for large poultry or feed companies, whereas others act as consultants to farmers, helping them make the best decisions about how to feed their animals.

#### Discussion

- 1 Outline the role of a poultry nutritionist.
- 2 What qualifications do poultry nutritionists need?
- 3 A number of factors need to be considered when formulating a poultry diet. Describe the factors and explain why these factors are important.
- 4 Design a nutritionally balanced feed for chickens at two different stages of development using an online ration tool.



Weblink

Ration tool

## Housing

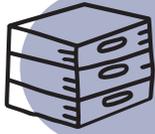
Artificial light is used to manipulate egg production and growth rates. Hens generally lay more eggs leading up to summer as day length increases. Artificial lighting can be used to simulate these conditions.

Most layer birds are exposed to 15 hours of light per day. This can be achieved by having timed lighting before sunrise and after sunset in free-range systems or providing artificial light for the entire 15-hour period in cage and barn systems.

Meat birds are exposed to up to 23 hours of light per day to encourage feeding. Research suggests there may also be a link between the colour of the light and the behaviour and growth rates of chickens.

### DID YOU KNOW?

Lights are kept dim for meat chickens because this makes them docile and calm.



### LET'S EXPERIMENT

## LIGHT COLOUR AND GROWTH RATES

### PURPOSE

To determine the effect of different light wavelengths on poultry growth

### HYPOTHESIS

Do you think light colour will have an effect on growth rates? If so, do you think red or blue light will be related to higher rates of growth?

### RISK ASSESSMENT



Brooder lamps can get very hot. Ceramic lamps do not emit visible light but can still cause burns. Wash hands before and after handling chicks.

### MATERIALS

- Two brooders or brooding areas
- One ceramic brooder lamp
- One infrared brooder lamp
- One cool-tone LED lamp
- Chicks
- Electronic scales

### METHOD

- 1 Set up the two identical brooders with feed, water and litter.
- 2 Install the infrared heat lamp in one brooder.

- 3 Install the ceramic heat lamp and the cool tone LED lamp in the other brooder.
- 4 Compare brooder temperatures and adjust the heights of the heat lamps to achieve similar conditions in both brooders. Repeat this procedure as the chicks mature and their temperature requirements change.
- 5 Randomly select chicks from each brooder. Weigh them at regular intervals and record weights in a table.

### RESULTS

- 1 Construct a table to record the average weight of each group over time.
- 2 Draw line graphs to show average growth rates over time for each light group.

### DISCUSSION

- 1 Interpret your results. Was there a difference between the groups?
- 2 How could you improve on this experiment to make it more reliable and fair?
- 3 What recommendations would you give to producers regarding light colour for brooders?

### CONCLUSION

Was your hypothesis correct, incorrect or partially correct?

## Records and financial management

### Feed conversion ratio

Records allow farmers to make informed decisions based on data. Records of costs and volumes of feed can be used to work out the feed conversion ratio (FCR) of meat birds. The FCR is a measure of how efficiently an animal can convert feed into weight gain.

$$\text{Feed conversion ratio} = \frac{\text{Weight of feed (kg)}}{\text{Weight gained (kg)}}$$

The lower the FCR, the more efficiently the food is converted to weight gain. Meat chickens have FCRs of approximately 1.8, meaning they need to eat 1.8 kg of feed to gain 1 kg in weight. The type of feed also affects the FCR. Cheaper feeds may be poorer quality and contain less protein and energy than more expensive feeds, meaning more needs to be fed to achieve target weights.

### Gross margins

#### AG IN FOCUS

#### GROSS MARGINS FOR CAGE EGGS AND BARN EGGS

##### Identify

Gross margin analysis can be used to determine the relative profitability of different enterprises. Cage and barn eggs have different production costs, but they also sell for different prices.

##### Understand

Table 13.3 lists some of the most significant variable costs involved in producing cage and barn eggs.

**Table 13.3** Variable costs to produce one dozen eggs in cage and barn production systems

Variable cost	Cage production (\$)	Barn production (\$)
Feed	0.68	0.73
Replacement pullets	0.21	0.27
Labour	0.04	0.10
Energy	0.03	0.03
Medicine and other chemicals	0.05	0.06
<b>Total variable costs</b>		

Cage eggs generally sell for a lower price than barn eggs. In this example, we will that assume that the cage eggs have sold for \$3.50 per dozen, while the barn eggs have sold for \$4.50 per dozen. These figures represent the gross income for one dozen eggs in each production system.

##### Discussion

- 1 Calculate the gross margin per dozen eggs for both cage and barn production using the formula:

$$\text{Gross margin} = \text{Gross income} - \text{Variable expenses}$$

- 2 Which production system has the higher gross margin for one dozen eggs?



- 3 Cage production can occur at a huge scale, with up to 100 000 birds in a shed. Barn production systems usually house up to 30 000 birds per barn. How many more eggs can a cage egg farmer produce from one shed, compared with a barn producer?
- 4 Explain why, even though barn production has a higher gross margin per dozen eggs, cage production is often more profitable.
- 5 What might be a better way to measure gross margins, rather than per dozen eggs?



## LET'S REVIEW

### LOOKING BACK

- 1 Why were poultry farms traditionally near towns or cities?
- 2 Identify different ways temperature can be adjusted in a brooder.
- 3 Why is it important to keep birds at optimum temperature?
- 4 Compare naturally ventilated and tunnel-ventilated sheds in terms of their energy use, maintenance and effectiveness in controlling shed climate.
- 5 Contrast the nutritional requirements of layers and meat birds at different stages of production and explain these differences.

### FOR YOU TO DO

- 1 Calculate the feed conversion ratio of your brooding chickens.
- 2 Examine bags of feed used for the school poultry. Determine what stage of production they are for and compare the nutritional contents and ingredients.
- 3 Robots have many possible roles in poultry production. Identify one issue in poultry production and design a robot to address the problem. Possible issues include feed waste and spoilage, identification of sick or injured birds, or environmental enrichment of cage and barn systems. Make a (non-working) model of your robot using recycled materials and present it to your class.

### TAKING IT FURTHER

- 1 Assess the school's poultry housing. Examine climatic and housing factors, including the susceptibility of the school birds to predators.
- 2 Draw up plans for a new and improved poultry house for the school's chickens.
- 3 Investigate sanitation robots and their use in the poultry industry. Compare the effectiveness of sanitation robots and human workers in keeping poultry sheds clean and disease-free.

## 13.5 Pests and diseases

### Pests

#### External parasites

Lice and mites are common external parasites of chickens. Lice feed on skin scales, feathers and scabs. They can survive for up to a week in the environment, especially in litter. Mites are blood suckers and can survive even longer off their host.

Integrated pest management (IPM) is used to control lice and mites. IPM uses a variety of different methods to control pests to avoid economic loss and reduce the likelihood of resistance building up in pest populations.

**Table 13.4** Integrated pest management for lice and mites

Chemical controls	Physical controls	Cultural controls	Biological controls
<ul style="list-style-type: none"> <li>Insecticides such as permethrin</li> </ul>	<ul style="list-style-type: none"> <li>Destroy or remove any boxes or containers infested birds have used.</li> <li>Exclude wild birds that may be infested.</li> </ul>	<ul style="list-style-type: none"> <li>Examine birds regularly.</li> <li>Quarantine new and infested birds.</li> </ul>	<ul style="list-style-type: none"> <li>Predatory mites that eat chicken lice and mites.</li> </ul>

#### Internal parasites

Coccidiosis is a gastrointestinal disease caused by coccidia protozoa. These small single-celled organisms damage the lining of the gut wall, causing bloody diarrhoea. Infected birds are often hunched up with their feathers fluffed due to pain. Mild infections may cause no signs, and birds might become immune to the parasites. However, young chicks and birds that are stressed or otherwise ill are very susceptible to coccidiosis.

The coccidia **oocysts** can be spread by direct contact and through infected faeces. They are coated with a tough wall and can survive for long periods in the environment. Cleaning and disinfection of sheds between batches of chickens is important in eliminating coccidia oocysts. Some chicken feeds contain a coccidiostat, which is a medication that helps control coccidiosis.

### Diseases

#### Marek's disease

Marek's disease is caused by a virus that enters via the respiratory tract. Affected birds may become paralysed, display neurological signs and develop tumour-like lesions on their internal organs and feather follicles. Once infected, birds are carriers for life, shedding the



Worksheets

Find out about red poultry mites by completing the worksheet *Integrated pest management for red poultry mites* on NelsonNet



**Figure 13.18** Electron micrograph image of a poultry mite

Alamy Stock Photo/The Natural History Museum

**oocysts** small capsules containing the reproductive cells of protozoal organisms

highly infectious virus in their feather dander. Marek's virus can survive for months in the environment but cannot be transmitted from a hen to her chick through the egg.

There is no treatment and infected birds should be culled. A vaccine against Marek's disease is often given to new chicks at the hatchery. The vaccine does not prevent infection with the disease but does reduce the amount of virus shed into the environment.

Marek's disease can be spread via contaminated clothing and vehicles, so on-farm biosecurity is an important preventative. Visitors to poultry farms should wear disposable overalls, chicks should be reared separately and disinfection of sheds should be carried out between batches of chickens.

### Newcastle disease

Newcastle disease is caused by a virus and infects a range of birds including chickens, turkeys, pigeons and parrots. It causes respiratory signs including shortness of breath, as well as diarrhoea, collapse and death. Most birds infected with Newcastle disease die, but those who survive the longest usually show nervous system signs including twisted necks.



Figure 13.19 Layer hen suffering from Newcastle disease

The virus is highly contagious and spread via direct contact with infected birds. Contaminated equipment, carcasses, water, food and clothing are also potential sources of infection. Viral particles are destroyed by sunlight, heat and acid, but can survive for weeks in cool, contaminated sheds or in manure.

Australia was declared free from virulent Newcastle disease in 2001, although there have been minor outbreaks of mild strains since then. Newcastle disease is a notifiable disease, meaning that there is a legal obligation to inform authorities if birds are known or suspected to be infected with the virus.

Outbreaks are managed according to the National Disease Management Plan, with slaughter of exposed or infected birds and disposal of infected products. Strict quarantine and movement controls are also placed on areas where suspected or confirmed cases have been reported. Vaccination of commercial flocks is compulsory in Australia. Newcastle disease has not been reported in New Zealand.

#### DID YOU KNOW?

New Zealand is the only country in the world free of the 'big three' bird diseases: Newcastle disease, avian influenza and infectious bursal disease.



## LET'S REVIEW

### LOOKING BACK

- 1 How do lice and mites feed on chickens?
- 2 When are chickens most vulnerable to coccidiosis?
- 3 Describe the signs of Marek's disease and Newcastle disease.
- 4 Give three examples of biosecurity measures that can be used to prevent poultry pests and diseases.

### FOR YOU TO DO

- 1 Examine the school chickens for signs of lice and mites.
- 2 Discuss the advantages and disadvantages of using integrated pest management rather than relying solely on chemicals.
- 3 Examine chicken feed from the agricultural plot to determine whether it contains coccidiostats.

### TAKING IT FURTHER

- 1 Research one other pest or disease of chickens and write a report outlining signs of infection, prevention methods and treatment options.
- 2 Assess the school's poultry housing in terms of biosecurity and disease prevention. Use the Farm Biosecurity app to determine the school's biosecurity risks.



Weblink

Farm Biosecurity app

## 13.6 Social and ethical issues

### Are cage eggs cruel?

Many consumers are concerned about the welfare of hens in cage production. The most common concern is that birds are unable to express natural behaviours. Chickens exhibit a number of natural behaviours including preening, foraging, nesting, dust bathing and perching.

Chickens also have social behaviours, including a pecking order. Birds establish social hierarchies and can recognise up to 30 individuals in their group. Once they know their place, pecking and fighting is rare. However, if new birds are introduced or if group numbers exceed 30, birds can be caught in a continuous battle to establish their pecking order. Hens in cage production are kept in small groups and can establish a stable pecking order. Barn, free-range and pastured birds often display more fighting and sustain more injuries due to continual social stress. Rates of cannibalism and death are also higher.



## LET'S DISCUSS

- 1 Which do you consider more important: the ability to express natural behaviours or safety from injury and stress?
- 2 Is cage or free-range production more ethically acceptable?

## Beak trimming and blinders

Beak trimming involves removing part of the top beak to control feather pecking, injury and cannibalism. It is performed on day-old layer chicks, and then is sometimes repeated at two to three months of age. Beak trimming can be painful and can cause problems with feeding. Blinkers, blinders and peepers are devices that are placed on a bird's beak to interfere with their vision and deter them from feather pecking. Red contact lenses have also been used to reduce aggressive behaviour, but can lead to irritation, infections and eye damage.

The Model Code of Practice for Poultry states that beak trimming should be avoided if possible, and producers should select birds for reduced feather pecking and aggressive behaviour. Contact lenses are not to be used, and blinkers must be avoided in cage systems and when nesting boxes are off the ground.



Shutterstock.com/Quirky China

**Figure 13.20** Blinkers can be used to reduce feather pecking.



### LET'S REVIEW

#### LOOKING BACK

- 1 Identify some natural chicken behaviours.
- 2 Which behaviours are chickens unable to express in cage systems?
- 3 Why is beak trimming performed and what are the alternatives?

#### FOR YOU TO DO

- 1 Observe the school chickens and record the occurrence and frequency of natural behaviours.
- 2 Conduct a class debate on the ethics of cage production.
- 3 Research designs of blinkers and design some human-sized examples for students to test.

#### TAKING IT FURTHER

- 1 Investigate furnished cages and other methods of environmental enrichment for cage hens.
- 2 Research one other ethical issue that is addressed in the Model Code of Practice.



Weblink

Model code of practice

## 13.7 Sustainability

### Sustainable practices and methods

#### Using chickens to repair soil

#### INDUSTRY IN FOCUS

#### LACHIE'S FARM FRESH EGGS



Credit: Jo Broad

**Figure 13.21** Lachie Broad with his maremma, Ellie

#### Identify

Lachie Broad runs a pastured egg business in Bodalla, on the NSW south coast. His hens are housed in a purpose-built solar-powered chicken caravan with roosts and nesting boxes. Once laid, eggs roll from the sloping nesting boxes directly onto a conveyer belt, reducing soiling of shells and making collection easy.

The caravan is moved in rotation around the family's dairy farm where the hens have constant access to nutritious irrigated pasture. Lachie sells eggs at a number of local farmers markets and in some retail businesses.

#### Understand

When hens are placed on pasture after dairy cattle, they scratch and distribute cow manure, as well as eat insects, including parasites and fly larvae. They also produce their own manure that adds to the soil organic matter and provides nutrients for plant growth.

Green feed such as pasture provides hens with chemicals called xanthophylls that give egg yolks a deep yellow to orange colour. Apart from producing attractive eggs, pastured production allows hens to explore their natural environment and express innate behaviours.



Video

Watch the *Landline* episode about another farmer using pastured production to regenerate the soil. How do their strategies compare to Lachie's?

Lachie's marenma dog, Ellie, protects the flock from eagles and foxes. The hens have bonded with their guardian dog and run straight to her if she barks a warning.

### Discussion

- 1 Explain the advantages of pastured production.
- 2 Draw a mind map to show interactions between the pastured hens and other enterprises and systems on Lachie's farm.
- 3 How has Lachie's system dealt with some of the normal disadvantages of free-range and pastured egg production?

## The impact of feeding chickens

Feed is the most expensive input for poultry production and has the greatest environmental impact. Selective breeding of meat chickens to have high growth rates allows farmers to use less feed and reduce costs.

Compared with other farm animals, chickens convert feed into meat very efficiently. While it takes 6 kg of feed to produce 1 kg of beef, the same amount of chicken meat can be produced with just 1.8 kg of food.

**Table 13.5** Feed conversion ratios of some farm animals

Animal	Feed conversion ratio
Beef cattle (steers)	6.0
Lambs	5.5
Pigs	2.5
Chicken meat	1.8



### LET'S DISCUSS

- 1 What inputs are used to grow, harvest and process cereal grains and oilseed crops for feed production?
- 2 What are some possible environmental impacts of growing these crops?

## Sustainable technology

### Using wastes to improve soils and make energy

Soiled poultry litter can be used as a soil conditioner. If used appropriately, it is a rich source of nutrients and organic matter. Some used litter is processed into pellets and sold as organic fertiliser. Unprocessed litter is often purchased in bulk by other farms for pasture improvement. Care must be taken when using bulk litter because it may contain animal proteins in the form of spilled feed, feathers or even dead birds. It is illegal to feed animal proteins to ruminant animals such as cattle and sheep due to the potential risk of disease, including mad cow disease (Bovine spongiform encephalopathy).

Poultry litter can also be processed and used as a **biofuel**. Spent litter is burned at 400–500°C to produce carbon dioxide and methane gases. These gases can then be combusted to produce heat and generate electricity. The power generated this way can be used to heat sheds or run ventilation fans. The remaining solids can then be used as fertiliser or soil amendments. Litter biofuel is a renewable energy source and an alternative to fossil fuels.

**biofuel** fuel made from living things

## Sustainable decision-making

Cage eggs have smaller **carbon footprints** than free-range systems because the birds produce eggs much more efficiently. In the short term, cage systems produce more eggs for less inputs using less land. Soiled litter and other waste products from intensive systems such as cage production must be disposed of appropriately. Poultry wastes that are disposed of inappropriately can lead to long-term consequences such as contamination of soil and groundwater. Soiled litter and manure can also release large amounts of greenhouse gases when left to decompose in piles.

While free-range and pastured production uses more land to produce less, the environmental impact is not a simple equation. Pastured egg production, for example, adds poultry manure to the soil in the long term. Much of the carbon in the manure is then locked up in the soil rather than being released into the atmosphere. Animal welfare advocates argue that free-range chickens have a higher quality of life than caged hens and believe this should be taken into account when comparing systems.

**carbon footprint** the total greenhouse gas emissions caused by an individual or activity



### LET'S DISCUSS

- 1 Which is more important: efficient production or animal welfare?
- 2 Compare the short-term costs and long-term consequences of cage systems to free-range and pasture systems.

## AG IN FOCUS

### SOMMERLAD MEAT CHICKENS: A SUSTAINABLE ALTERNATIVE?

#### Identify

Sommerlad chickens are a slow-growing Australian meat breed. Bred for Australian free-range conditions, Sommerlads are reported to be a healthier, more sustainable option to the imported Ross and Cobb meat breeds that dominate the Australian meat bird industry. Slow growth, however, means that their cost of production and use of inputs such as feed and electricity can be higher.



© Grassland Poultry

#### Understand

Commercial meat chickens are based on two overseas breeds and grow quickly to reach market size as early as five weeks after hatching. The high growth rates and heavy carcasses of these birds can lead to heart disease and joint problems, especially for birds harvested at older ages. Footpad dermatitis, an inflammatory skin condition, is also common. Bred for intensive indoor conditions, these birds often don't venture far in free-range conditions, preferring to avoid heat stress and stay near sources of feed and water.

**Figure 13.22** Sommerlad hens foraging on a free-range farm



Sommerlad chickens take 12 to 16 weeks to grow to market size. Because of the slower growth rates, their meat has more texture and a richer flavour than commercial meat birds. They are heat tolerant with stronger legs and enjoy foraging. They also have lower mortality rates than commercial breeds.

### Discussion

Imagine you are a meat bird farmer running a barn enterprise. You currently have three growing sheds and raise Ross x Cobb chickens but are considering changing to free-range production. After attending an industry conference, you become interested in Sommerlad chickens and decide to investigate whether they would be a sustainable alternative for your chicken farm.

- 1 Construct a mind map outlining the short- and long-term impacts of changing over to Sommerlad chickens in terms of environmental, financial, animal welfare and other impacts.
- 2 Which breed of meat chicken will you choose to make your farm more environmentally and financially sustainable in the future? Justify your decision based on your assessment above.



Web link

Learn more about these chickens at the Sommerlad poultry website



## LET'S REVIEW

### LOOKING BACK

- 1 Compare the feed conversion ratios of meat chickens and other farm animals.
- 2 Explain the benefits of pastured egg production for other livestock farmers.
- 3 Explain why cage production eggs have a smaller carbon footprint.

### FOR YOU TO DO

- 1 Conduct a class debate on the following statement: 'Cage production is the most environmentally sustainable egg production system.'
- 2 Investigate organic fertilisers available at the local garden centre or used at school. Which ones contain poultry manure, and what are their NPK ratios?

### TAKING IT FURTHER

- 1 Research how electricity is used in poultry farms.
  - a What aspects of poultry farming use the most electricity?
  - b Observe and record temperature and airflow for various locations within the school's poultry house.
  - c Based on your recordings, design a new poultry house that will aim to reduce the electricity use of the enterprise. (Hint: consider ways to heat, cool and increase airflow in your house.)
- 2 Research biofuel production from other agricultural waste products.



Web link

Energy costs of broiler production



Web link

Optimising farm energy use

## 13.8 Marketing

### Marketing eggs

#### The market

Fresh eggs are increasing in popularity in Australia. The market expanded 54% between 2008–2018, with the average Australian now consuming 245 eggs per year. Over 6.2 billion eggs were produced and sold in the 2017–2018 financial year, at a value of over \$940 million.

Eggs are packaged and marketed according to their production method, with cage, free range and barn laid eggs representing the majority of eggs sold. Speciality eggs, including pastured, organic, corn fed and nutrient-enhanced are also sold.

The CSIRO 2018 Australian Egg Industry Community Research report described egg consumers as very concerned with animal welfare and how their food is produced. Most consumers surveyed said that the egg industry should be regulated and that the type of production system was the most important factor in determining which eggs they purchased. This is supported by the rise of free-range egg sales, which outstripped cage egg sales for the first time in 2018, as can be seen in Table 13.6.

**Table 13.6** Production systems and sales for 2017-18

Production system	Volume sold (2017–18) (%)	Change in volume (since 2016–17) (%)
Cage	43.99	-4.93
Free-range	45.38	+4.06
Barn	9.12	+0.75
Speciality	1.51	+0.12



Weblink

Explore the CSIRO's findings on the egg industry

Eggs are mainly packaged and sold fresh within Australia. Some also enter the processing sector and are then sold as egg pulp, liquid eggs, egg powder and other products. A small volume of fresh eggs and egg products is exported, mainly to Hong Kong, Singapore and Sri Lanka.



**Figure 13.23** Egg marketing chain

#### Specifications and egg grading

After collection, eggs are transferred to the grading and packing room. They undergo a number of tests and are sorted according to weight.

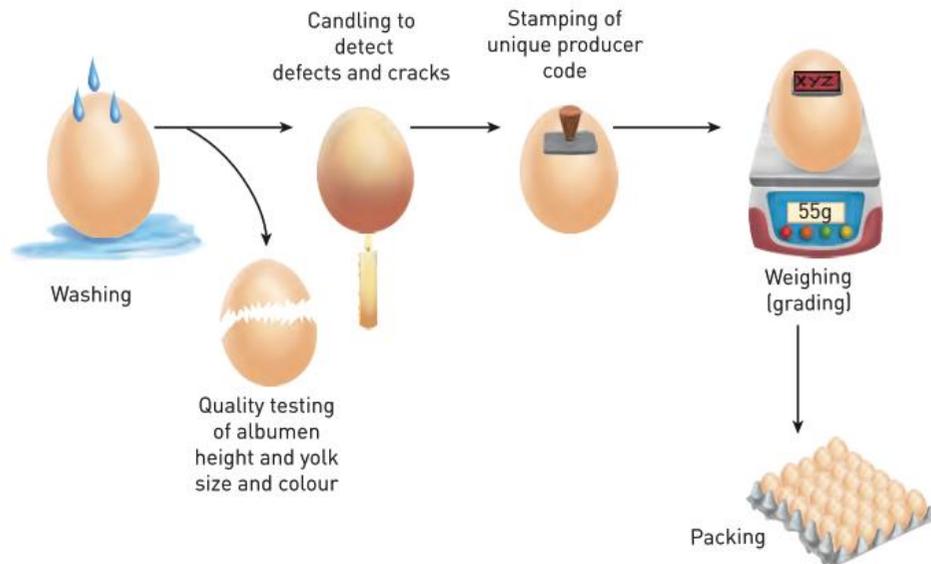


Figure 13.24 Egg grading



LET'S ENGAGE

## JUDGING EGGS

### PURPOSE

To assess the quality and grade of eggs

### RISK ASSESSMENT



Wash hands before and after this activity.

### MATERIALS

- Fresh eggs from school hens
- Candling equipment (from incubation and candling activity)
- A suitable flat surface for egg breakout

### METHOD

#### Judging the exterior

- 1 Check the egg shells for cleanliness, texture, shape and soundness. Shells should be clean, smooth and uniform with no cracks or ridges. There should be one distinctly pointy end and one blunt end.

#### Judging the interior: Candling

- 2 Examine eggs for blood spots, imperfections and cracks. Yolks should be visible with a distinct outline and air spaces should be small.

#### Judging the interior: Breakout method

- 3 Carefully crack an egg onto a clean, flat surface. Examine the albumen

and yolk. The albumen should be clear, thick and firm, with no spots or discoloration. The yolk should have a distinct outline and round shape with no mottling, blood spots or embryo development. The cracked egg should not spread out and should instead rise up high and plump above the surface, as can be seen in Figure 13.25.

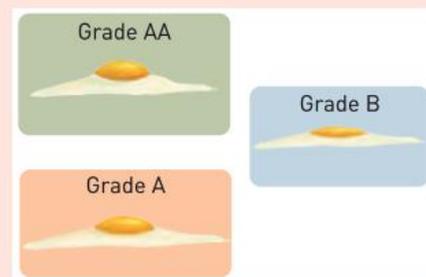


Figure 13.25 Grading eggs using the breakout method

### DISCUSSION

- 1 Write a report on your findings.
- 2 Create a class summary of the results from egg judging. What management decisions would you suggest based on the quality of the school's eggs?

## Egg marketing strategies

### How are eggs sold?

Eggs sold for human consumption must comply with the Food Standards Code. They must be clean, free of chemical contaminants and stamped with the producer's unique code. To meet the specifications for free-range production, producers must also label cartons with their stocking rate.

Almost half of all eggs are sold at supermarkets. Most of these eggs are from large-scale producers who dominate the market and sell directly to large retailers. A number of small-scale specialty producers sell their eggs using direct marketing at farmers markets, local grocery stores, fruit shops and other businesses.

### Value-adding

Eggs can be processed into a number of value-added products and by-products, including egg pulp, powder, liquid or powdered egg, and scrambled egg mix. Some egg companies are now producing egg-based pre-cooked meals that are snap frozen and exported or sold locally to hospitals, aged care facilities and the army.

## Marketing chicken meat

### The market

Australian chicken meat consumption per capita has increased from 4.6 kg in 1965 to 47 kg in 2016. Chicken meat is affordable compared with other meats and is seen as a healthy option. The availability of ready-to-eat and processed chicken products has also opened up new markets and increased consumer demand. Most chicken meat is destined for the domestic market, but a growing proportion is being exported.

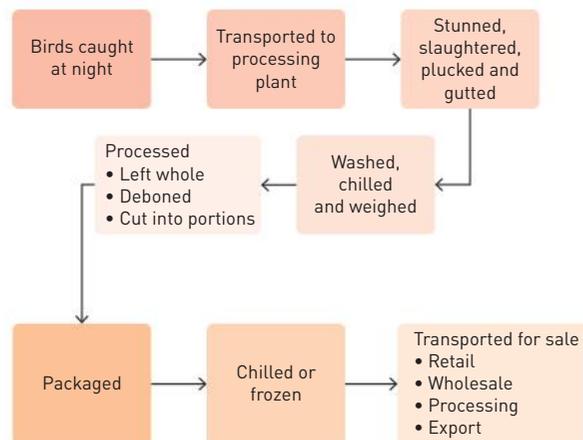


Figure 13.26 Meat marketing chain

### Specifications for chicken meat

Whole chickens are graded on weight. Chicken meat must be free of chemicals and contaminants and have no visible damage. Meat must be kept chilled under 5°C or frozen below -18°C.

### Chicken meat marketing strategies

Chicken meat is mainly sold through large companies directly to retailers. Some producers market their own meat but the closure of a number of small animal abattoirs throughout the country has made it difficult for many of these farms to process meat birds.

Many poultry farms are vertically integrated, meaning the business owns more than one step in the marketing chain. Large producers often own feed mills, hatcheries and processing plants.

### Value-adding

The popularity of chicken meat is due in part to the variety of value-added products that are available, including BBQ chickens, roasts, Maryland pieces, skinless breast and thigh pieces, rissoles, mince and crumbed chicken.



Worksheets

Practise analysing the specifications for chicken meat by judging your own carcass. Follow the instructions on the NelsonNet activity sheet



## LET'S REVIEW

### LOOKING BACK

- 1 Describe the trends in cage, barn and free-range egg sales over time.
- 2 According to the CSIRO report, what is the most important factor in determining the type of egg that consumers purchase?
- 3 Identify three food safety requirements for eggs sold for human consumption.
- 4 What information must be provided on free-range egg cartons?
- 5 Why has chicken meat consumption increased since the 1960s?
- 6 Define the term 'vertically integrated' and give an example of vertical integration in a poultry enterprise.

### FOR YOU TO DO

- 1 Make a list of all the value-added chicken products sold in your local area. Research the marketing chain for one of these value-added products and draw it as a flowchart.
- 2 Write a report on the changes in chicken meat production and consumption in Australia over time. Use the Australian Chicken Meat Federation's website to research the data.
- 3 Investigate a recent promotional campaign for eggs.
  - a Identify the target audience for this campaign.
  - b Describe the campaign: what is the message and how is it being delivered?
  - c Assess the effectiveness of this campaign. Do you think it is an effective way of increasing consumer awareness of and demand for eggs?

### TAKING IT FURTHER

- 1 Design an egg carton for your school farm. Make sure to include nutritional data, stocking density and a 'packed on' date.
- 2 Conduct a marketing survey of teachers and students at your school inquiring about:
  - a how often they consume eggs
  - b at which meals they generally eat eggs
  - c the most important factors that influence their decision to purchase eggs, including price, freshness, health benefits and animal welfare concerns.
- 3 Create your own value-added egg product. Design a promotional campaign for your product involving two methods of communication (e.g. posters, podcasts, television commercial or social media page). Consider the data you have gathered from the marketing survey when designing your product and promotion.



Web link

Australian Chicken  
Meat Federation



Web link

Australian Eggs



Web link

SurveyMonkey

# Let's summarise

## How has poultry farming changed over time?

Before European settlement of Australia and New Zealand, a number of bird species were hunted and managed for meat, eggs and feathers. Chickens were and remain the most popular poultry species since their arrival.

The emergence of large-scale suppliers of chicken meat and eggs has transformed the poultry industry. Birds have been selectively bred to be much more productive and efficient than their old backyard relatives.

Use the following terms to construct a mind map showing the changes that have occurred in poultry farming in the recent past.

Selective breeding and hybrids	Climate control	Specialisation (hatcheries, breeding farms, etc.)
Gene markers	Consumer demand	Biosecurity
Barn, free-range and pastured production	Disease prevention	Location of farms



Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about poultry farming.

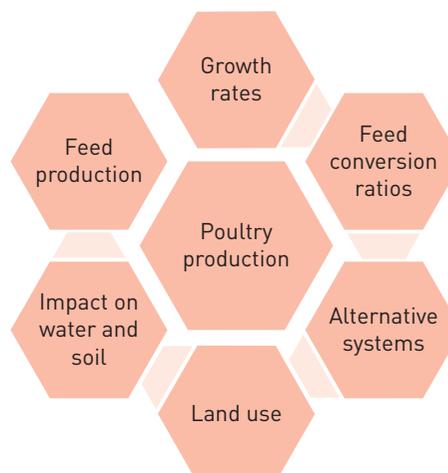
## How can chickens be produced ethically?

Consumer interest in animal welfare has changed the nature of egg farming, with more birds now being kept in free-range systems than cages. Construct a table to compare the different production systems in terms of the following factors that affect animal welfare: freedom to express natural behaviours, protection from injury, disease and death, sources of stress, environmental conditions (climate, space, noise, air quality). Now that you have learnt about poultry production, which systems would you recommend?

## Are chickens a sustainable alternative to other farm animals?

Chickens have been selectively bred to grow rapidly and convert feed into meat very efficiently. Cage production is a very efficient way of producing eggs whereas pastured production can be used to replenish soils and improve pasture health.

Compare poultry production with other meat systems using the following criteria.



# Enterprises of the future

Section

4



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# Bees and other insects

## CHAPTER SUMMARY

Bees are one of the most useful insects in agriculture. They pollinate crops, which enables fertilisation and seed setting. Without fertilisation there is no grain, fruit, chocolate or coffee production. Honeybees produce honey and other products such as beeswax, pollen, propolis and royal jelly. But bees aren't the only useful insect in agriculture. Edible insects have long been a popular food in non-Western countries. Given the world's rising population, edible insects such as mealworms and crickets could provide a more sustainable option for eating meat.

**How do bees and other insects affect agricultural production?**

**Can insects replace meat as a source of protein for human consumption?**

## 14.1 Introduction

Bees and other insects are important to agriculture production all around the world. Australia produces 25 000–30 000 tonnes of honey annually. Bees also assist the growth of other crops like cocoa by helping the pollination process.

Increasing multiculturalism in Australia has opened up opportunities for edible insects. While previously seen as a delicacy around the world, such as in Cambodia, insects such as crickets are increasingly being included on restaurant menus here in Australia. Edible insects are considered a more sustainable protein enterprise because they take up less space and use fewer resources.

**DID YOU KNOW?**

Insects are eaten by more than 2 billion people, every day!

# Bees

## 14.2 Functions and anatomy

### Functions

#### Produce

Bees produce many different useful products. Table 14.1 describes these products and how they are used.



**Figure 14.1** Bees make many products aside from honey, including beeswax and royal jelly.

**Table 14.1** Produce made from bees

Product	What is it?	Uses
Honey	Nectar collected from flowers is regurgitated by bees to change it into a liquid form. The liquid is sealed in cells creating a honeycomb effect.	<ul style="list-style-type: none"> <li>• Food</li> <li>• Sugar</li> </ul>
Beeswax	Natural secretion from wax glands on the sides of honeybees.	<ul style="list-style-type: none"> <li>• Forms honeycomb cells</li> <li>• Skincare products</li> <li>• Candles</li> <li>• Furniture polish</li> </ul>
Resin	Sticky liquid that oozes from the buds of certain trees. Chewed and mixed with bee saliva to create 'bee glue'.	<ul style="list-style-type: none"> <li>• Seals any gaps in beehive</li> <li>• Protects against climate changes such as wind and cold</li> </ul>
Royal jelly	Saliva from the worker bees, used to feed the queen bee. Because of the amount of vitamins in the saliva, the queen bee grows twice the size of the worker bees.	<ul style="list-style-type: none"> <li>• Food for the queen bee</li> <li>• Boosts the immune system of humans</li> </ul>
Manuka honey (medicinal honey)	<p>A honey native to Australia and New Zealand, created by bees that pollinate the native manuka bush.</p> <p>Manuka honey has been found to be particularly high in an antibacterial compound called methylglyoxal. While most honey contains methylglyoxal, manuka honey has particularly high concentrations because of the nectar from the manuka bush.</p>	<ul style="list-style-type: none"> <li>• Developed into dressings to treat wounds</li> <li>• Antibacterial qualities</li> <li>• Repair tissue</li> <li>• Ease inflammation</li> <li>• Fights infection</li> </ul>



Video

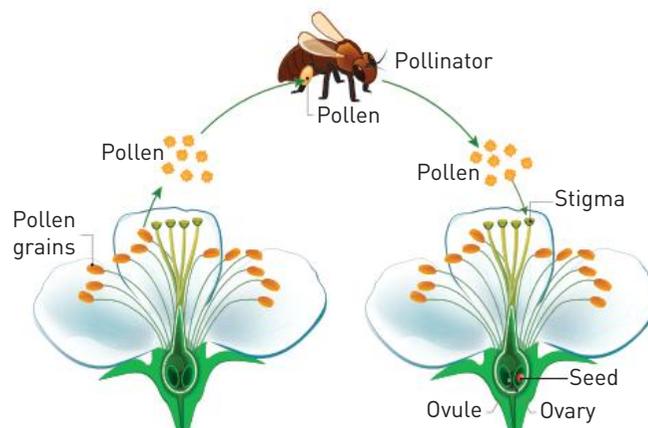
Watch the *Landline* episode to explore the popularity of Western Australian honey.

## DID YOU KNOW?

Sellers often sell fake manuka honey because it goes for a higher price. For example, New Zealand producers made 1700 tonnes of manuka honey in 2014 but somehow 10000 tonnes were sold.

## Agriculture production

Honeybees, butterflies and some other insects play a crucial role in agricultural production. They transfer pollen from the male part of a flower to the female part of the flower. When an insect lands on a flower to pick up nectar, pollen also attaches to its body. Then, when it flies to the next flower, the pollen is transferred. This process is called pollination.



Shutterstock.com/Designua

**Figure 14.2** The pollination process

## DID YOU KNOW?

An estimated third of the entire world's food production is dependent on pollination.

Bees are essential for some of our favourite products, including chocolate and coffee. In Australia, it is estimated that the benefit from honeybee pollination is \$4–6 billion annually. Several crops rely on bees and insects for pollination, with some of Australia's agricultural enterprises entirely dependent on pollinators. For example, without bees, the Australian fruit and vegetable industries would be destroyed. It is estimated that about 65% of all agricultural horticulture and crops in Australia are dependent on bees and other pollinators.

**Table 14.2** The reliance of different crops on honeybees

Plants, fruits and crops	Reliance on honeybees for pollination
Avocado, almond, onion, sunflower	100%
Cucumber, mango, apple, asparagus, cherry, kiwifruit, rock melon, pumpkin	90%
Apricot, watermelon, other melon, plum	70%
Peach, nectarine	60%
Pear	50%
Orange, canola	30%
Cotton	20%
Grapes, tomato	10%



## LET'S DISCUSS

What will happen to Australia's agricultural industry if the bee population dies out?

## AG IN FOCUS

### ARE BEES THE NEXT SPIES?

#### Identify

A number of companies have developed 'bee backpacks', small devices that can be attached to bees to track their behaviour. The lightweight sensors weigh about the same as a grain of rice.

#### UNDERSTAND

Australian researchers at CSIRO, alongside those working for Hitachi, used the sensors to track bees entering and exiting the hive and where they went. This helped researchers understand bee movement and behaviour patterns and to track how diseases might travel between colonies. For example, the study showed that 20% of bees move to a different hive for a short period.



**Figure 14.3** Bee sensors

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Meanwhile in the US, a sensor called RoboFly has been developed. These sensors are powered by the energy from the bee's movement and are also recharged when the bee returns to the hive. The intention is that bees could be used to monitor crops because they usually forage all day (whereas drones, which are used frequently for crop monitoring, require charging every 20 minutes). These sensors could monitor and collect information about the environment and the crops.

### Discussion

- 1 What data will be gathered by the sensors?
- 2 Compare how each company intends to use the sensors.
- 3 Discuss any privacy concerns that could be raised from the development of the US bees, which can collect information about crops.

## Anatomy

### The bee

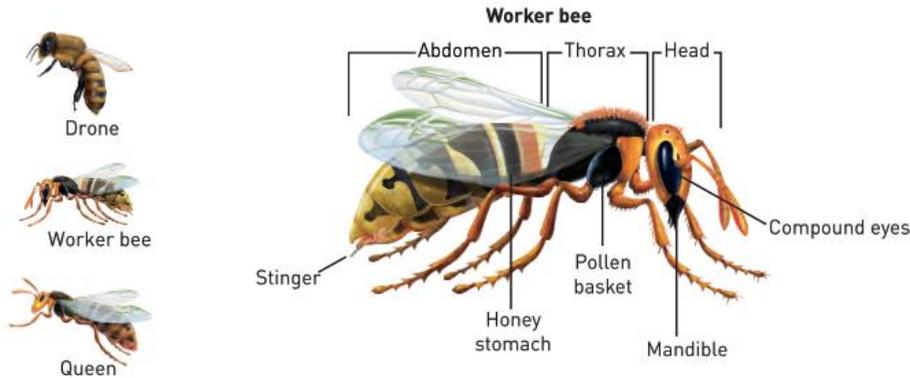


Figure 14.4 Anatomy of a worker bee

Bees are made up of three sections, the abdomen, thorax and head. Table 14.3 describes the functions of each part of a bee.

Table 14.3 Anatomical functions of a worker bee

Part	Function
Compound eyes	A group of many eyes that each have a separate lens and can look in different directions
Pollen basket	Where pollen collects on a bee when they land on a flower
Honey stomach	Where bees store the nectar before regurgitating it as honey
Stinger	A poisonous barbed weapon used to defend itself and the hive. The stinger is an evolutionary part left over from when female bees would insert their eggs into a different insect. When a person is stung, the honeybee stinger lodges itself in the skin, and both the stinger and abdomen is torn away from the bee.
Mandibles	Appendages next to the mouth of a bee that move from side to side and are used to help bees cut and carry things



Worksheets

Review your knowledge about the *Anatomy of a bee* with the worksheet.

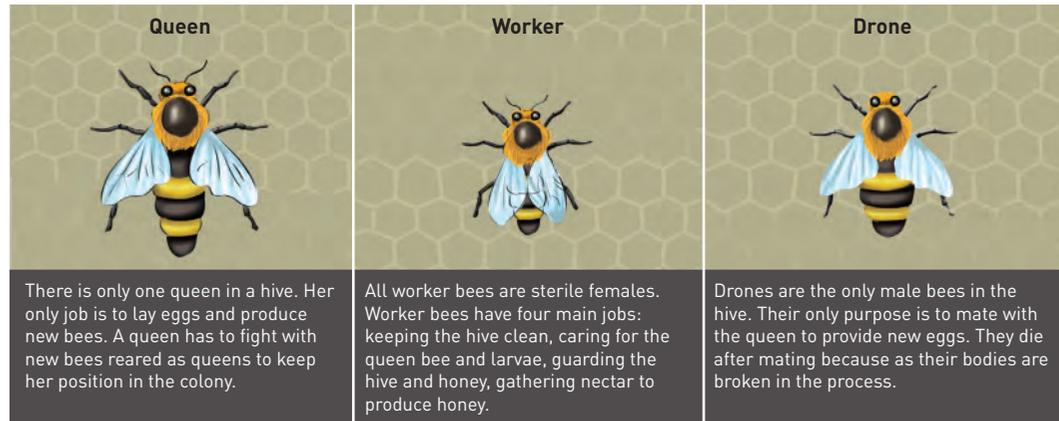
### Types of bee

Bees are social insects and live together in highly organised colonies headed by a queen bee. Each colony can have up to 50 000 bees.

**DID YOU KNOW?**

A collection of hives is called an apiary.

There are three types of bees in a hive: worker bees, drone bees and one queen bee. They each have a different job to do.



**Figure 14.5** Types of bees in a colony

### DID YOU KNOW?

Drone bees get thrown out of the hive in winter to save food because they eat too much.



WebLink

Learn about Australian native bees with the CSIRO guide.



WebLink

Use the Aussie Bee Native Bee ID Guide to help spot native bees

## Breeds of bee

Australia has both native bees, such as the Banksia bee, and introduced bees, such as the European honeybee. Both honeybees and native bees play a role as pollinators of crops and wild flowers. Some wild flowers have suffered from the presence of honeybees because these flowers can only be pollinated by native bees. Some native bees use a special pollination technique required by certain flowers called buzz pollination. Honeybees do not use this technique and remove pollen without pollinating the flowers.



## LET'S REVIEW

### LOOKING BACK

- 1 List five different products made by honeybees.
- 2 What can be beeswax be made into?
- 3 What is Manuka honey?
- 4 Why does Manuka honey have special medicinal properties?
- 5 Describe the three types of bee in a hive and what their jobs are.



### FOR YOU TO DO

- 1 Draw and label a diagram of a worker bee.
- 2 Research the anatomy of a queen bee.
  - a Draw and label a diagram of the queen bee.
  - b Describe the anatomical differences between a queen bee and a worker bee.
  - c Now research the anatomy of a drone bee and answer the same questions.

### TAKING IT FURTHER

- 1 Investigate the importance of bees to the Australian agriculture industry.
- 2 Research other products produced by bees, such as bee pollen, honeycomb and bee venom.

## 14.3 Production

### Production cycle

#### Lifecycle of a honeybee

Bees have a complete lifecycle, meaning they go through all four stages of an insect lifecycle: egg, larva, pupa and adult. The length of the lifecycle differs for the type of bee; for example queens only take about 16 days to develop while drones take about 24 days.

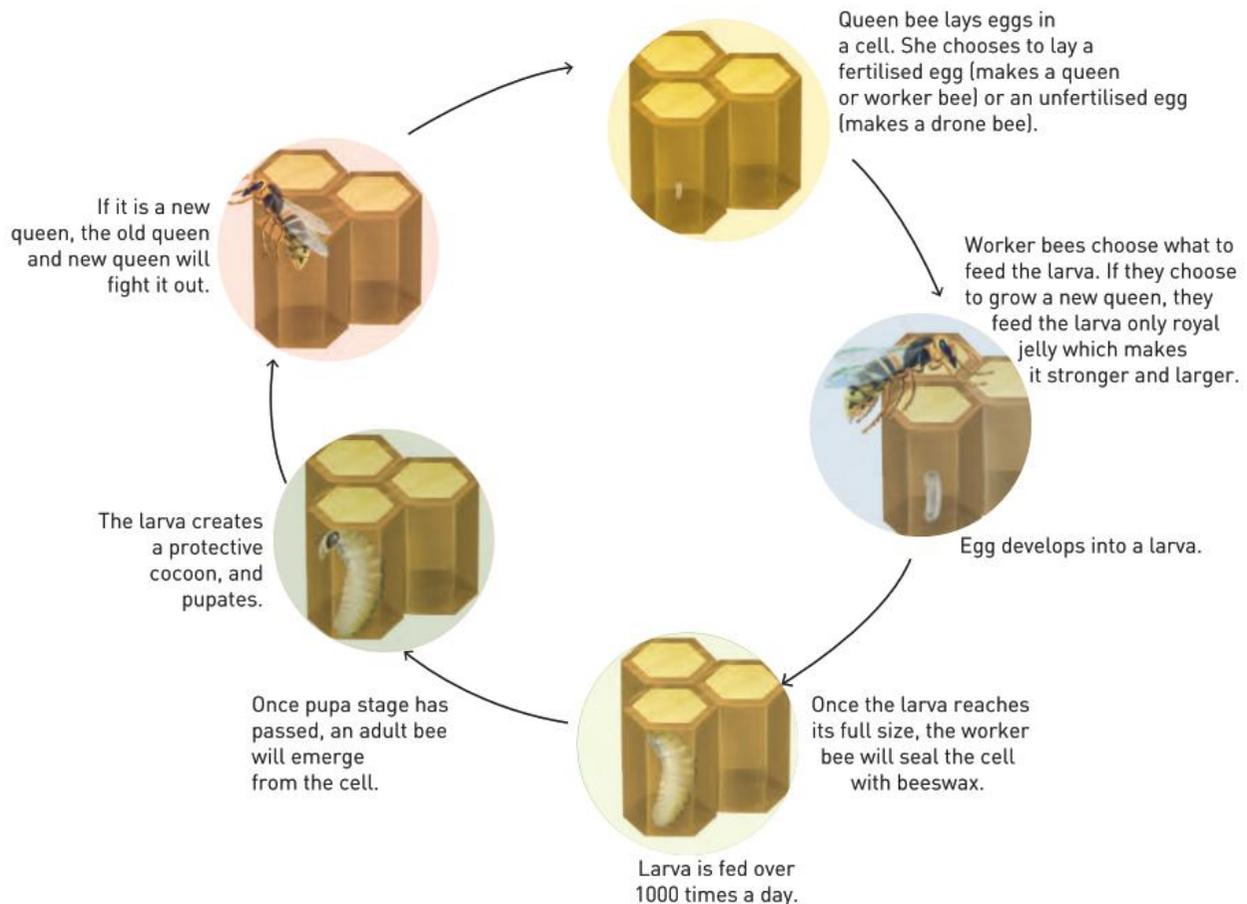


Figure 14.6 The lifecycle of a bee

**swarming** when a queen and worker bees leave an overcrowded hive to find a new home

In late winter, the queen bee will begin to lay many eggs quickly. By spring, the brood should be large and healthy, ready to harvest all the nectar. However, sometimes the brood might expand too much, meaning there is not enough food to feed them. If this happens, another queen bee might be born and decide to leave the hive and start a new colony, taking half the worker bees with her. This is called **swarming**.

**DID YOU KNOW?**

A bee in the larva stage will eat more than 1000 meals a day.

## Production systems

### Aboriginal production system

Australia has eleven species of native stingless honey-producing bees. Native bees live in a colony and make honey by collecting and processing nectar. However, they make considerably less honey than European honeybees. Aboriginal Australians farmed the native honey by tying light materials, such as hair, feathers or blades of grass, to the bees. The extra weight made the bees fly slower, so they could be easily followed back to their hives. Aboriginal Australians were well aware of the importance of sustainability, and even if the hive was at the top of a tree, they would not cut the tree down to reach it. Instead, they would carve holes into the bark to climb up and would only ever harvest part of the honey and wax, so the bees would survive, and they could harvest again later.

### Native bee production systems

While native bees can be produced using a box hive system, they perform better when left in a natural setting, such as in inside logs, because sometimes the hive can die when being transferred from nature to a box. In addition, the box hive systems do not provide as much warmth for the bees, which like a warm, humid atmosphere.

The native bee boxes are smaller than those used for European honeybees. Because they lack the same amount of warmth as natural production systems, the boxes must be placed in warm area, in a high place to replicate the natural setting of inside a branch, log or tree.

### Traditional hive systems



Worksheets

Make your own beehive with this practical worksheet.

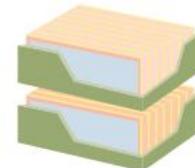
#### 1 Covers

The cover should be able to protect against the weather, providing shelter from rain and wind. An inner cover acts as insulation, making sure no warm air escapes the hive.



#### 2 Honey supers

The supers are where the bees make and store their honey. Each super contains 10 frames of honeycomb for honey collection.



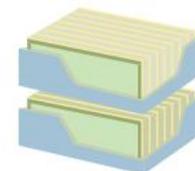
#### 3 Queen excluder

The queen excluder is used to keep the queen bee in the bottom half of the hive, in the brooding zone.



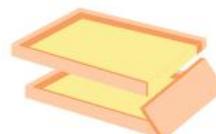
#### 4 Brood chambers

Brood chambers each have 10 frames of honeycomb. The queen will lay her eggs in this honeycomb, and the workers will raise the baby bees here. One brood chamber houses the larvae, the other houses their food.



#### 5 Bottom board

The bottom board supports the entire hive.



**Figure 14.7** A Langstroth beehive

The most common type of traditional beehive is called a Langstroth beehive. This is a vertical stacked beehive that is adaptable and flexible. Different sections such as brood boxes and honey supers can be added, depending on the size of the colony. The brood boxes are located at the bottom, and the honey supers at the top.



## LET'S REVIEW

### LOOKING BACK

- 1 How long is the development cycle for a drone bee versus a queen bee?
- 2 What is swarming?
- 3 Describe how Aboriginal Australians farmed the native stingless bees.
- 4 How did Aboriginal Australians implement sustainable practices with native bee production?
- 5 What is the most common type of traditional beehive?
- 6 Why is it recommended to keep native bees in logs?

### FOR YOU TO DO

- 1 Make a poster detailing each stage of the bee lifecycle.

### TAKING IT FURTHER

- 1 Compare the sustainability of each of the three types of production system: the Aboriginal system, native bee system and traditional beehive.

## 14.4 Management

### Environmental management

#### Distribution of enterprises

Native bees and European bees are located in different areas around Australia.

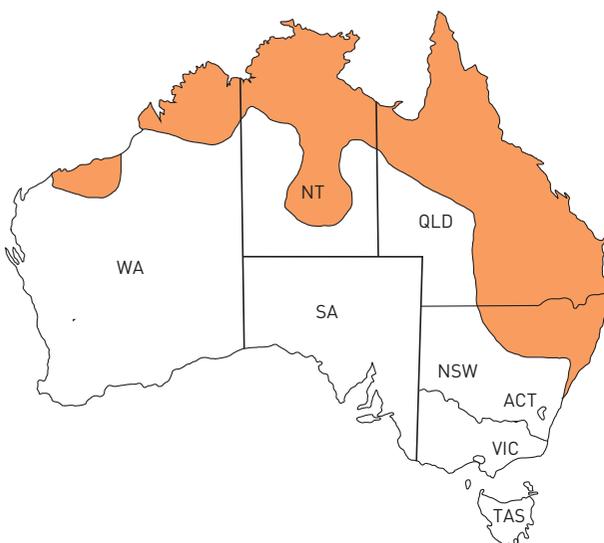


Figure 14.8 Location of native bees

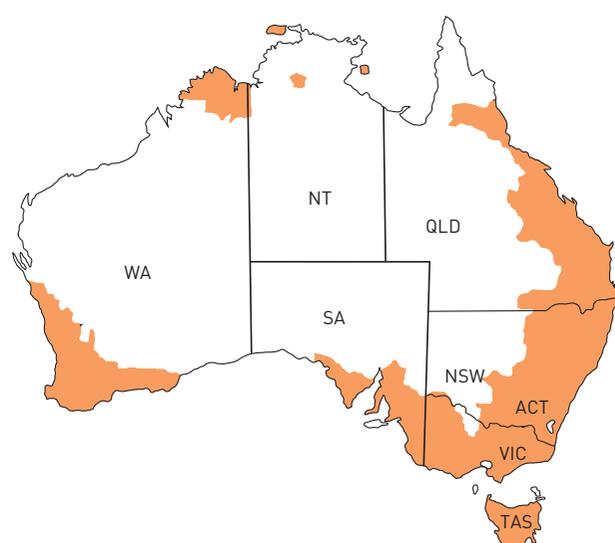


Figure 14.9 Location of European honeybees



Explore urban vs rural beekeeping by watching the two-part ABC show, *The Great Australian Bee Challenge*.

European honeybees can cope with the cooler temperatures of southern Australia, while native bees need the humidity and heat of the north-east. While native bees can produce plenty of honey in areas such as Queensland, if they are in more temperate locations such as Victoria, honey cannot be harvested because the bees only create enough to feed themselves; taking it will starve them.

## Climate

Climate is more of a problem for native bees than the European honeybee. Instead, climate affects beekeepers in a more roundabout way: bees need nectar from plants and climate affects whether those plants can grow. Therefore, most production occurs close to the coast where there is regular rainfall and native fauna is able to grow and provide food for the bees. The majority of bees in Australia collect nectar from native flora.

While bees won't fly when temperatures drop to around 13°C, they generally do not mind cold temperatures and will stay in the hive keeping warm until temperatures rise again. In winter, when temperatures are regularly below 13°C, bees will not fly and collect nectar, instead they feed on the honey inside the hive until spring.



## LET'S DISCUSS

- 1 Global warming is affecting temperatures around the world and causing seasonal disturbances, such as hotter temperatures earlier in spring. What effect do you think this will have on bees?

## Enterprise management

### Reproduction

#### The reproduction process

The queen bee is the only female bee that can reproduce because all worker bees are sterile. She can reproduce via sexual or asexual reproduction. For sexual reproduction an egg must be fertilised, and therefore the queen bee and a drone bee will mate. The queen bee announces her intention by leaving the hive and flying upwards. The drones then gather around her and she mates with several of them while flying.

During the mating process, a drone bee's genitals are ripped from his body.

Once the queen has mated, she stores the sperm for later. This means she can actively choose whether or not to fertilise an egg during the laying process. The development and hatching of unfertilised eggs is called parthenogenesis (asexual reproduction). She reproduces by laying the eggs in the hive.

**DID YOU KNOW?**

Drone bees die after mating.

**DID YOU KNOW?**

Worker bees are from fertilised queen eggs, while drone bees are from unfertilised queen eggs.

### Artificial insemination and breeding

Queen bees and drone bees are genetically bred, in a similar way to other animal enterprises. Preferred traits include resistance to disease, calmness, and longevity. To ensure genetic diversity, specialised bee breeders can artificially inseminate a queen bee. They will mix the semen from different genetically strong drones before inseminating the queen.

### Nutrition

Bees generally find their own food by looking for nectar in plants. Different plants will provide different nutrition. If a colony does not receive enough food, worker bees may eat the drone bee eggs or the drone bees themselves.

A beekeeper can provide extra food for their colony, if the bees are not receiving enough from nature. Common food items that can be given are sugar or syrup. This can be delivered to the bees directly, via a tray or sprayed onto flowers where bees can collect it naturally.

In addition to collecting nectar for adult bees, bees also collect pollen for the bee larvae. Pollen provides the larvae with protein, helping them grow.



Data scenario

Investigate the type of food bees prefer with this data scenario.



## LET'S REVIEW

### LOOKING BACK

- 1 Explain the differences in location for native bees and European honeybees.
- 2 Explain the difference between sexual and asexual reproduction in bees.

### FOR YOU TO DO

- 1 Research other matriarchal insect societies, such as those of spiders. How do their reproductive processes compare to bees?
- 2 A farmer is investigating the possibility of starting a native stingless beehive in inner-city Melbourne because they recently heard that urban beekeeping is possible. They have asked you for your recommendation. Prepare a report detailing why you either recommend or do not recommend this proposal.

### TAKING IT FURTHER

- 1 Investigate how to establish a beehive in your backyard.
- 2 Research the impact of crop loss on bee production.

## 14.5 Pests and diseases

### Pests

#### Varroa mite

The varroa mite is one of the most dangerous pests for honeybees. Australia is currently the only continent that does not have the mite. Eradication has so far not been possible in any affected country. The varroa mite is very small, the size of a



Figure 14.10 Varroa mites are very difficult to spot.



Video

Watch the *Landline* episode discussing measures to prevent the varroa mite reaching Australia.

sesame seed, and attacks bee larvae in their cells. They prefer to attack drone larvae, but will also attack workers. They will suck the blood from the larvae until the larvae die. They will then lay eggs and ten days later new mites emerge to attack new larvae. Because of its size and dark colour, the varroa mite is difficult to spot on adult bees. It travels between hives on the back of worker or drone bees that have wandered off.

It is expected that the varroa mite will reach Australia. Unfortunately, because Australian bees have no resistance to the pest, it is expected that 95–100% of all feral honeybees will die.

### DID YOU KNOW?

When the varroa mite reached New Zealand, the number of native bees dropped by 90%.

## AG IN FOCUS

### PROTECTING AUSTRALIA FROM THE VARROA MITE

#### Identify

In 2018 the varroa mite was detected in Port Melbourne on a ship that had sailed from the USA.

#### Understand

A bee colony, arriving from the USA, was found to be infected with the varroa mite. The varroa mite was discovered after the ship's captain had spotted several dead bees around the ship. When the ship arrived, the colony was examined by Agriculture Victoria, which confirmed the presence of the mite.

The colony was destroyed, but there were still concerns that some bees could have travelled from the ship into Melbourne. Thankfully, this was unlikely because the cold weather at the time meant the bees were lethargic and keeping to the hive. Biosecurity officers checked gardens within a 2 km radius of the port.

Victorian authorities are particularly vigilant about checking for the varroa mite, and therefore likely saved the rest of Australia from the infestation. 'Sentinel hives' have been established in areas of green space around the Port of Melbourne and other ports around Australia. When bees are imported, they can travel off the ship and into Melbourne before the ship docks and has been checked by biosecurity officers. These sentinel hives are monitored closely for any sign that an imported bee has arrived and joined the hive, bringing with it the varroa mite.

#### Discussion

- 1 How was the varroa mite infestation spotted?
- 2 How is Agriculture Victoria working to prevent the varroa mite from entering Australia?
- 3 Describe how the sentinel hives work.
- 4 Using your knowledge of IPM practices from other chapters, can you suggest any other techniques that could be used to help prevent the varroa mite entering Australia?

## Diseases

### American foulbrood disease

**Table 14.4** The signs and symptoms of American foulbrood disease

<b>Name</b>	American foulbrood disease (AFB)
<b>Cause</b>	<i>Bacillus</i> bacteria
<b>How it spreads</b>	Through contaminated equipment and frames. Larvae are infected by bacteria through food given by a nurse bee. The larvae are only susceptible during the first 24 hours of life.
<b>Symptoms</b>	<ul style="list-style-type: none"> <li>• Unusual cells or a scaly appearance (usually spotted by damaged caps)</li> <li>• In a cell where a normal larva should be developing, the larva is actually dissolved into a thick liquid.</li> <li>• Death</li> </ul>
<b>Prevention</b>	Regular inspection, hive hygiene and prevention of cross-contamination
<b>Control</b>	Antibiotics are used to control the bacteria. However, antibiotics are not effective in all hives because they leave residue and bacteria develop resistance within a few years.



Worksheets

Learn about bee colony collapse disorder.



## LET'S REVIEW

### LOOKING BACK

- 1 Which continent has not been infected with the varroa mite?
- 2 Explain how the varroa mite kills a colony.
- 3 Describe the symptoms of AFB.
- 4 What is the danger of using antibiotics to treat AFB?

### FOR YOU TO DO

- 1 Inspect a beehive for pest and diseases.
- 2 Investigate how to prevent the spread of AFB.
- 3 Design a leaflet for beekeepers warning them of the dangers of the varroa mite and how to spot it.
- 4 Investigate remote catch boxes and how they are being used to monitor for varroa mites.

### TAKING IT FURTHER

- 1 What is biosecurity and how does it protect honey production in Australia?
- 2 The small hive beetle was introduced to Australia due to the importation of queens from other countries. Research the small hive beetle and prepare a report detailing:
  - a how it affects honey production in Australia
  - b how Australia's biosecurity policies now help prevent the introduction of new pests.



Weblink

Preventing spread of AFB disease

## 14.6 Social and ethical issues



### LET'S DISCUSS

- 1 Do you think honey is a vegan-appropriate product?

### Pesticides

In 2008 millions of bees were found dead in Europe. An investigation was carried out and found the reason for the deaths was the pesticide, clothianidin. This pesticide disrupts the nervous system of agricultural pests, but also harmed bees, resulting in:

- a destroyed sense of direction (so they couldn't find their hives)
- damage to the queen bee's reproductive system
- sterile drone bees
- the death of millions of bees.

After five years of multiple studies into the pesticide and others like it, the EU announced a temporary halt on usage of three neonicotinoids (the world's most popular pesticides, one of which is clothianidin). In 2018 it banned the use of the pesticides entirely, outside of greenhouses. However, since both the temporary halt and the ban, bee populations have not recovered. This has led farmers to argue that pesticides weren't the only cause of death and they are being unfairly punished. They claim that is costing the EU agriculture sector 880 billion euros annually because crop yields are not as high without the pesticides.



Video

Explore why bees are dying in the Riverina food bowl with this *Landline* episode.



### LET'S REVIEW

#### LOOKING BACK

- 1 What is clothianidin?
- 2 How does clothianidin affect bees?
- 3 What is the EU solution to clothianidin use?
- 4 Why do farmers think they are being unfairly punished?

#### FOR YOU TO DO

- 1 Conduct a class debate on whether the EU should reintroduce the use of clothianidin as a pesticide.
- 2 Research what bee colony collapse disorder is.
  - a Design a solution to prevent bee colony collapse disorder from occurring.
  - b Prepare a report or presentation detailing how you will solve this deadly disorder.

#### TAKING IT FURTHER

- 1 Evaluate how reintroduction of clothianidin will affect the agricultural industry, taking into account both increased crop yields and potential bee deaths.

## 14.7 Sustainability

### Sustainable practices and methods

#### Flow hive

A flow hive is a different type of beehive that allows beekeepers to extract honey without opening the hive (which disturbs the bees). A flow hive uses keys to twist the honey frames slightly, allowing honey to flow straight into jars without disturbing the hive. The use of flow hives has significantly reduced the death and disturbance caused to honeybees when extracting honey. This technology is beneficial to beekeepers as well and reduces physical labour in the honey production process.

However, beekeepers are concerned the ease of the system might encourage novices to try beekeeping, and that lack of knowledge about biosecurity and hygiene could lead to diseases and pests spreading.



Figure 14.11 A flow hive in the Sydney Botanic Gardens

Alamy Stock Photo/Stephen Dwyer



Video

Explore urban beekeeping as a sustainable practice. Discuss some of the benefits and disadvantages of keeping a hive in a city.

### Sustainable technology

#### Banksia bees

The Banksia bee, an Australian native bee, is able to create a biodegradable alternative to plastic. A biotech company based in New Zealand found that the Banksia bee creates a material for their nests that is water-repellent, flame-resistant, and can resist high temperatures and chemicals. The company is now trying to reverse engineer the process to be able to make this material on a commercial scale to be used as an alternative to plastic. Researchers are examining the DNA of the bees to find the genes that gives the bees the ability to make the plastic-like material.

While the company's researchers do not believe it could be used for single-use plastic items, they plan to sell into other industries such as the outdoor gear industry because recent tests by Greenpeace showed large amounts of toxic chemicals in outdoor gear such as tents and coats. This product will allow them to use a non-toxic compound to create the same waterproof effect.

### Sustainable decision-making

#### AG IN FOCUS

#### FRANKENBEES

##### Identify

One proposed solution to the declining bee populations is to genetically modify honeybees into a stronger species, which some have termed 'frankenbees'.



## Understand

Genetic modification of honeybees could result in a stronger species that is more able to cope with both environmental and human-made issues. They could breed resistance to pests like the varroa mite, or pesticides like clothianidin. In the long term, this would improve production for both beekeepers and crop farmers (who would be able to use the most effective pesticides again, increasing crop yield). Because yields would increase, this would help feed a growing population.

The use of genetically modified bees may help sustain honey and crop production, but it would do nothing to reduce the pressure on natural bee populations. In addition, by developing these bees, the use of pesticides will increase, causing long-term damage to other environments. Solutions such as this may negate our responsibility to the environment and animal species, if we can just 'breed a new one'.

## Discussion

- 1 Discuss the long-term impacts on sustainability from developing a frankenbee.
- 2 Can agricultural production be increased without harming the environment?
- 3 Debate the statement: 'The world needs farming practices that don't harm bees, not frankenbees (genetically modified super bees)'.



## LET'S REVIEW

### LOOKING BACK

- 1 How is a flow hive different from the conventional beehive?
- 2 What are the key strengths of the material Banksia bees produce?

### FOR YOU TO DO

- 1 Research the RoboBee, a robotic bee that has been developed to help pollinate crops.
  - a Describe the product.
  - b How can it help agricultural production?
  - c How do you think the RoboBee will affect our feeling of responsibility to protect the environment?
- 2 Design your own frankenbee.
  - a Identify your local climate. Write a short paragraph about the weather your bee will need to be bred to suit.
  - b Outline three key traits you think are important for your bee.
  - c Discuss the traits you chose, and why you thought they were important.

### TAKING IT FURTHER

- 1 Evaluate the impact Banksia bee plastic will have on sustainability.



WebLink

RoboBees

## 14.8 Marketing

### The market

Australia is one of the top ten exporters of honey in the world. Major export markets are China, the Middle East and North America. Australian honey varieties are recognised for their high quality and unique flavours, due to the availability of a wide range of native flora to the bees.

In 2018–19, the value of honey and beeswax produced in Australia was approximately \$132 million. The 2019 farmgate price for honey was between \$3.70 and \$4 per kilogram. To fulfil consumer demand Australia also imports honey from China, Argentina and New Zealand.

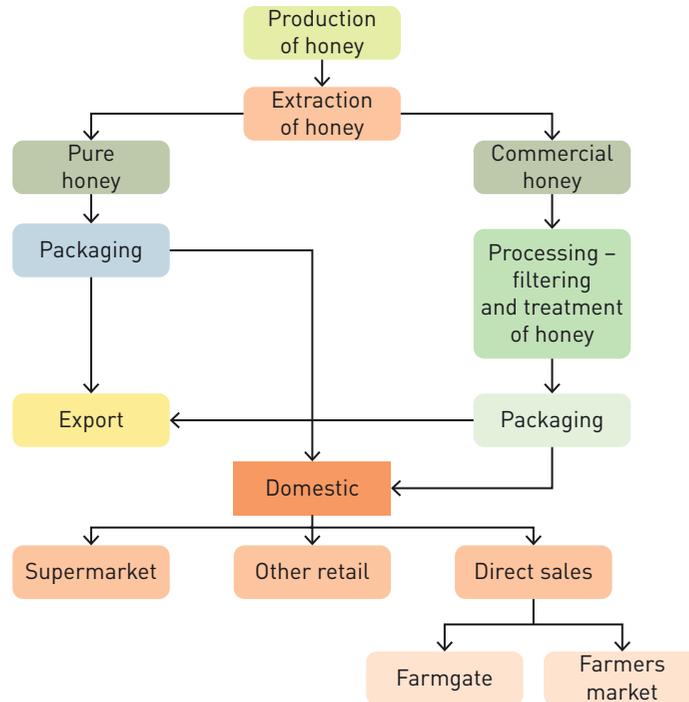


Figure 14.12 Marketing chain for honey

### Market specifications

Honey has several market specifications it must meet, based on factors such as:

- appearance: clear to turbid, no crystallisation
- odour: sweet, no chemical smell
- taste: sweet and strong
- colour: white, light amber to dark amber.

In addition, it must contain more than 60% reducing sugars (the sugar made from nectar by bees) and no more than 21% moisture.

Table 14.5 Types of honey

Honey types	Characteristics
Pure/raw honey	<ul style="list-style-type: none"> <li>• Honey not treated in any way</li> <li>• Contains wax, pollen grains, propolis and royal jelly</li> <li>• May not appear crystal clear</li> <li>• Usually sold by small, local speciality producers</li> </ul>
Commercial honey	<ul style="list-style-type: none"> <li>• Treated at high temperature</li> <li>• Filtered to a very low micron level (amount of water contamination in the product)</li> <li>• Usually found in major supermarkets</li> </ul>



## LET'S ENGAGE

## BEESWAX WRAPS

### PURPOSE

To make beeswax wraps. Beeswax is a by-product of honey production and can be used to produce value-added goods. Beeswax wraps are a sustainable and durable alternative to plastic cling film and can be easily made. They are also a great fundraiser for school agriculture programs!

### RISK ASSESSMENT



Hot beeswax and oven trays can cause serious burns. Use oven mitts and take care when transferring trays to and from the oven.

### MATERIALS

- Block of beeswax
- Patterned cotton fabric (clean recycled cotton will suffice)
- Pinking shears
- Old baking trays
- Cheese grater
- Paint brush
- Oven

### METHOD

- 1 Preheat oven to 85 °C.
- 2 Cut pieces of fabric to required size with pinking shears and place on baking trays.
- 3 Use cheese grater to grate beeswax.
- 4 Sprinkle beeswax over material and place in oven until beeswax has just melted.
- 5 Carefully remove from oven and use paintbrush to spread beeswax over fabric.
- 6 Allow to cool before use.

### DISCUSSION

- 1 Packs of three beeswax wraps sell for \$30 or more in some retail outlets. Calculate the cost of producing the beeswax wraps. Is this value-added product a worthwhile pursuit for some beekeepers?
- 2 Design packaging for your beeswax wraps using recycled paper.

## Marketing strategies

Table 14.6 Strategies for marketing honey

Marketing strategies	How it works
Direct marketing	<ul style="list-style-type: none"> <li>• Honey and other products sold at farmgate. Most farms have shops at the front, so honey can be extracted, processed, labelled and sold at the farm (vertical integration).</li> <li>• Considered more authentic</li> <li>• Have to do marketing themselves, often online or at local farmers markets</li> </ul>
Wholesalers/Contractors	<ul style="list-style-type: none"> <li>• Buy honey from many different producers and package and sell it as a company product. A company usually have their own beehives as well.</li> <li>• Better advertisement so therefore attracts more customers</li> <li>• Sells into major suppliers, so access to greater market</li> </ul>



Worksheets

Explore the value of export markets with the *Superbee* worksheet.



## LET'S REVIEW

### LOOKING BACK

- 1 Which countries does Australia export honey to?
- 2 What is the farmgate price of Australian honey?
- 3 Explain the difference between pure honey and commercial honey.
- 4 Explain the difference between direct selling and wholesale or contractor selling.



**> FOR YOU TO DO**

- 1 Conduct a blind smell and taste test on five different brands of honey.
  - a Which one is your favourite? Why?
  - b Which one is your least favourite? Why?
  - c Was there a relationship between preferred taste and price of product?
- 2 You are a small local honey producer who is about to attend their first farmers market to sell honey. Create a marketing plan to be carried out in the two weeks leading up to the farmers market. You will need to:
  - a plan social media releases and website design
  - b posters or flyers for the event
  - c business cards
  - d undertake any other marketing you feel is necessary.

**TAKING IT FURTHER**

- 1 Interview a local honey producer to find out more about their marketing strategies.
- 2 Compare the honey market in Australia to another country of your choice. Prepare a report detailing the similarities and differences.

# Insects

## 14.9 Functions and anatomy

### Functions

#### Produce

Some cultures use other insects as food. More than 1900 insect species have been identified as potential human food. Some insects are very nutritious, such as crickets and mealworms, with high levels of vitamin B12 and protein. One study found that crickets have higher protein and vitamin content than meats such as chicken and beef. Table 14.7 shows some of the study's key findings about the nutrition of insects and meats.

**DID YOU KNOW?**

It takes 11 000 crickets to make a 1 kg bag of flour.



Video

Explore how insect production is emerging in Australia with this *Landline* episode.

**Table 14.7** The nutritional value of insects and meats

Per 100 g portion	Beef	Pork	Chicken	Mealworms	Cricket	Mopane caterpillar	Honeybee brood
Calories	169	186	152	247	153	409	499
Protein	20.6 g	20.1 g	19.9 g	19.4 g	20.1 g	35.2 g	15.2 g
Fats	9.3 g	12.4 g	7.2 g	12.3 g	5.06 g	15.2 g	3.64 g
Saturated fats	3.8 g	3.5 g	1.81 g	2.93 g	2.28 g	5.74 g	3.64 g

Per 100 g portion	Beef	Pork	Chicken	Mealworms	Cricket	Mopane caterpillar	Honeybee brood
Sodium	60 mg	62 mg	80 mg	53.7 mg	152 mg	-	19.4 mg
Calcium	5 mg	7 mg	8 mg	42.9 mg	104 mg	700 mg	30 mg
Iron	1.95 mg	0.8 mg	0.88 mg	1.87 mg	5.46 mg	-	18.5 mg

In this study, mealworms were found to be more calorific than traditional meat such as pork and chicken, while crickets had 180% more iron than beef, a red meat usually viewed as high in iron.

**DID YOU KNOW?**

Cricket flour has 69% protein compared with around 10% in regular wheat flour.

Aboriginal and Torres Strait Islander peoples extensively used insects from their surroundings as food, medicine and as part of their cultural beliefs. Insects such as green tree ants have found a contemporary use in the niche food market, being infused into products such as gin and goats' cheese. Mealworms have become a popular source of food for chickens, replacing fishmeal, a controversial feeding option that depletes fish stocks purely to farm other fish.



Shutterstock.com/1000 Words

**Figure 14.13** Fried insects are a delicacy in parts of Asia.

**Table 14.8** Aboriginal Australians' use of insects

Insect	Use
	<ul style="list-style-type: none"> <li>• Food item, high in fat</li> <li>• Ten grubs can provide daily protein needs</li> <li>• The grubs are named after the witchetty stick used to dig them out</li> </ul>

Alamy Stock Photo/Bill Bachman

**Figure 14.14** Witchetty grub



- Medicine for headaches
- The nests are boiled and strained through coconut fibre to create a medicinal liquid
- The ants can also be crushed and rubbed on the skin

**Figure 14.15** Green tree ants

Alamy Stock Photo/imageBROKER

Insect	Use
 <p><b>Figure 14.16</b> Honeypot ants</p>	<ul style="list-style-type: none"> <li>• Medicine</li> <li>• Cleans the digestive system</li> <li>• Worker ants are overfed so their stomachs expand. In times of food shortage, the ants regurgitate some of their stored food to feed the others</li> <li>• Ants are dug out using a special technique to reach them; only a few are eaten at one time to ensure the colony continues to survive</li> </ul>
 <p><b>Figure 14.17</b> Bogong moth</p>	<ul style="list-style-type: none"> <li>• Food</li> <li>• Very high in fat</li> <li>• Collected from rock crevices where they gather in large numbers</li> <li>• Cooked moths are ground into meal</li> <li>• Ceremonies were conducted when the Bogong moths migrated south</li> </ul>
 <p><b>Figure 14.18</b> Bush cockroach</p>	<ul style="list-style-type: none"> <li>• Medicine</li> <li>• A local anaesthetic</li> <li>• Liquid is squeezed from the cockroach's anus and rubbed on the skin</li> </ul>

Alamy Stock Photo/John Cancalosi

Alamy Stock Photo/Auscape International Pty Ltd

Alamy Stock Photo/Genevieve Vallee



Learn more about Aboriginal and Torres Strait Islander peoples' use of insects with the NelsonNet worksheet.

## Production

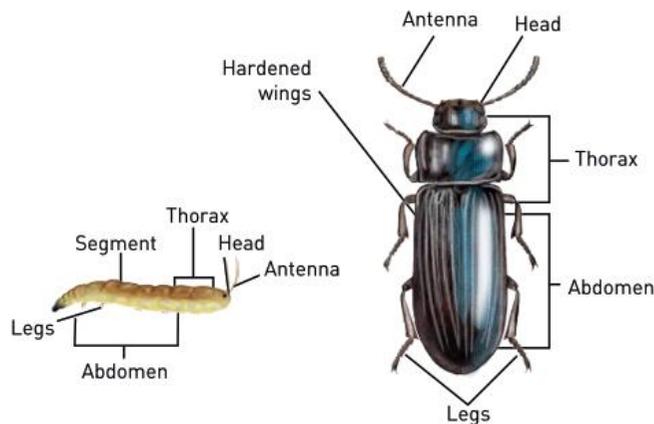
In addition to their uses as a food source, insects can also be hugely beneficial to other agricultural production as a biocontrol agent. Insects, such as the ladybird, wasps and lacewings, help with both the pollination process and controlling pests such as aphids.

### DID YOU KNOW?

Green lacewings get their name from their intricate wing pattern that resembles lace.

## Anatomy

An insect has a segmented body described as head, abdomen and thorax. Every insect will have this segmented body but will have different features. Additional features can include antenna, wings, legs, tails and stings. Insects also have different shaped mouths, which determines what food they can eat.



**Figure 14.19** The segmented body of a mealworm larvae and its adult form, the darkling beetle



## LET'S REVIEW

### LOOKING BACK

- 1 Identify three edible insects.
- 2 Describe how Aboriginal Australians used three different insects.
- 3 How are ladybirds useful to agricultural production?
- 4 What are the three segments of an insect called?

### FOR YOU TO DO

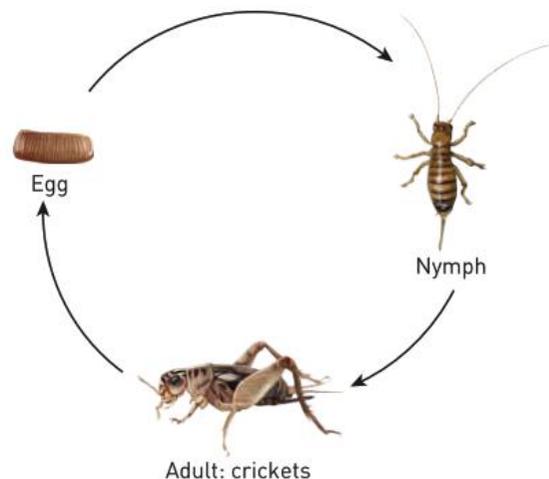
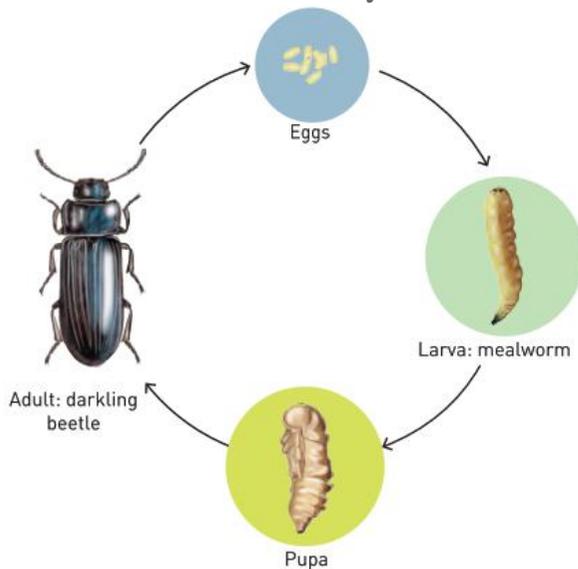
- 1 Using Table 14.7, determine which insect would be suitable for:
  - a someone with an iron deficiency
  - b a high calcium supplement for egg-laying chickens
  - c a body builder with a high-protein diet
  - d a high-fat supplement to increase weight gain in an animal when finishing off.
- 2 Build a model of an insect that can be eaten by humans.
- 3
  - a Interview teachers at your school, or your peers: Would they eat insects for food? Why or why not?
  - b Prepare a short presentation detailing your findings.

### TAKING IT FURTHER

- 1 Research the contemporary uses of insects in Australian food industry.
- 2 How did Aboriginal Australians farm insects sustainably?

## 14.10 Production

### Production cycle



**Figure 14.20** A complete insect lifecycle: darkling beetle **Figure 14.21** An incomplete insect lifecycle: crickets

There are three or four stages in the lifecycle of an insect: eggs, larva or nymph, pupa, and adult. Insects can have a complete or incomplete lifecycle. A complete lifecycle follows all four stages of development, such as those of the butterfly, beetles or bees (you can find out more about a complete lifecycle in the bees section of this chapter).

An incomplete lifecycle only has three stages – eggs, larva and adult. There is no pupal stage. Instead, the insect grows by moulting several times. Insects such as cockroaches, aphids and grasshoppers follow this cycle. Moulting is when the insect sheds its outer shell, or exoskeleton, to grow.

Depending on the species, some insects are used for food as larvae (for example, mealworms) or adults (for example, crickets).



Shutterstock.com/Ole\_CNX

**Figure 14.22** A modular system using egg cartons

## Production systems

### Modular system

Modular systems are common in small-scale insect farms, especially in African and Asian nations. They consist of several tubs or buckets that are used to separate eggs, larvae and adults. These systems can be arranged vertically to save space, and are normally housed in warm, dark sheds.

Feed is added directly to the baskets and faeces or frass is collected for compost. Harvesting involves simply collecting the larvae (for example, mealworms) or the adults (for example, crickets) from the containers.

### Automated system

This is a less common insect farming system because of the expensive set-up costs. Automated systems are only used by larger corporations who can afford to invest in automated technology, like robotics. In this system, tubs or baskets are still used to raise insects, but tasks such as feeding, cleaning, and harvesting are automated. These systems are usually much larger, producing more insects than smaller modular enterprises.



Worksheets

Explore automated insect production with the *Aspire industrial insect production* worksheet.



### LET'S ENGAGE

## BUILDING A MEALWORM FARM

### PURPOSE

To build a mealworm farm

### MATERIALS

- Darkling beetles
- Six storage baskets numbered from 1 to 6 (depending on how many beetles you have; you might want 12 baskets to create two towers)
- Aluminium foil
- Mesh screen used for windows
- Nylon screen
- Oat bran and vegetable scraps

### METHOD

- 1 Line the sides of all baskets with aluminium foil so the mealworms can't climb out of the baskets.
- 2 Line the bottom of baskets 1, 2 and 6 with aluminium foil.
- 3 Line the bottom of basket 3 and 4 with mesh screen used for windows, so frass and eggs can fall through the mesh.
- 4 Line the bottom of basket 5 with nylon mesh so frass can fall through but eggs stay in the basket.
- 5 Label basket 1 as 'Nursery'; 2 as 'Growing'; 3 as 'Adults'; 4 as 'Eggs'; 5 as 'Harvest'; 6 as 'Frass'. Stack these as shown in Figure 14.23. There should be no gaps between baskets to prevent light coming into the baskets.



1	Nursery
2	Growing
3	Adults
4	Eggs
5	Harvest
6	Frass

**Figure 14.23** Your mealworm farm tower

- 6 Fill basket 3 – Adults with feed, such as oat bran and vegetable scraps. Add the darkling beetles to the basket.
- 7 Top up food for your adult beetles regularly.
- 8 After three weeks, many eggs should have fallen through the mesh screen from the adult tray. Pour the egg basket into the nursery basket.
- 9 After another three weeks (six weeks after you started your farm), your eggs should have hatched. Add some feed to your growing tray. Move the small larvae from the nursery to the growing tray. Leave some of the larvae in the growing tray because some mealworms should be left to pupate and become adult beetles to continue the growing cycle. When they become adult beetles, move

them to the adult basket to start the production cycle again.

- 10 After another three weeks, move the larvae from the growing basket to the harvest basket. Mealworms are ready to be harvested after spending a week in a harvest basket.
- 11 **Please note: remember to regularly top up the Adults, Growing and Harvest baskets with feed.**
- 12 Check on the frass bucket regularly – you can make the insect poo into compost or just empty the tray.

#### DISCUSSION

- 1 Describe how the life cycle of a mealworm mirrors your production system.
- 2 How could you improve efficiency of your farm?
- 3 What management techniques could you improve?
- 4 Design an experiment to investigate how the type of feed affects growth rate of the mealworms. Conduct the experiment and report on your findings.
- 5 Investigate how you would build an insect farm for crickets. Design a system and compare it with your mealworm farm. How do they differ?



## LET'S REVIEW

### LOOKING BACK

- 1 Draw a diagram of the complete and incomplete lifecycles of insects.
- 2 List three insects that have a complete lifecycle, and three that have an incomplete lifecycle.
- 3 Explain the differences between modular and automated insect production systems.

### FOR YOU TO DO

- 1 Why it is important to understand the lifecycle of insects?
- 2 Evaluate the benefits of an automated insect farm over a modular insect farm.

### TAKING IT FURTHER

- 1 Build the cricket farm you designed in the Let's Engage activity. Farm crickets in addition to your mealworms.
- 2 Research the lifecycle of a cricket.
  - a Draw a diagram of the cricket's lifecycle.
  - b How does this compare with the lifecycle of a mealworm?
  - c How will the cricket's lifecycle affect farming them?

## 14.11 Management

### Environmental management

#### Climate

Light, temperature and humidity can all affect insect growth rates, and hence production.

**Table 14.9** Effects of environmental conditions on insect production

Factor	Optimum conditions	Effect on production	Problems associated with incorrect levels
Light	<ul style="list-style-type: none"> <li>Dim conditions because sensitive to light</li> <li>Not complete darkness</li> </ul>	<ul style="list-style-type: none"> <li>Process of moulting and growing influenced by light</li> <li>Dim conditions ensure insects follow usual pattern of growth</li> </ul>	<ul style="list-style-type: none"> <li>Without day–night rhythm, the insect will complete its lifecycle randomly, such as hatching and pupating off schedule (don't follow usual pattern of growth)</li> </ul>
Temperature	<ul style="list-style-type: none"> <li>25–27°C</li> </ul>	<ul style="list-style-type: none"> <li>Influences growth rate</li> <li>The warmer the environment, the faster the lifecycle is completed</li> </ul>	<ul style="list-style-type: none"> <li>Cool temperatures will make insect dormant</li> <li>Freezing insects used as method of processing or slaughtering</li> </ul>
Humidity	<ul style="list-style-type: none"> <li>Can cope with wide range</li> <li>40–80%</li> </ul>	<ul style="list-style-type: none"> <li>Ensures insect survival</li> </ul>	<ul style="list-style-type: none"> <li>Too high can drown the larvae</li> </ul>

### Enterprise management

#### Housing

When housing insects, it is important to maintain appropriate stocking densities. While insects do live in fairly high stocking densities in nature, they still need space. If stocking densities are too high (and there is not enough space for each insect), they may start eating each other. If you do notice cannibalism beginning to occur, insects can be split into more trays or boxes, so they have more space. All stages of life (eggs, larvae, pupae and adults) are reared in separate trays to avoid cannibalistic behaviour (such as the adults trying to eat the larvae).

#### Nutrition

As with any other agricultural enterprise, insects should receive proper nutrition or they will die or not grow properly. Farmed insects should be fed a mixture of grains, such as bran or wheat (carbohydrates), with fruit and vegetables, such as apples or sweet potatoes. Insects do not need to be fed water separately. Instead, they receive their required water intake from their food, mainly the fruit and vegetables. Therefore, it is important for their diet to include a mixture of grains and fresh produce.



Worksheets

Investigate how type of feed affects growth rate with the *Mealworm meals* experiment practical worksheet.

#### DID YOU KNOW?

Mealworm frass will change colour depending on what they are fed. For example, if you feed them sweet potato, their frass will be orange.

## Records and financial management

### AG IN FOCUS

#### PROFIT ANALYSIS FOR AN INSECT FARMER

##### Identify

A local insect farmer has asked you to conduct a profit analysis for them. They cannot decide whether they should farm their crickets and sell them whole or grind them into flour. The farmer has one million crickets ready for harvest and wants to work out a gross margin per 1000 insects.

##### Understand

A local farmer spends the following variable costs on their insect farm to produce one million crickets.

Feed	\$200/tonne, 10 tonnes bought
Housing materials	\$3000 for plastic trays
Electricity for climate-controlled warehouse	\$500 per month, for 4-month lifecycle
Labour costs	1 worker at \$18.29 per hour, for 12 weeks, working 37.5 hours a week
Initial group of crickets	\$4500

They have two options to sell:

##### Option 1

The farmer can sell their crickets whole to a local specialty restaurant that will pay \$240 for 1 kg of crickets (there are approximately 4000 crickets per 1 kg whole).

##### Option 2

The farmer can grind the crickets and sell them as flour. To create 1kg of flour, 11 000 crickets are needed. Each 100 g of cricket flour sells for \$25. However, the farmer must also pay extra to grind the crickets (one extra worker at \$18.29 per hour, for 10 days' work, 8 hours a day) and packaging (\$5000).

##### Discussion

- 1 Using the gross margin template on NelsonNet, calculate the gross margin per kilogram for both options.
- 2 Which option is most profitable for the farmer?
- 3 Why does vertical integration result in a higher profit?
- 4 Why might the farmer choose option 1?



Template

Gross margin template



### LET'S REVIEW

#### LOOKING BACK

- 1 Identify three environmental factors that may affect insect production.
- 2 Explain how light can affect insect production.
- 3 Outline the nutritional needs of insects.



**> FOR YOU TO DO**

- 1 Design an experiment to test the effect of temperature on insect growth.
- 2 Dig up soil in your agriculture plot and look for eggs and larvae of insects.
- 3 Design a sustainable diet for your mealworm farm.

**TAKING IT FURTHER**

- 1 Investigate insect farming systems in China and Ghana and compare the two production systems. Prepare a report detailing your findings.
- 2 Analyse the effect of raising the temperature on the lifecycle of a darkling beetle.

## 14.12 Pests and diseases

Insects are often considered pests themselves, despite their usefulness for agricultural production and as a food source. Insects used as biocontrol agents (to kill other pests) can also be farmed for human consumption, providing both protection from agricultural pests and food.

### AG IN FOCUS

#### GREEN TREE ANTS

##### Identify

Weaver ants, often called green tree ants, can be found in Australia and through Asia up to China and across Africa. These ants are consumed in many countries in Asia, such as China, India and Thailand. Aboriginal and Torres Strait Islanders use weaver ants for medicine. The ants also act as a biocontrol agent for many crops including cashews, mangos, coconuts, citrus fruit and tea.



Shutterstock.com/Adele Heidenreich

**Figure 14.24** Australian green tree ants

##### Understand

Weaver ant larvae and pupae can be consumed as food, providing approximately 7 g of protein per 100 g. These ants have a fast lifecycle, meaning populations regenerate quickly. This means overharvesting is rarely a problem, and the population and farming is sustainable as long as farmers do not harvest all the eggs at once.

Weaver ants protect from other pests, and have been used as a biocontrol agent, where they are deliberately introduced to a crop to kill another pest. However, they do cause problems at harvesting, particularly with fruit crops.

Recent studies in Thailand have shown that weaver ants can be used both as a biocontrol and harvested for human consumption, making them the perfect insect. Some Australian farmers have already started producing these insects, with products such as green tree ant infused gin and goats' cheese created. These insects were even served to Prince Charles when he visited Australia.



Video

Find out how green tree ants are being used in food and beverage production.



### Discussion

- 1 Why are weaver ants useful?
- 2 How is sustainable production ensured?
- 3 Design a production system to farm weaver ants.



### LET'S DISCUSS

- 1 Right now, we grow crops that contain about 15% protein. Using pesticides, we kill insects containing 70% protein, just so we can harvest a crop containing 15% protein. In a rapidly expanding population, do you think this is right?
- 2 What kinds of biosecurity measures should insect farms take to prevent diseases?



### LET'S REVIEW

#### LOOKING BACK

- 1 Why should we consider farming 'pest' insects?
- 2 Describe what a biocontrol agent is.

#### FOR YOU TO DO

- 1 Research AdDNV, a disease affecting commercial cricket farms in Europe.
- 2 Design a preventative program to ensure your mealworms are not infected with any pests or diseases.

#### TAKING IT FURTHER

- 1 Evaluate the impact of farming pest insects for human consumption.

## 14.13 Social and ethical issues

### Insect welfare

Despite being an animal food product, insects are in a grey area when it comes to animal welfare. Animal welfare regulations generally require evidence of sentience to be considered an animal (and hence to be covered under the regulations limiting harm and distress). However, no studies have ever investigated the sentience of insects, or if they feel pain.

#### DID YOU KNOW?

Lobsters were once called the cockroaches of the sea.

Studies have shown that insects can feel both stress and fear. The methods of killing insects include freezing them, suffocation by increasing CO<sub>2</sub> or nitrogen, spraying hot water on them, or crushing them. Research has shown that some methods of killing cause more stress to the insects. Despite this, there are no regulations about humane methods of raising or killing insects, and they do not fall under animal welfare laws because they are not considered sentient.



## LET'S DISCUSS

Consider your feelings on different types of protein eaten around the world.

- 1 Would you eat dog meat? Why or why not?
- 2 What about beef? Why or why not?
- 3 How do your thoughts on the killing of insects differ from the other animals?
- 4 Do you think insects deserve the same amount of welfare as animals such as cows, and dogs?



## LET'S DISCUSS

- 1 The use of insects as a feed for ruminant animals such as sheep and cows has been banned in Australia. Why do you think this is?
- 2 How will this ban affect insect production in Australia in the coming years?



## LET'S REVIEW

### LOOKING BACK

- 1 Identify three methods of processing (killing) insects.
- 2 Why are insects not currently considered animals for the purpose of animal welfare regulations?

### FOR YOU TO DO

- 1 Conduct a survey of teachers or your peer group to determine why people are resistant to eating insects.
- 2 Conduct a class debate on the statement: 'Insects are not sentient and therefore should not receive the same welfare regulations as other animal enterprises.'
- 3 Previously, when Western desire for a product used in developing countries increases, price also increases (such as with quinoa).
  - a How might this affect non-Western countries?
  - b Design a solution to ensure Western demand does not result in a steep price hike for insects.

### TAKING IT FURTHER

- 1 Design a humane insect farming system. Consider animal welfare both during production and in harvesting.

# 14.14 Sustainability

## Sustainable practices and methods



### LET'S DISCUSS

- 1 Identify three ways waste products from insect production could be used.

### DID YOU KNOW?

In countries such as the Democratic Republic of Congo, farming is conducted sustainably, with people eating what is seasonally available rather than farming all year round like Western countries do. This means that in months with more rainfall, they eat lots of caterpillars because these are more available.

### Insect feed

The type of food insects are fed can determine how sustainable the farm is. Many farmers feed insects grain products, such as wheat or oats. This increases the protein content in the insects, and helps them grow faster. However, this means valuable crops that could be used for humans are instead being used to feed insects. Instead, some farms feed their insects leftover scraps. This can include rice hulls, by-products of grain producers such as bran hulls and leftover fruit and vegetables. By feeding insects waste products, insect farming can be a more sustainable enterprise.

Insects also have a very high feed conversion ratio – they require two times less feed than chickens, four times less than pigs and 12 times less than cattle to achieve a similar weight gain ratio. This means less resources need to go into feeding them.

## AG IN FOCUS

### REBEL FOOD – TASMANIA'S INSECT PRODUCER

#### Identify

Rebel Food Tasmania is aiming to create a new sustainable farming system in Australia, bringing insects to the Australian food scene.

#### Understand

Rebel Food Tasmania recently



© Rebel Food Tasmania

Figure 14.25 Mealworms eating apple at Rebel Food

launched its new business after spending months researching the best way to sustainably produce delicious insects. The company grows whole insects and sells them directly to local restaurants and businesses. It farms crickets with a low stocking density to ensure the welfare of the insects is considered.

Rebel Food Tasmania has sustainability at its heart. It farms the crickets using egg cartons, feeding them different types of food waste to experiment with how the crickets' flavour changes – so far the company has tried root vegetables, apples, pumpkins, and even wine marc (using the grape mush left over after squeezing). In addition to fresh fruit and vegetable scraps, it uses waste products from the local craft brewing industry to ensure the insects have a high protein content. Rebel Food uses renewable energy sources to power its climate-controlled rooms, keeping the temperatures warm for the crickets. Once the egg cartons used to house the insects are used (after each harvest), they are turned into compost.

The insects are harvested by first cooling them down. When insects are cooled, they become dormant. Once dormant, they are put into a freezer to kill them. This causes less stress to the insects as they are dormant during the process.

### Discussion

- 1 Describe three management techniques Rebel Food Tasmania uses to create a sustainable insect farming business.
- 2 How does Rebel Food ensure the welfare of the insects it farms?
- 3 Do you think insect farming is sustainable? Justify your answer.

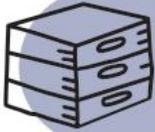
### Using insects for animal feed

Under Australian law, not all animals can be fed insects for food. Some, such as chickens, can. By feeding chickens at least a part diet of mealworms, less grain needs to be used. This frees up grain supply for humans, another way of ensuring grain is not grown solely to feed animals that then feed humans.



Data scenario

Investigate the impact of mealworms on aquaculture production with this data scenario.



### LET'S EXPERIMENT

## INSECTS AS FEED

### PURPOSE

To investigate the effect of mealworms on weight gain in meat chickens

### HYPOTHESIS

What effect do you think mealworms will have on weight gain in meat chickens?

### MATERIALS

- Chicken coop or poultry brooder
- 10 one-day-old meat chickens
- Water
- Chicken feed with 22% crude protein
- 200 g of mealworms
- Weighing scales

### METHOD

- 1 Divide the chickens in two groups of five chickens each and set up a divider in the brooder to create two equal sized pens.
- 2 Weigh 2 kg of chicken feed and place it in the feeder in one pen.

- >
- 3 Weigh 1.5 kg of chicken feed and place it the feeder in the second pen. Add 50 grams of live mealworms to the feed every day for 10 days.  
This means that both groups of chickens receive 2 kg of food for the 10 days.
  - 4 Weigh the chickens from both pens daily for 10 days and record the results.

#### RESULTS

- 1 Construct a table to record the weight gain of your chickens.
- 2 Calculate the average weight for each group on each day.
- 3 Draw a stacked line graph to show to growth rates of the chicks over the ten days.

#### DISCUSSION

- 1 Which group of chickens gained more weight?
- 2 Would you recommend adding mealworms to the diet of meat chickens? Justify your answer.
- 3 Is your experiment valid? Explain your answer.

#### CONCLUSION

Was your hypothesis correct, incorrect or partially correct?

## Sustainable technology

### Nutrient recycling

A company has developed a new technology, termed ‘nutrient recycling’, to recycle waste into food for insects. Recyclable items such as plastics are removed from waste products from places such as food factories, supermarkets, hospitals, schools and farms. The remaining material is then crushed into a paste, with the paste being able to feed insects. The AgriProtein site can currently manage 100 tonnes of waste each day.

The company then farms black soldier flies on the paste. They make the flies into meal, with the intention of using this as an alternative to fish meal. This prevents use of fishmeal (which can result in over-farming of fish stock) purely to feed other fish. The overall development of this technology has resulted in less waste going to landfill sites and reduced overfishing.

## Sustainable decision-making

### AG IN FOCUS

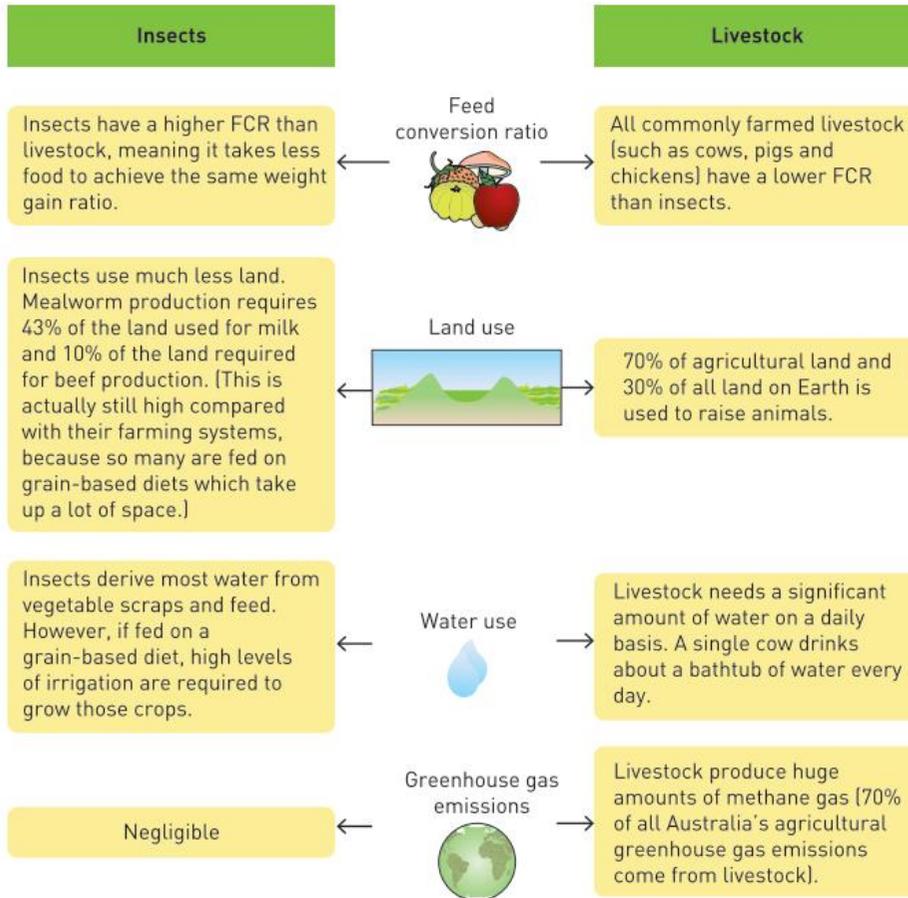
#### IS INSECT FARMING MORE SUSTAINABLE THAN LIVESTOCK FARMING?

##### Identify

Arguably, insects could be a more sustainable protein source than other livestock.

>

## Understand



**Figure 14.26** Summary of key findings about the sustainability of insect farming, compared to other enterprises

## Discussion

- 1 Compare the sustainability of insect farming and livestock farming.
- 2 Discuss the short-term impacts of insect farming on sustainability.
- 3 Discuss the long-term impacts of insect farming on sustainability.
- 4 Design a leaflet to increase demand for insects in Australia, focusing on the effect this will have on sustainability.



Watch the YouTube video to find out more about insects as a sustainable farming alternative.



## LET'S REVIEW

### LOOKING BACK

- 1 Why is using grain for insects less sustainable than other insect feedstocks?
- 2 Compare the FCR for insects with that of other livestock.
- 3 What types of food can be fed to insects for a more sustainable enterprise?
- 4 What is nutrient recycling?
- 5 What market is AgriProtein creating insect meal for?



### > FOR YOU TO DO

- 1 Work with a classmate to prepare a PowerPoint presentation comparing one aspect of sustainability between insects and livestock farming. Present it to your class.
- 2 How can you implement sustainable practices in your mealworm farm?

### TAKING IT FURTHER

- 1 Consider the issue of the growing population. Assess the effect of not increasing demand for insects before the population hits 9 billion people.
- 2 Evaluate the impact of Australia moving away from livestock enterprises and towards insect-based farming.

## 14.15 Marketing

### The market

The insect market can be segregated depending on a large number of factors:

- type of insect (such as cricket or mealworm)
- product type (such as whole insect or flour)
- application (such as human food or animal feed).

Whole insects are the most popular type of product. Much like other enterprises, whole insects are the base product, which farmers can then value-add into different products.

Insects are eaten in approximately 80% of countries. While the insect industry is only beginning to grow in Australia, insects have been a major economical commodity in countries across Asia and Africa for many years.

### DID YOU KNOW?

Thailand is one of the biggest producers of edible insects, with 20 000 medium or large-sized insect farmers.

**Table 14.10** The global edible insect market

	2017	2023 estimate
Asia Pacific	\$173.9 million	\$477 million
Latin America	\$92.2 million	\$250 million
Europe	\$82 million	\$261.5 million
North America	\$44 million	\$154 million
Middle East and Africa	\$14.2 million	no figures



Weblink

Explore more statistics about the global edible insect market.

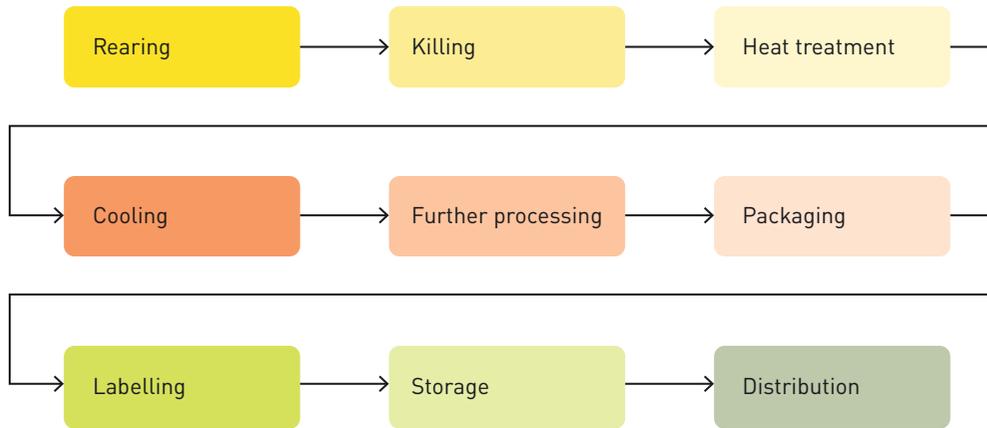


Worksheets

Explore the global insect market with the NelsonNet worksheet.

Many analyses of the edible insect industry expect demand to rise in the next five years, with Europe expected to experience the greatest growth.

The marketing chain for insects includes several steps to treat the insects, such as heating them to destroy pests.



**Figure 14.27** The insect marketing chain

## Market specifications

There are no current specifications in Australia specifically for insects. Instead, insect farmers must follow the general food production laws, which require labelling of what is contained in a product, where it came from and the nutritional value. In addition, there are general guidelines for food production. Insects originally raised for animal food cannot be sold for human consumption. Products must be:

- free from toxins
- produced and packaged in sanitary conditions
- guaranteed that the product is not farmed from wild insects.

The Insect Protein Association of Australia is working with the government to develop food safety regulations for insect farmers.

When importing insects to be used for either human or animal food, the insects must be both dead and heat-treated. Heat-treating the insects kills off any pests and diseases and ensures Australia's strict biosecurity regulations are not broken.

## Marketing strategies

Insects can be sold through several channels. The most common of these is direct marketing. The method of direct marketing will differ depending on location; for example, in Thailand, insects are commonly sold at street food stalls, whereas in Australia direct marketing via the internet is more popular.

### Direct marketing

Most insect farmers will sell direct to their customers. This can be via several different methods:

- *online sales*: farmers market their produce online via a website or social media
- *direct to restaurants*: farmers sell directly to specialty restaurants that are looking for insects
- *street food*: a very common selling technique in countries such as Thailand where insects are sold at market stalls on the street.

### Speciality suppliers

Some farmers will sell their products to speciality suppliers who will either sell the product on or develop the product by value-adding (see below). This can be easier for the farmer because the speciality supplier takes full responsibility for supplying to customers, whereas in direct marketing, the farmer has to find the customers themselves.



Weblink

Research some of the biosecurity and food safety checks required for the sale of insects for human consumption in Australia.

## Value-adding

Value-adding is a very important aspect of insect production. While whole insects are the biggest market, there are a huge range of products that insects can be made into. Some popular items include insect meal for fish, protein bars, protein powders or flours, and more specialised items such as fried insects, or even chocolate crickets.



Edible Bug Shop

**Figure 14.28** Insects can be made into other products, such as these candied ants and white chocolate with crickets.

## INDUSTRY IN FOCUS

### PRODUCT DEVELOPER

#### Identify

The Edible Bug Shop was founded in 2007 by Skye Blackburn, and was Australia's first edible insect farm. She has developed a range of value-added insect products, such as dukkah powder, salt, chocolate, candy and tortilla chips. She intends to make insects more appealing to Western consumers by introducing them to eating insects through value-added items that seem more palatable (like chocolate).

Skye markets her products directly to consumers by appearing in the media and conducting cooking shows and collaborating with other businesses. Her marketing very much focuses on the sustainability of eating insects and aims to educate consumers about insects.

Skye uses skills as both an entomologist and food scientist. She uses her knowledge of bugs to help develop the best farming techniques, and her experience as a food scientist to develop the products.

#### Discussion

- 1 What products does Skye make?
- 2 What skills are needed for an entomologist and food scientist?
- 3 Describe Skye's marketing strategy.
- 4 Develop your own value-added product for your mealworms. Start your research by looking at the Edible Bug Shop website.
- 5 Create a marketing campaign including at least one method of advertising (such as a video, poster or leaflet) to advertise your new value-added insect product. Use Chapter 4 Agricultural business to assist you.



## LET'S REVIEW

### LOOKING BACK

- 1 Which countries' population eats the most insects?
- 2 Where will the insect market grow most in the next five years?
- 3 Draw a diagram of the insect marketing chain.
- 4 Explain the differences in direct marketing strategy between Australia and Thailand.
- 5 List four ways insects can be value-added.

### FOR YOU TO DO

- 1 Conduct a market survey to determine which advertising strategy would be most useful for a farmer selling insects direct to consumers:
  - a as a sustainable alternative to other proteins
  - b as a special delicacy
  - c for the health benefits.
- 2 Create a marketing campaign based on your research. Your campaign should be for a insect of your choice and involve at least two forms of advertisement.

### TAKING IT FURTHER

- 1 Do you think the edible insect market in Australia will grow? Justify your answer.
  - 2 Evaluate the effectiveness and suitability of direct marketing for edible insects.
-

# Let's summarise



WebLink

Complete the chapter review test on NelsonNet to review what you have learnt about bees and other insects.

## How do bees and insects affect agricultural production?

Bees and insects are very beneficial to agricultural production, acting as pollinators that help fertilise crops. Insects can also act as biocontrol agents, eating pests that might harm crop production. However, some agricultural practices such as pesticide and insecticide use is harming the helpful pollinators. In addition, pests such as the varroa mite could decimate Australian bee populations if they are introduced in Australia.

Create a table identifying strategies to help protect bees and other pollinators from both agricultural and non-agricultural harmful pests or practices.

Strategies	Description
Biosecurity	
Sentinel hives	
Introducing biocontrols	
Clothianidin	

## Can insects replace meat as a source of protein for human consumption?

Insects have long been eaten in many countries and are beginning to increase in popularity in Western countries such as Australia. Insects can provide large amounts of protein and other key dietary needs, while using less land and water, and emitting less greenhouse gases than other animal enterprises.

Create a mind-map detailing the benefits of farming insects as a source of protein for a growing population.



# Hydroponics

## CHAPTER SUMMARY

Hydroponic processes were used by ancient civilisations, but it wasn't until the 1940s that modern hydroponics were first successfully used to supply fresh vegetables for troops on Wake Island, a refuelling stop for airlines. Now, as NASA's astronauts prepare to fulfil the vision for space exploration with increasingly lengthy missions, scientists are trying to find a way for astronauts to grow their own food and hydroponics may be the only solution.

**Can hydroponics replace conventional vegetable production?**

**Is hydroponics a more sustainable production system than traditional vegetable growing?'**

## 15.1 Introduction

Growing plants in water is not a new concept. Historical records show many ancient societies grew plants without soil. For example, the suspended gardens of Babylon, crops grown in the sandy banks of the Nile River in Ancient Egypt, and the Aztec development of chinampas, which were floating islands where they planted vegetables and flowers.

**hydroponics** the process of growing plants without soil, most commonly in water

Modern **hydroponics** technology developed around 70 years ago and has opened up new opportunities for agriculture. In a world with a rapidly growing population, hydroponics allows previously unusable land, such as deserts or cities, to be used for agriculture. Hydroponics can provide locally grown crops, such as lettuce and tomatoes, with arguably less impact on the environment. In addition, as research develops, hydroponics becomes important for space exploration, with experiments growing crops taking place on the moon and on the International Space Station.

## 15.2 Functions and structures



Worksheets

Introduce yourself to hydroponics terminology with the *An introduction to hydroponics* worksheet.

### Functions

Hydroponic systems use water instead of soil to produce plants. Nutrients in liquid, powder or granular form are mixed with water and supplied to plants. The key functions of a hydroponic system are to allow plants to grow where and when they shouldn't normally such as:

- crops growing in all seasons. Plants that traditionally grow in summer due to the high temperature, such as tomato and cucumbers, can be grown all year round using indoor climate control facilities.
- crops growing in areas not previously able to be used for agriculture, such as urban areas (cities), deserts and mountains
- crops growing in space. Hydroponics has the promising prospect of providing fresh food for scientists involved in long-term space exploration.



**Figure 15.1** In hydroponics, plants are not grown in soil



Weblink

Read the *Guardian* article to find out how Australian arid land in WA can now be used to grow fresh vegetables.

Hydroponics provides consistency of production throughout the year, regardless of the soil or climatic limitations. In addition, it is possible that hydroponic production could be a sustainable alternative to traditional agriculture.

## AG IN FOCUS

### KENNEDY SPACE CENTER SPACE LIFE SCIENCES LAB

#### Identify

NASA is developing new technology to support growing plants in space.

#### Understand

At Kennedy Space Center, scientists are testing growing radishes, lettuce and green onions in a hydroponics system. They experiment with different light, heat and carbon dioxide levels as well as using different plant species to examine how these factors affect growth. They are experimenting to see which plants grow well together in hydroponic spaces as well as how plants grow under different coloured lights.

The aim of their research is to eventually be able to provide fresh vegetables for astronauts in space. Currently, missions to the International Space Station are for fairly short periods of time. But now, scientists and engineers are planning for the first manned trip to Mars, a mission that would last a lifetime. Costs for the mission would be greatly reduced if astronauts could grow their own fresh food.

#### Discussion

- 1 What factors are scientists at Kennedy Space Center experimenting with?
- 2 Write a hypothesis for the effect of the three environmental factors on plant growth.
- 3 Design an experiment to test the effect of carbon dioxide levels on plant growth.
- 4 Research why the soil found on Mars is unable to grow vegetables.



Worksheets

Learn more about growing vegetables in space with the *Mars* worksheet.



Video

Find out how lettuce is grown in space with the Space Station Live YouTube video.

#### DID YOU KNOW?

Chinese scientists have tried to grow cotton on the moon. Sadly, the crop failed because it was too cold at night for the plants to survive.

### Produce

Hydroponics can be used to grow most traditional crops but it has proven to be most effective in growing a variety of herbs, eggplants, capsicums, tomatoes, cucumbers, lettuce, bok choy and other leafy greens. The plants produced using hydroponic systems grow quicker and are healthier because being inside the glasshouse reduces incidence of disease and pests. It also reduces the prevalence of bacterium such as *E. coli* because of the sterile growing environment.

### Structure

To understand how hydroponic production works, it is important to understand how a plant uses nutrients to grow. A plant grows from seed or cuttings and consists of leaves, stems and roots. They later develop flowers, fruit and new seeds. Leaves use carbon dioxide and moisture in the presence of chlorophyll and sunlight to make carbohydrate or plant food. This process is called photosynthesis. The products of photosynthesis are distributed via **phloem** tissues throughout the plant. Plants can access other nutrients via their roots. Nutrients are dissolved in water and plant roots absorb the water along with nutrients via root hairs. Once a plant takes up nutrients, they are transported via the **xylem** to the rest of the plant. Plants use nutrients to grow, develop and carry out all other processes necessary for living. The main principle behind hydroponic production is that if a plant has access to quality nutrients in sufficient amounts consistently, it will grow better.

**phloem** transports sugars around the plant

**xylem** transports water and mineral nutrients around the plant



## LET'S REVIEW

### LOOKING BACK

- 1 Identify common plants that are grown using hydroponics.
- 2 What are the three main reasons to grow crops hydroponically?
- 3 How does hydroponic production differ from traditional plant growing?
- 4 Why do plants grow better in a hydroponic system?

### FOR YOU TO DO

- 1 Draw and label a diagram showing how plants feed.
- 2 Research how one ancient society used hydroponics. Choose from the Aztecs, Babylonians or Ancient Egyptians.
- 3 Watch the YouTube video about hydroponic farming. Explain why hydroponics could be considered a sustainable alternative to traditional agriculture.

### TAKING IT FURTHER

- 1 Investigate how plants are grown on the International Space Station. Outline:
  - a four objectives of their research
  - b which vegetables they are trialling growing on the International Space Station
  - c how gravity will affect plant growth. (Hint: think about how water and nutrients flow up the plant.)



Video

This farm of the future uses no soil and 95% less water.



Weblink

Growing plants on the International Space Station

## 15.3 Production

### Production cycles

Hydroponics follow the same general production cycle as traditionally grown crops, with the added benefit that some steps (such as soil preparation) can be skipped.

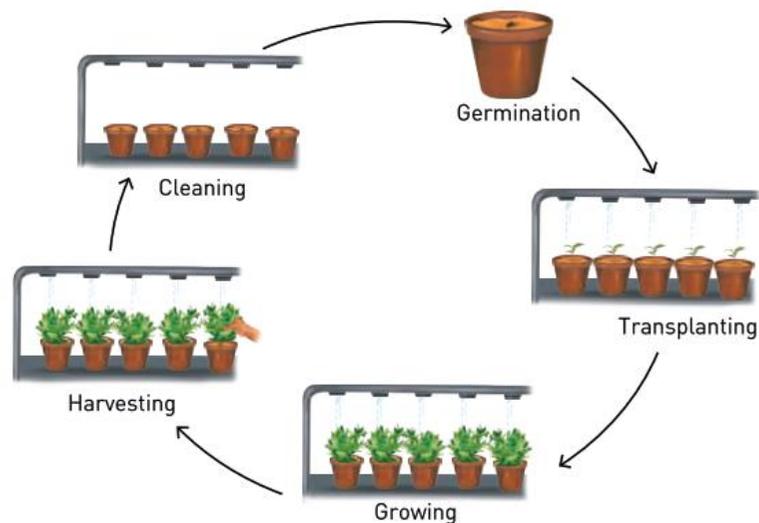


Figure 15.2 Production cycle of hydroponic crops

## Germination

Aboriginal Australians germinated seedlings using hydroponic methodology. They would tear bark off trees and make a cup, fill it with growing medium and water and allow the seeds to germinate in the cup. They would then plant the bark in the soil to grow crops.

Germination in modern-day hydroponic systems cannot occur in growing media, because the medium is not usually strong enough to hold the seed in place. Special grow cubes such as rockwool cubes or vermiculite should be used. Two to three seeds are put in each grow cube and placed in water. Seedlings can be thinned out at the transplanting stage.



**Figure 15.3** Rockwool cubes used to germinate seedlings

## Transplanting

Transplanting seedlings into a hydroponic system is a very easy process. The seedlings are thinned out if too many are growing from one cube. Then, the growing cubes are placed within the final growing medium in the hydroponic system. If vermiculite has been used, it can be washed off before the plants go into a nutrient film technique system.

## Growing

Hydroponically grown plants need everything a soil grown plant needs – oxygen, heat, light and nutrients. Nutrients are delivered in a liquid solution, so feeding is controlled by the flow of water. Plants can be grown in greenhouses where temperature can be kept warm in controlled environments.

## Harvesting

Hydroponic plants are harvested like any other plants. In large commercial hydroponic farms, robotic technology is often used to harvest the product. Harvesting can also be done by hand.

## Cleaning

One of the benefits of a hydroponic system is that it creates a sterile environment, making it much more difficult for pests and diseases to enter the system. At the end of each crop cycle, the hydroponic system should be cleaned and sterilised to ensure the sterile environment continues.

## Production systems

There are several different hydroponic systems available. Table 15.1 describes six common types of hydroponic system.

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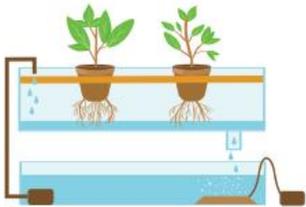
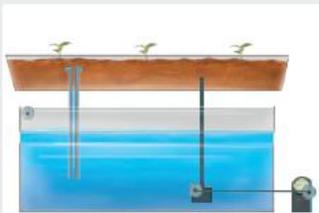
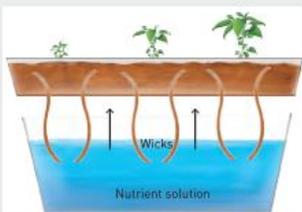
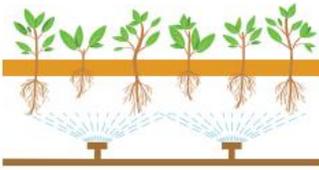
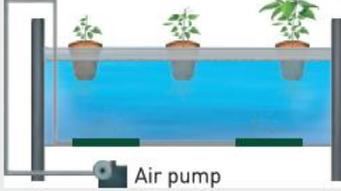


Learn about Aboriginal use of paperbark to assist with seedling germination because of its water-holding qualities.



Compare the advantages and disadvantages of hydroponics production systems with this worksheet.

**Table 15.1** Hydroponic production systems

System	Description	Image
Nutrient film technique	<ul style="list-style-type: none"> <li>- Most recognised system</li> <li>- Wide plastic channels with holes where seedlings are suspended</li> <li>- Plants suspended and lower roots have access to nutrients circulating through channels constantly</li> <li>- Upper roots exposed to oxygen</li> </ul>	 <p><b>Figure 15.4</b> A nutrient film technique hydroponic system</p>
Ebb and flow	<ul style="list-style-type: none"> <li>- Grow tray with growing medium instead of channels</li> <li>- Temporarily floods grow tray with nutrient solution, which then drains back into reservoir</li> <li>- Connected to a pump and timer to control this process</li> </ul>	 <p><b>Figure 15.5</b> Ebb and flow hydroponic system</p>
Drip	<ul style="list-style-type: none"> <li>- Most widely used in commercial production</li> <li>- Plants in pots filled with growing medium or slabs of rockwool</li> <li>- Nutrient solution transported from reservoir is dripped onto individual plants</li> <li>- Dripping controlled by a timer</li> </ul>	 <p><b>Figure 15.6</b> A drip hydroponic system</p>
Wick	<ul style="list-style-type: none"> <li>- Very basic system</li> <li>- Plants in grow tray are connected to reservoir of nutrient solution via wicks</li> <li>- Nutrient solution is transported to plants via <b>capillary action</b></li> </ul>	 <p><b>Figure 15.7</b> A wick hydroponic system</p>
Aeroponic	<ul style="list-style-type: none"> <li>- Plants placed in holes in grow trays with bare roots exposed to air</li> <li>- A fine mist of nutrient solution sprayed over roots every few minutes</li> </ul>	 <p><b>Figure 15.8</b> An aeroponic hydroponic system</p>
Passive	<ul style="list-style-type: none"> <li>- A grow tray is placed directly above nutrient solution tray</li> <li>- Roots submerged in nutrient solution</li> <li>- An aerator, like those used in home fish aquariums, is used to circulate nutrient solution</li> </ul>	 <p><b>Figure 15.9</b> A passive hydroponic system</p>



Data scenario

Investigate how the type of system affects growth rates with the data scenario.

**capillary action** the spontaneous flow of a liquid into a narrow tube or porous material that does not require the force of gravity

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## INDUSTRY IN FOCUS

### PRODUCTION MANAGER

#### Identify

A hydroponic production manager is involved with choosing the most cost-effective plants to be grown hydroponically. They develop systems and schedules for growing. Production managers create conditions suitable for plant growth all year round, by manipulating the temperature and humidity, and by providing artificial lighting in some cases. The production manager determines what nutrients must be used to grow the best, and researches and trials new ways of working to ensure the most efficient hydroponic system possible. They must test and control the quality of water in the system, maintaining the exact pH needed to grow the crop. The production manager must also manage the employees, keep records on budgets and financially plan for the year ahead.

#### Discussion

- 1 What skills are necessary to be a successful production manager?
- 2 How does the role of a production manager affect:
  - a profit
  - b employees
  - c plants.
- 3 The production manager is required to manage people, plants and profit. What effect does this have on the skills needed?



## LET'S REVIEW

### LOOKING BACK

- 1 Draw a diagram of the hydroponic production cycle.
- 2 What materials can be used for hydroponic germination?
- 3 How did Aboriginal Australians use hydroponic processes?
- 4 Identify six types of hydroponic systems.
- 5 How does an aeroponic system differ from a nutrient film technique system?

### FOR YOU TO DO

- 1 Compare the advantages and disadvantages of using a wick system over an ebb and flow system.
- 2 Research the deep water culture system and describe how it works.

### TAKING IT FURTHER

- 1 Compare the production cycle for hydroponically grown vegetables with soil grown vegetables.
- 2 Evaluate which hydroponic system would be most suitable for your school farm. Consider factors such as location, size, ease of use and materials available.

## 15.4 Management

### Environment management

#### Distribution and climate

The most important consideration when building a hydroponic facility is the availability of water and sunshine throughout the year. Greenhouses used to house hydroponic farms need a lot of natural light to heat them up. This means less energy has to be used to power temperature and lighting controls inside the greenhouse. Sundrop and Costa are two big hydroponics enterprises in Australia, with glasshouses located in Port Augusta, South Australia, and Guyra, New South Wales, respectively.



#### LET'S DISCUSS

- 1 How might the following factors influence the location of hydroponic farms?
  - a daylight hours
  - b temperatures
  - c humidity
  - d number of cloud-free days in a year.
- 2 Where would be a good location for a hydroponic farm in Australia?

### Housing

#### Glasshouses



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**Figure 15.10** A hydroponics glasshouse

Hydroponics are often set up in traditional glasshouses, a type of greenhouse made with glass. These buildings protect the plants from pests, weeds, frost and wind, while allowing plenty of sunshine. Glasshouses are designed to absorb and trap solar radiation as heat. However, to deal with extreme temperatures in the sunny areas of Australia, climate-controlled systems are installed to keep the environment inside uniform and stable. These systems can control the temperature, keeping it within the perfect growing range.

### Vertical farms

Some hydroponic facilities are built vertically in a ‘stacked shelves’ style to maximise space. This allows high amounts of production in areas such as cities where space is limited. However, vertical farms use a lot of energy to power lighting. Due to the vertical stacking, light from the glasshouse windows cannot reach all plants equally. This means lighting must be powered on each shelf to make sure plants grow at the same rate. While it is a useful means of production in urban areas, the environmental impact due to the energy use is concerning.



iStock.com/y-studio

**Figure 15.11** A vertical hydroponics farm requires each shelf to be artificially lit.

### Lighting

Another critical aspect of hydroponics is the use of light. As discussed earlier, plants require light to perform photosynthesis. If natural light is not available or lacking intensity, high-intensity discharge lights are used instead. Different coloured lights are used at different points in the growing cycle. Blue light is used for young plants and green leafy vegetables like lettuce, while orange light is used for fruiting and plants that flower.

### CO<sub>2</sub> pumping

Greenhouses and glasshouses also use their climate-control systems to increase carbon dioxide levels. Carbon dioxide (CO<sub>2</sub>) is an essential reactant of photosynthesis. Photosynthesis uses light energy to convert CO<sub>2</sub> and water into sugar and oxygen. The plant uses these sugars for two jobs: cellular respiration for maintenance and basic cell functions, or for growth. Therefore, the rate of growth (called net assimilation rate) equals photosynthesis minus respiration. By increasing CO<sub>2</sub> in glasshouse production, plant growth is improved. However, it is important to note that adequate light, water and essential nutrients are also needed to maximise photosynthesis.



iStock.com/JYU



Data scenario

Investigate the effect of different light colour on the growth rate of hydroponic plants with this data scenario.



Video

Explore how different light colours affect plant growth.

**Figure 15.12** Young seedlings lit from blue lights to encourage growth

## Enterprise management

### Growing medium

A growing medium is the material in which plants are grown instead of soil. Growing media function in the same way that soil does: they can help deliver nutrients to the plant as well as support the roots of the plant.



Worksheets

Explore different growing media with the NelsonNet worksheet.

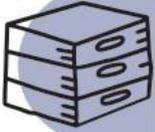
**Table 15.2** Types of growing media and their characteristics

<p style="text-align: center;"><b>Rockwool</b></p> <ul style="list-style-type: none"> <li>• Manufactured by melting basalt rock</li> <li>• High water-holding capacity</li> <li>• Provides good aeration without waterlogging the plant</li> <li>• Alkaline</li> </ul>  <p style="text-align: right; font-size: small;">Shutterstock.com/ Lytyynenko Bogdan</p> <p><b>Figure 15.13</b> Rockwool</p>	<p style="text-align: center;"><b>Perlite</b></p> <ul style="list-style-type: none"> <li>• Mineral that has been superheated in a kiln until it expands like popcorn</li> <li>• Excellent air-holding capacity</li> <li>• Neutral pH</li> <li>• Does not hold onto nutrients</li> </ul>  <p style="text-align: right; font-size: small;">Shutterstock.com/ naramit</p> <p><b>Figure 15.14</b> Perlite</p>	<p style="text-align: center;"><b>Vermiculite</b></p> <ul style="list-style-type: none"> <li>• Naturally occurring silicate that expands significantly when heated</li> <li>• Sterile</li> <li>• Retains nutrients, water and air</li> </ul>  <p style="text-align: right; font-size: small;">Shutterstock.com/ Anton Starikov</p> <p><b>Figure 15.15</b> Vermiculite</p>
<p style="text-align: center;"><b>Peat moss</b></p> <ul style="list-style-type: none"> <li>• Dead plant material (moss) that has decomposed in the absence of air in peat bogs over many years</li> <li>• Acidic pH making it sterile</li> <li>• Can hold water several times its weight</li> </ul>  <p style="text-align: right; font-size: small;">Shutterstock.com/ Anton Starikov</p> <p><b>Figure 15.16</b> Peat moss</p>	<p style="text-align: center;"><b>Coconut fibre</b></p> <ul style="list-style-type: none"> <li>• Outer husk of the coconut</li> <li>• Neutral pH</li> <li>• Holds moisture well</li> <li>• Excellent aeration</li> </ul>  <p style="text-align: right; font-size: small;">Shutterstock.com/ AnMenshikova</p> <p><b>Figure 15.17</b> Coconut fibre</p>	<p style="text-align: center;"><b>Clay pebbles</b></p> <ul style="list-style-type: none"> <li>• Made by heating clay to a very high temperature, making it sterile</li> <li>• Excellent drainage capacity</li> <li>• Prone to drying out</li> </ul>  <p style="text-align: right; font-size: small;">Shutterstock.com/ Meister Photos</p> <p><b>Figure 15.18</b> Clay pebbles</p>



### LET'S DISCUSS

- 1 Which of the growing media do you think is most environmentally sustainable?



## LET'S EXPERIMENT

## TESTING THE BEST GROWING MEDIUM FOR LETTUCE SEEDLINGS

### PURPOSE

To test the effectiveness of different hydroponic media to grow lettuce seeds

### HYPOTHESIS

Which hydroponic media do you think will produce the fastest-growing lettuce?

### MATERIALS

- Four different growing media such as: rockwool starter cubes, oasis cubes, vermiculite, pine bark, peat moss, peat pellets, clay pebbles, coconut fibre, perlite
- Eight seedling trays (two seedling trays for each growing medium)
- Water
- Lettuce seeds
- Optional: greenhouse or polytunnel to grow seedlings

### METHOD

- 1 Soak the growing media.
- 2 Place equal volumes of growing media in each of the growing trays
- 3 Sow the lettuce seeds according to direction on the seed packet – there should be at least six seeds in each growing tray to ensure repetition.
- 4 Irrigate each tray with the same volume of water. Sit the trays in a tray or dish of water to ensure they don't dry out.
- 5 Place in greenhouse or polytunnel if using. If not, place the grow trays in a sunny area.
- 6 Water each tray with the same volume each day.
- 7 Each day, record the growth of each seedling. Measure the height of each of the seedlings and calculate the average for each medium. Record the average height of each group every three days for three weeks.

### RESULTS

- 1 Construct a table to record your results.
- 2 Construct four line graphs or a stacked line graph, showing the growth rate – one for each growing medium.

### DISCUSS

- 1 Discuss your results. Which material was the best for germinating the lettuce seedlings? Which was the worst?
- 2 Assess the validity and reliability of your experiment. How could you improve on the methodology?
- 3 What recommendations would you make to farmers growing lettuce hydroponically?
- 4 Design an experiment to test how light colour affects the growth rate of lettuce seedlings.

## Nutrient solution

One of the most important aspects of hydroponic production is understanding the requirements of plant nutrients for specific plant types and growth stages. A plant typically requires a combination of major and minor nutrients. Major nutrients (such as nitrogen, phosphorus and potassium) are required by plants in large quantities, while minor nutrients (such as chlorine, iron and zinc) are required in trace amounts but are essential for the healthy



Worksheets

Investigate growth rates of soil-based systems and hydroponics systems with the practical worksheet.

growth of plants. Nutrient formulations are always based on the type of crop, growth stage and variety. For example, the nutrient solution for a flowering tomato crop is different from the nutrient solution for a leafy green vegetable. Different nutrients promote different growing patterns. For example, phosphorous promotes flowering while nitrogen promotes development of leaves. This means that the type of crop (tomatoes that flower versus lettuce that needs green leaves) and stage of development (early stages need leaves versus later stages need flowers) affects the nutrient solution.

A nutrient solution is affected by many different factors.

**Table 15.3** Factors affecting a nutrient solution

Factor	Effect
pH	<ul style="list-style-type: none"> <li>The pH of the nutrient solution affects which nutrients can be taken up by plants.</li> <li>At a lower pH it is easier for plants to pick up micronutrients, but macronutrients become unavailable.</li> <li>Depending on the pH, different nutrients can also react with each other creating new compounds that are toxic to plants.</li> </ul>
Water quality	<ul style="list-style-type: none"> <li>Water can contain minerals such as sulphur, calcium and iron.</li> <li>These can affect the concentration of nutrients needed in the nutrient solution.</li> <li>Some water also contains 'pest' minerals such as sodium or chlorine. These minerals kill plants and therefore all water needs testing for hydroponic systems.</li> </ul>
Temperature	<ul style="list-style-type: none"> <li>Temperature of the nutrient solution affects plant growth.</li> <li>Warmer nutrient solutions have been found to increase the quality of the plant.</li> <li>Warmer solutions reduce the amount of dissolved oxygen available for the plants.</li> </ul>



## LET'S ENGAGE

### COMPARING NUTRIENT SOLUTIONS

#### PURPOSE

To examine different nutrient solutions and compare them in terms of composition and plant growth. Hydroponic growers can use commercial nutrient solutions or mix their own.

#### MATERIALS

- Four plastic ice cream containers or similar tubs
- Styrofoam sheets (from fruit boxes or packaging)
- Bok choy seedlings
- Four nutrient solutions including one commercial hydroponics preparation, a soluble inorganic fertiliser and two organic liquid fertilisers such as worm juice, seaweed solution or compost tea

#### RISK ASSESSMENT



Use the template on NelsonNet to prepare a risk assessment for this activity.

#### METHOD

- Cut a piece of styrofoam to fit snugly in the top of the ice cream container.

- Cut four holes to place seedling roots through.
- Fill containers with appropriately diluted nutrient solutions, labelling each container.
- Wash any growing media from the seedling roots and place through holes.
- Position styrofoam in container to allow roots to be partially submerged in nutrient solution.
- Check fluid levels regularly and top up as needed.

#### DISCUSSION

- Examine the packaging of the nutrient solutions you have used.
  - Do they all have information about the types of nutrients and their concentration?
  - Which ones have the most information?
  - How might access to this information help growers?
- Which nutrient solution was associated with the best plant growth?
- Which solution would you recommend to hydroponics growers?



Template

Risk assessment template

Incorrect make-up of a nutrient solution results in decreased plant growth, decreased plant quality and even death of plants. It is important to look out for signs of nutrient deficiencies to ensure a successful crop.

### Nitrogen deficiency

Nitrogen deficiency results in early maturation of plants. Crop quality and yield are often reduced. It is characterised by:

- general **chlorosis** of lower leaves
- stunted and slow growth – results in small leaves
- **necrosis** of older leaves.

### Phosphorus deficiency

Phosphorus-deficient plants grow at a slower rate than normal plants. Phosphorus is a vital nutrient for plants because it allows the plant to use the light energy from the sun. It is often difficult to spot a phosphorus deficiency until it is too late to save the plant. Some symptoms are:

- slow growth resulting in fewer leaves
- build-up of carbohydrates in the plant resulting in odd discolouration at later stages, with leaves turning purple.



**Figure 15.19** Chlorosis of rose flower leaves due to nitrogen deficiency



**Figure 15.20** Purpling leaves of rapeseed plant due to phosphorus deficiency

Alamy Stock Photo/Nigel Cattlin

Shutterstock.com/aleori

**chlorosis** leaves of typical green colour turn pale and yellow

**necrosis** death of plant cells, leaves can turn black



Worksheets

Explore other technology being developed for hydroponic production with the *Technology* worksheet.



Weblink

Find out how to spot other nutrient deficiencies.

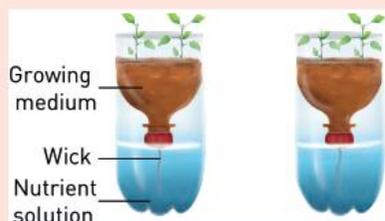


## LET'S ENGAGE

### SETTING UP A SIMPLE WICK HYDROPONIC SYSTEM

#### PURPOSE

To investigate the effectiveness of different materials as a wick in a hydroponic production system



**Figure 15.21** A completed wick system

#### MATERIALS

*Note: there should be enough of each of below materials for a class size.*

- Lettuce seedlings (you could use the seedlings grown in the earlier experiment)
- Empty 2 L soft drink bottles
- A selection of wicks approximately 40 cm long, such as shoelaces, string, wool, thin rope, felt, nylon, polyester, etc.
- Scissors
- Drill



Template

Risk assessment template

>

- Growing media
- Water
- Nutrient solution or nutrient solution kit

**RISK ASSESSMENT**

 Use the template on NelsonNet to prepare a risk assessment for this activity.

**METHOD**

- 1 Cut the top off a 2L soft drink bottle (about a third of the way down).
- 2 Drill a small hole through the lid.
- 3 Tie the top of each wick into a knot. Thread the wick through the hole in the lid. The tied knot should be on the inside of lid, with thread hanging down from lid.
- 4 Fill the bottom third of your soft drink bottle with nutrient solution.
- 5 Place the top of the soft drink bottle upside down inside the bottom of the

bottle and make sure the wick dangles from the lid into the solution.

- 6 Place growing medium in the top half of the bottle, covering the tied knot of the wick.
- 7 Place your seedlings into the growing medium. If using cubes, place them directly in; if using a different starter growing medium, you will need to transplant the seedling.
- 8 Place the bottle in a sunny place and watch your seedlings grow. Top up with water and nutrients as needed.

**DISCUSSION**

- 1 Compare your system to that of your classmates. Which wick materials transport liquid fastest?
- 2 How does type of wick material affect production?
- 3 What wick material would you recommend to farmers?
- 4 How could you improve your hydroponic system?

## Records and financial management

Hydroponic farmers, like other farmers, need to keep both a calendar of operations and financial records. In addition, hydroponic farmers must keep accurate records regarding the use of nutrient solutions.

### AG IN FOCUS

#### A HYDROPONIC BOK CHOY FARM

##### Identify

A local corporation runs a hydroponic farm, growing bok choy in a glasshouse. The glasshouse is 20 hectares and the corporation produces 30 000 kg of bok choy annually.

##### Understand

The farm manager carries out the following tasks throughout the year:

- manages six growing seasons in one year, due to the faster growth rates of hydroponic vegetables
- cleans and disinfects after each growing season
- germinates the seedlings
- transplants seedling into larger system for growing
- harvests using robotic technology.

##### Discussion

- 1 Create a calendar of operations for the case study farm.
- 2 The farmer sells the bok choy at \$3.50 per kg. The farm has variable costs of \$39 000 annually, most of which is for the high electricity bill required to climate



Template

Gross margin template



control the greenhouse. Conduct a gross margin analysis for the farmer. Use the gross margin template on NelsonNet to assist.

- 3 Discuss some management strategies the farmer could use to improve gross margin.

### DID YOU KNOW?

Workers in glasshouses must wear sunglasses in case the glass roof panels break and they reflexively look up.



## LET'S REVIEW

### LOOKING BACK

- 1 Explain the importance of light to a hydroponic system.
- 2 What is a vertical farm?
- 3 Describe six types of growing media.
- 4 What are the top three nutrients required for a nutrient solution?
- 5 Describe the symptoms of:
  - a a nitrogen deficiency
  - b a phosphorus deficiency.

### FOR YOU TO DO

- 1 Evaluate three different growing media for a hydroponic system.
- 2 Once your hydroponic vegetables are growing, examine them for any symptoms of nutrient deficiency. Note down any symptoms you spot and research what type of deficiency it could be.
- 3 Discuss how plants use the three macronutrients: nitrogen, potassium and phosphorus.

### TAKING IT FURTHER

- 1 Investigate the nutrient requirements of tomato plants. Compare the nutrients required with those of your lettuce crop.
- 2 Design your own hydroponic greenhouse.
- 3 Research how light colour affects plant growth. Discuss your findings.
- 4 Explain why Australia's biggest two hydroponic farms, Costa and Sundrop, are located where they are.

## 15.5 Pests and diseases

One of the main benefits of a hydroponic system is the minimal pest and disease problems. As an enclosed sterile system, it is difficult for pests and diseases to enter. However, depending on the system, some common indoor pests can be problematic.

## Pests

**Table 15.4** Indoor plant pests

Pest	Description
Spider mites	Spider mites are very common indoor pests. They are only about 1 mm long and are difficult to spot due to their small size. These arachnids leave webs on plants.
Thrips	Thrips are another difficult-to-spot indoor pest. Slightly bigger than spider mites, at 5 mm long, they leave black spots on the tops of leaves. Leaves will also turn brown as the thrips suck nutrients from the leaves.
Aphids	Aphids are one of the most annoying pests for farmers and are the reason everyone loves ladybirds (which eat them). Aphids suck sap out of leaves.

## Diseases

As with pests, diseases are uncommon due to the sterile nature of a hydroponic system. Indoor plant diseases are the most common in a hydroponic system.

**Table 15.5** Indoor plant diseases

Disease	Description
Powdery mildew	Caused by fungi. Appears as patches of grey-white powder on leaves. The plant will stop growing, and if untreated will die.
Grey mould	Attacks the petals of flowers, causing fruit to rot as it becomes soft. The plant becomes completely covered with grey mould. Often due to too high humidity.
Root rot	Due to excessive water inhibiting root growth. Roots will turn to mush, and plants will die.

## Integrated pest management for hydroponic systems

While hydroponic systems are less likely to encounter pests or diseases, an integrated pest management plan should still be prepared in case of any outbreaks. Some control methods are listed in Table 15.6.

**Table 15.6** Management of hydroponics systems

IPM component	Strategies
Physical	<ul style="list-style-type: none"> <li>• Netting to cover the plants</li> <li>• Screens blocking sections of the glass/greenhouse</li> <li>• Planting trap plants (plants that insects prefer) so the pests will eat those rather than the growing crop</li> </ul>
Cultural	<ul style="list-style-type: none"> <li>• Choosing growing media correctly because some materials are more prone to disease than others</li> <li>• Correct make-up of nutrient solutions as too much or too little nutrients can increase prevalence of pests and diseases</li> <li>• Modifying the environment using glass/greenhouse climate control to better suit the crop and not the pests</li> </ul>
Biological	<ul style="list-style-type: none"> <li>• Release biological control agents (insects that will control the pest and not harm the crop). Some examples include:               <ul style="list-style-type: none"> <li>• Encarsia (a parasitic wasp) to control whitefly</li> <li>• Californicus (a predatory mite) attacks spider mites</li> </ul> </li> </ul>
Chemical	<ul style="list-style-type: none"> <li>• Using pesticides</li> </ul>
General management and prevention	<ul style="list-style-type: none"> <li>• Using disinfectant foot pads and clean overalls before entering the glasshouse</li> <li>• Sterilising after each crop is harvested</li> </ul>



Worksheets

Explore whether hydroponics are a safer system with this worksheet exploring *E. coli*.



Alamy Stock Photo/bluckwinkel

**Figure 15.22** Insects adhere to the sticky surface of fly traps. The numbers are monitored to know if or when to treat for infestation.



## LET'S REVIEW

### LOOKING BACK

- 1 Describe four common pests or diseases that attack indoor plants.
- 2 What is IPM?
- 3 What is the benefit of a hydroponic system over traditional vegetable growing?

### FOR YOU TO DO

- 1 Investigate the biological control of indoor pests. Research three indoor pests and the biological controls that can be used against them.
- 2 Discuss the management practices required to ensure a sterile hydroponic environment.
- 3 Design a leaflet warning hydroponic farmers about one indoor pest or disease. Make sure to discuss:
  - a what it looks like
  - b symptoms
  - c treatment.

### TAKING IT FURTHER

- 1 Design an IPM program for your school hydroponic vegetables.
  - a Identify prevention methods covering all four principles.
  - b How would your school IPM program differ to that of a commercial grower?

## 15.6 Social and ethical issues



### LET'S DISCUSS

Hydroponic vegetables are grown in a sterile environment with minimal threat of bacteria. However, inorganic chemicals are used to create the nutrient solutions used.

- 1 What is the definition of organic?
- 2 Do you think hydroponic plants should be sold as organic?

### Corporation management

Hydroponic farming has many benefits similar to feedlots: both allow for constant production, reducing reliance on climatic factors. In addition, both products grow uniformly, with exact nutrition formulated and given, allowing for reliable production. However, like feedlots, hydroponics may continue the push towards industrialisation of food. Hydroponics requires a huge investment in infrastructure and developing technologies, relying on investors to provide money.

#### DID YOU KNOW?

Sundrop farms, one of Australia's biggest hydroponic farms, cost approximately \$200 million to build.

This results in large companies dominating the food supply, putting smaller businesses and family farms out of business. It also means that smaller start-ups cannot invest in the technology and start their own hydroponics farm.



### LET'S DISCUSS

- 1 What is the impact of large companies dominating the food supply? Consider positives and negatives.

### Inorganic chemicals

The use of chemicals has long been seen as a problem with traditionally grown crops and their use of herbicides and pesticides – so why should hydroponics be any different? Hydroponics are grown purely from the inorganic nutrients given using a formulated solution. Some argue the system is highly unnatural, with super nutrient doses, artificial lights, chemical pH stabilisers and elevated CO<sub>2</sub> levels all creating an unnatural environment.

The plants are grown in a sterile environment, and therefore produce sterile food. While this can be a benefit, because it limits the spread of harmful bacteria, it also limits the spread of good bacteria. No studies have been conducted yet to investigate the long-term impact of hydroponic vegetables on the gut microbiome and our immune systems. Our immune systems adapt and develop by interacting with bacteria. If we are no longer exposed to bacteria, our immune system may not develop and function properly.

Hydroponics is generally considered a more sustainable alternative to traditional farming, with no soil erosion or degradation and less water use (you can find out more about the sustainability of hydroponics in section 15.7).

Organic farming is a set of principles designed to look after the environment by not using artificial chemicals and focusing on soil health. Hydroponics therefore sits at a controversial point: it is a system designed to look after the environment, but also uses artificial chemicals to grow.



## LET'S REVIEW

### LOOKING BACK

- 1 Why do large companies dominate hydroponic production?
- 2 How are feedlots and hydroponic systems similar?
- 3 Why are hydroponic systems considered unnatural?
- 4 How might hydroponic production affect the health of a consumer?

### FOR YOU TO DO

- 1 Conduct a class debate on the following issue: 'Which is more ethical, organic farming or hydroponics?'
- 2 What is more important, natural growing or environmental sustainability? Justify your answer.
- 3 Design a leaflet to give to consumers, explaining why you think hydroponics should be considered organic produce.

### TAKING IT FURTHER

- 1 Discuss whether hydroponics abdicates us of our responsibility to look after agricultural land.

## 15.7 Sustainability

### Sustainable practices and methods

#### Hydroponics

Hydroponic production is argued to be a more sustainable method of production than traditional farming. This is because it often uses less water than traditional farming, does not result in soil degradation, and can be built close to cities, limiting emissions from delivering food in trucks. Hydroponics also makes contaminated or infertile land useful, because glasshouses or greenhouses can be built on land that previously couldn't be farmed. Table 15.7 shows some of the features that make hydroponics more sustainable than conventional production.

**Table 15.7** Hydroponics as a sustainable alternative

Advantages	Disadvantages
No soil needed	Requires high amounts of electricity for lighting, heating and cooling systems
Efficient use of space and location	Requires fresh water or the ability to treat seawater (which then requires electricity)
More control over nutrients and pH	Water-borne diseases can spread quickly, affecting crops or consumer health
Minimal use of pesticides; no environmental pollution or health hazards	
Uses less water than conventional production	

### DID YOU KNOW?

Studies have shown hydroponics can use up to 95% less water than traditional soil-based systems.

## Aboriginal use of hydroponics

Aboriginal Australians practised growing plants in water for food. As farmers, they grew nardoo, an aquatic fern, in the banks of rivers. Nardoo populations would often increase in the muddy banks left behind after rivers flooded. Nutritious spores are contained in an underwater stalk. Nardoo was made famous by explorers Burke and Wills, who starved while in the bush because they could not prepare it correctly.

It contains an enzyme that breaks down Vitamin B1 (a vitamin needed for energy and brain function). Aboriginal peoples would roast the spores from the nardoo plant and grind them to create a powder for cakes. The roasting destroyed the enzyme that breaks down vitamin B1, and it was missing this crucial step that resulted in the demise of Burke and Wills.

Bulrush was another aquatic plant grown by Aboriginal peoples, particularly those located along the Murray–Darling river systems. As well as being a nutritious starchy food, the underwater stems contain fibre that could be made into very strong and durable string, which was made into large nets, up to 180 metres in length. It was also used to make waist belts, headbands and bags.



**Figure 15.23** Nardoo was grown and harvested by Aboriginal Australians for food.

## AG IN FOCUS

### THE RAMINGINING COMMUNITY PROJECT

#### Identify

Ramingining is an Aboriginal community about 450 km from Darwin. The community was keen to grow its own produce but was limited by the lack of fresh water and the hot weather in the region.

#### Understand

The Ramingining Hydroponic Greenhouse Project is a collaboration with the Arnhem Land Progress Aboriginal Corporation (ALPA), Food Ladder and the Australian Government, created as a jobs

opportunity for the community. Instead of growing via soil, a hydroponic greenhouse required limited water use, because it could recycle the water used. Growing in clay pellets instead of soil, the community produce vegetables such as cucumber, tomatoes, capsicum, rockmelon, spinach, brussels sprouts and cabbage. While it can't produce enough to replace all produce freighted in from Darwin, it supplies the local grocery store and provides jobs for the local community.

The greenhouse is 100% Aboriginal-owned and is the first hydroponic system to be set up in a remote community in Australia. The project has the potential to deliver wide-ranging benefits for the Ramingining community, such as the opportunity to learn plant production skills and new employment and educational opportunities for local people.

- 1 What type of crops are grown by the Ramingining community glasshouse?
- 2 Explain how environmental factors affected the project direction.
- 3 Discuss the benefits of the project for the local community.
- 4 Is hydroponics a sustainable alternative for these remote communities?



Figure 15.24 Ramingining community greenhouse

Arnhem Land Progress Aboriginal Corporation



Video

Watch the ALPA video showcasing the greenhouse.

### Growing media

Hydroponic production uses a variety of growing media, peat moss being one option. However, peat moss is considered an unsustainable resource because it takes millions of years to form. Peat moss is most commonly found in wetland areas, which are particularly susceptible to environmental damage. There are environmental concerns about the harvest and use of peat moss because overharvesting destroys the wetland area, as has been seen in Europe. Other countries such as Canada have brought in sustainable harvesting practices, harvesting 60 times less peat moss than is regenerated annually, to ensure protection of the wetland environment.

Another common growing medium is rockwool. Rockwool cannot currently be reused, but research is being conducted to investigate how to recycle rockwool for hydroponic production. This involves trialling melting down old rockwool, such as the insulation in demolished buildings, and recycling the product. European recycling companies completely dismantle the rockwool, take out tangled dry roots, disinfect and re-use.

## Sustainable technology

### Energy

Hydroponics is often considered a sustainable alternative to traditional soil-farming, but that all changes when you consider the electricity bill. Large climate-controlled, artificially lit glass or greenhouses result in a large electricity bill, which therefore carries a large **carbon footprint**. The large carbon footprint is due to the methods of producing electricity. Despite an increase in renewable energy sources, coal power is still the main source of electricity in Australia and results in a large carbon footprint for hydroponics farmers. Vertical farms often result in even greater carbon footprints because they require more light than greenhouses.

One study in the UK estimated that traditional soil greenhouses used approximately 250 kW of energy per year per square metre but a vertical farm used approximately 3500 kW for the same area, with 98% of this energy needed for lighting and climate control.

Some hydroponic farms are looking at renewable sources of energy to reduce their carbon footprint and therefore create a more sustainable enterprise.

**carbon footprint** the total greenhouse gas emissions caused by an individual or activity



Worksheets

Assess the sustainability of hydroponics in more detail.

### AG IN FOCUS

#### SUNDRUP FARMS

##### Identify

Sundrup farms is a hydroponic facility in Port Augusta, South Australia. Employing 175 people, Sundrup uses solar power and sea water to grow 15 million kilograms of truss tomatoes a year, which it sells to Coles on contract.

##### Understand

\$200 million was spent to build the Sundrup facility. A 51 500 m<sup>2</sup> field of solar panels powers the 20 hectares of glasshouses. Solar panels (23 000 of them) capture energy from the sun. The energy is used to heat and light the glasshouses as well as convert seawater to fresh water. This means Sundrup only relies on the electricity grid for 10–15% of its power needs (usually in winter).

Sundrup does not take any fresh water from the environment for its farms. Instead it takes sea water and, using the energy from its solar field, desalinates the water (removes the salt) to create a very pure freshwater in which to grow the tomatoes. Sundrup produces 450 000 m<sup>3</sup> of fresh water a year using this method.

The facility is an example of sustainable production that will provide a consistent supply of tomatoes throughout the year, not only to South Australia but also interstate.

- 1 Explain how the Sundrup system works.
- 2 Draw a flowchart showing the Sundrup production process.
- 3 Sundrup has created a sustainable energy and water usage system. Discuss whether this system is feasible for other hydroponic farms.



Alamy Stock Photo/Lincoln Fowler

**Figure 15.25** Sundrup uses 23 000 solar panels to power their hydroponics farm.



Video

Watch the *Landline* episode about Sundrup farms to find out more.

## Sustainable decision-making

### AG IN FOCUS

#### THE IMPACT OF HYDROPONICS VS TRADITIONAL GROWING

##### Identify

Hydroponics systems are often considered a more sustainable alternative to traditional farming, but they can also negatively affect farmers.

##### Understand

Hydroponic systems require a huge amount of investment and capital to set up, which means many farmers cannot access the system at all. In addition, initial set-up of the system requires high usage of plastics to build the greenhouses. Some commonly used materials, such as rockwool, result in a lot of waste. Unless the farm has access to a renewable energy source, hydroponics systems carry a large carbon footprint due to the amount of electricity required for climate control.

In the long term hydroponics systems do use much less water than traditional farming, with some studies finding as much as a 95% decrease. This is because many hydroponic systems recycle used water. In addition, farmers could convert to renewable energy, but this requires a lot of investment.

Many of the decisions hydroponics growers make affect sustainability. The choice of growing media, for example, greatly affects the sustainability of the enterprise (such as peat moss, which can damage wetland environments if overharvested). While high concentrations of artificial chemical nutrient solutions result in shorter growing seasons (and hence result in a short-term profit increase for the farmer), studies are unsure if this will have long-term effects on the health of consumers.

##### Discussion

- 1 Discuss some of the short-term effects of using a hydroponic growing system.
- 2 Discuss some of the long-term impacts of using a hydroponic growing system.
- 3 Conduct a class debate on the statement: 'Hydroponic production is a more sustainable alternative to traditional growing systems.'



### LET'S REVIEW

#### LOOKING BACK

- 1 What are two advantages of growing plants using hydroponic systems?
- 2 Explain how Aboriginal Australians used two plants grown in hydroponic systems.
- 3 Explain why peat moss is considered an unsustainable growing media.
- 4 What is a carbon footprint?

#### FOR YOU TO DO

- 1 Design an environmentally friendly commercial hydroponics system. You need to:
  - a choose a location in Australia. Consider water supply and climate.
  - b choose a growing medium.
  - c design the system. Which production system will you use? How will you power your facility?
  - d prepare a presentation on your design.



- 2 Investigate Costa, another large hydroponics grower in Australia. Compare its production system to that of Sundrop farms. Which is more sustainable? Justify your answer.
- 3 How can Indigenous techniques be used to create a more sustainable farming system?



Costa farm

### TAKING IT FURTHER

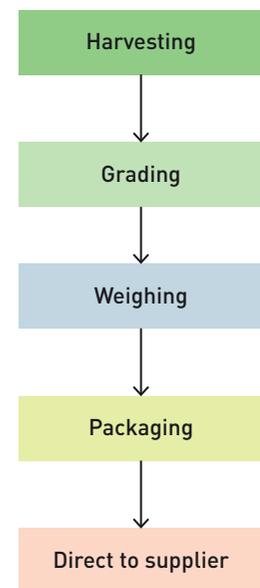
- 1 Evaluate which of the following options is more sustainable.
  - a Growing media: rockwool or coconut fibre
  - b System: vertical farm versus glasshouse
- 2 Hydroponics protects our soils, yet has a large carbon footprint.
  - a Debate which is more important: protection of our soils or reduction of carbon emissions?
  - b Given your answer to part a, what production system would you therefore recommend for future farmers?

## 15.8 Marketing

### The market

Hydroponic production is sold both domestically and exported to other countries. Vegetables are the fourth-highest grossing agricultural enterprise in Australia, after beef, wheat and dairy products. The majority of lettuce and tomatoes grown in Australia are grown hydroponically by large corporations such as Sundrop and Costa. Most of this produce is sold direct to supermarkets. Growing markets for hydroponic vegetables include other leafy green vegetables, cucumbers and berries.

Hydroponic farms are usually located closer to consumers, which means the food is generally fresher and quicker to market. Because the farms are large corporations, they often have vertically integrated their production and packaging on site before delivering direct to the retailer.



**Figure 15.26** Marketing chain for hydroponic crops

### AG IN FOCUS

#### COSTA FARMS

##### Identify

Costa is one of the largest hydroponic producers in Australia. It grows a variety of vegetables, and its large hydroponic glasshouse is located in Guyra, NSW.

##### Understand

Costa grows tomatoes in a 30-hectare glasshouse, producing about 15 million kg per year. Costa's tomato glasshouse is located within freight distance of major cities such as Newcastle and Sydney. Costa is a fully integrated farm, meaning it operates all stages of the marketing chain: grading and packaging on site, and controlling

the logistic and delivery services. Due to its location and vertical integration, Costa tomatoes are often in store at a retailer within 24 hours of harvest. Due to its size, Costa has been able to directly market and supply to major retailers such as Woolworths. Costa also organises its own export and wholesale deals, partnering with overseas companies such as African Blue, which is a Moroccan company supplying berries globally. This overseas partnership allows Costa to sell product counter-seasonally to Australia – meaning it can still sell stock when demand for a product drops in Australia due to seasonal demand.

### Discussion

- 1 How does Costa's location affect its production of tomatoes?
- 2 How has Costa vertically integrated its tomato business?
- 3 Discuss the benefits and disadvantages of vertical integration.

## Market specifications

Market specification for hydroponic vegetables are much the same as for traditionally grown vegetables. Guidelines created by FreshSpecs are provided to growers and must be followed. Buyers such as Woolworths and Coles have extremely strict guidelines. This is one benefit of hydroponic production: because the nutrient profile and lighting is so exact, all crops generally grow in the same way. There are limited pests and diseases affecting the plants, which means more produce passes the strict guidelines set by FreshSpecs.



### LET'S ENGAGE

## JUDGING LETTUCE

### PURPOSE

To develop skills in assessing the quality of hydroponically grown lettuce

### MATERIALS

- The lettuce you grew hydroponically in the soft drink bottle
- Market specifications for the lettuce you grew
- Junior judging sheet
- Labels and pen

### METHOD

- 1 Get into groups of four. Place each of your lettuces on a plate in front of you. Label these plates 1 to 4.
- 2 Using the specifications, assess the quality of each plate.
- 3 Record placings and comments in a table.

### DISCUSSION

- 1 Did the lettuce meet market specifications?
- 2 Discuss the specifications themselves. Do you think the specifications are too strict (or not strict enough)?
- 3 What affect would it have on the grower if the lettuce didn't meet market specifications?
- 4 What management techniques could you implement to make sure your lettuce meets market specifications?



Weblink

You can access market specification at the FreshSpecs website .

## Marketing strategies

### Contract

Most hydroponic farms in Australia sell direct to retailers, under contract. For example, before beginning production, Sundrop negotiated a 10-year contract with Coles. This ensured that it could spend the large investment in building the farm because it was guaranteed a customer.

### Other methods of selling

Small-scale hydroponic producers have personalised contracts with restaurants catering to their requirements. Cafes, family-owned food businesses and local produce markets are regular buyers of fresh vegetables. Costa Farms operates a logistics business connecting these smaller producers to their local markets

### Advertising and promotion

Hydroponic producers are strongly encouraged to market their product as hydroponically grown. After outbreaks of bacteria such as *E.coli*, consumers often look specifically for hydroponic produce, which is more likely to be pest and disease free. In addition, the sustainability of hydroponic production appeals to many consumers so it is useful to use this as a unique selling point.

### Value-adding

Hydroponic vegetables can be value-added in similar ways to traditionally grown vegetables. Leafy greens are a commonly grown hydroponic vegetables. These can be washed, dried and packaged to increase shelf life. Produce that does not make it to first grade market is used by processors for slicing, dicing, cutting, chopping, cooking, mixing, grinding, smoking, drying, packaging and canning.



## LET'S REVIEW

### LOOKING BACK

- 1 Which vegetables and fruits are commonly grown hydroponically in Australia?
- 2 What are the benefits from hydroponic farms being located close to consumers?
- 3 How are hydroponic vegetables commonly sold?
- 4 Why is it beneficial to market produce as hydroponically grown?

### FOR YOU TO DO

- 1 Design a marketing campaign for your hydroponically grown lettuce. You should create at least two forms of advertisement, design a logo and slogan, and create sustainable packaging. Use Chapter 4 Agricultural business to help you.
- 2 Explore the Sundrop website. Identify their target market and unique selling point.
- 3 Brainstorm ways of value-adding to your lettuce.

### TAKING IT FURTHER

- 1 Evaluate the impact of marketing vegetables as being produced hydroponically.
- 2 Research hydroponic farming in the United Arab Emirates.
  - a Why is the UAE suited for hydroponic production?
  - b How will hydroponic production benefit citizens of the UAE?
  - c How will hydroponic production limit countries currently importing food into the UAE?
  - d Discuss how hydroponic techniques may differ between the UAE and Australia.



Weblink

Sundrop farms

# Let's summarise

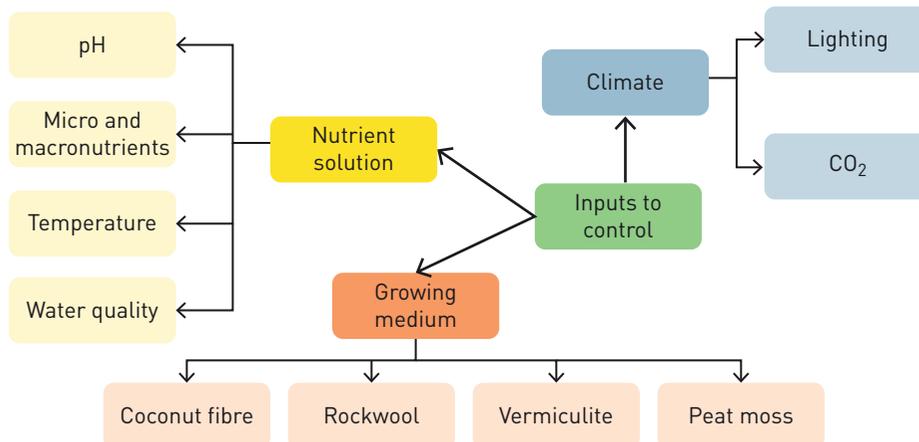
## Can hydroponics replace conventional vegetable production?

Hydroponics production could potentially replace traditional vegetable production given the ability to produce more food in smaller spaces.

Create a mindmap detailing the management and production strategies that allow hydroponic farmers to do so.

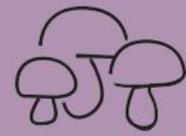
## Is hydroponics a more sustainable production system than traditional vegetable growing?

Hydroponics uses a lot of technology and strategies that can make it a more sustainable system than traditional vegetable growing. However, high electricity usage and choice of materials can affect the sustainability of the enterprise. Using the words suggested in the mindmap below, prepare a report discussing whether hydroponics is a more sustainable system than traditional vegetable growing.



Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about hydroponic production.



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# Fungi

## CHAPTER SUMMARY

Fungi are unique organisms that share characteristics with both plants and animals. Fungi have a long history in Australia, with native fungi featuring in Aboriginal lore. Today, mushroom farmers grow fungi in sheds, bags, buckets and even in logs. Some also forage for wild fungi. Fungi have a unique reproductive process, using their spores to reproduce. We can use spore prints to identify and grow mushrooms.

Mushrooms can be grown in many types of material, from recycled coffee grounds to old clothes. Fungi are also important for soil health and can be used to recycle manures, green waste and even plastic, making it a very sustainable enterprise.

**How are fungi linked to other agricultural enterprises?**

**How do we manage production to make the best mushrooms while looking after the environment?**

## 16.1 Introduction

Fungi might look like plants but they actually share more in common with animals. They cannot photosynthesise, but instead need to consume food from their environment. Although they have cell walls like plants, these structures contain chitin, a substance found in the shells of lobsters and prawns.

Fungi include mushrooms, toadstools, truffles, moulds, yeasts, rusts and smuts. Some species, such as common white mushrooms, are a nutritious food crop. Other species, such as leaf rust in cereal crops, cause damage and disease.

Mushroom farming, also known as fungiculture, is an intensive agricultural industry worth almost \$400 million to the Australian economy each year and involves around 80 large-scale growers across the country. There are also several smaller producers who cultivate specialty species.

Along with many other benefits, multiculturalism has brought with it new and exciting mushroom varieties and production methods. Japanese mushrooms such as enoki and shimeji are gaining popularity, while German oyster mushrooms and East Asian shiitake mushrooms can now be found in most supermarkets around the country.

**Table 16.1** Commercially cultivated mushroom varieties



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Hortimages

**Figure 16.1** White button – *Agaricus bisporus*

Along with cup and flat white mushrooms, the most popular edible mushrooms in Australia



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Brandon

**Figure 16.2** Swiss brown – *Agaricus bisporus*

A brown version of the white button mushroom with a firmer texture



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anant thong

**Figure 16.3** Shiitake – *Lentinula edodes*

An Asian mushroom with medicinal and culinary uses



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Hongyan

**Figure 16.4** Oyster – *Pleurotus ostreatus*

Soft, velvety texture in a variety of colours



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Kaiskyne Studio

**Figure 16.5** Shimeji – *Hypsizygus tessellatus*

A Japanese mushroom with a crunchy texture and nutty flavour



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junyanjiang

**Figure 16.6** Enoki – *Flammulina velutipes*

A popular Japanese mushroom with a crisp texture, used in soups and salads

## 16.2 Functions and structures

### Functions

The most commonly grown edible fungi in Australia are *Agaricus bisporus* mushrooms. These include white button, cap and flat mushrooms, as well as portobello and Swiss brown mushrooms.

Some mushrooms are both edible and medicinal. Shiitake mushrooms reduce blood cholesterol and may stimulate the immune system in HIV and AIDS patients. Reishi mushrooms have been used for centuries to treat infections and are sometimes referred to as 'the elixir of immortality'. Lion's mane mushrooms stimulate the growth of brain cells and are being investigated as a potential treatment for Alzheimer's disease. Other types of fungi, including the mould **penicillin**, are cultivated for medicine.

**penicillin** an antibiotic, or medicine, used to treat bacterial infections; made from *penicillium* mould

#### DID YOU KNOW?

Medicinal mushrooms and other natural therapies can affect the dosage and action of certain medications. Always seek medical advice before trying alternative therapies.

Soil fungi play many important roles in plant health, decomposing wastes and recycling nutrients. Mycorrhizal fungi help plants access more water and nutrients from the soil, a relationship you will learn more about later in this chapter.

Yeasts are important agricultural organisms involved in the production of several products including bread, cheese, alcohol and biofuel. They are also being used to produce lab-grown milk and eggs.

**Table 16.2** Products made using yeast



Shutterstock.com/  
Nata-Lia

**Figure 16.7** Bread

Baker's yeast (*Saccharomyces cerevisiae*) produces carbon dioxide, causing bread dough to rise.



Shutterstock.com/  
Mariyana M

**Figure 16.8** Alcoholic beverages

Alcohol is a by-product of the fermentation of plant sugars by *S.cerevisiae*.



Shutterstock.com/Ermak  
Oksana

**Figure 16.9** Cheese

Torula yeast is used to ripen and flavour brick and limburger cheeses.



iStockphoto.com/svengine

**Figure 16.10** Biofuel

*S.cerevisiae* ferments sugars and plant wastes to form bioethanol.



Alamy Stock Photo/Keith  
Homan

**Figure 16.11** Lab-grown milk and eggs

Genetically modified *S.cerevisiae* is used to grow animal products in the laboratory.



Shutterstock.com/Natalya  
Osipova

**Figure 16.12** Kombucha and other products

Sweet tea is fermented with *S.cerevisiae* and bacteria.

## AG IN FOCUS

## ABORIGINAL USES OF FUNGI

## Identify

Long before European arrival, fungal lore allowed Aboriginal peoples to avoid toxic species and identify helpful and edible ones.

## Understand

Lore refers to a body of knowledge and cultural traditions that are passed down, usually orally, from generation to generation. Fungal lore is the intellectual

property of Indigenous peoples and has been constructed over tens of thousands of years through observations and experience.

Fungi were and still are used for food, medicine and in cultural practices. Native bread truffles can grow to the size of a football and taste like boiled rice. Dug out of cracks in the soil, the truffles can be ground to a paste, baked and eaten. Aboriginal peoples of central Australia have relied on these truffles for food and as a precious water resource for thousands of years.

Other mushrooms have been used as medicines and as dyes for hair and skin. Scarlet bracket fungus has traditionally been used to relieve teething pain in babies, although it is poisonous if swallowed. Some fungi can be used as tinder for fires, and at least one species of truffle, when rubbed in the armpits, is reported to suppress hair growth.

Native ghost fungi glows in the dark. Reports from early European explorers stated that local Aboriginal peoples associated these eerie fungi with spirits.

## Discussion

- 1 List some of the ways native fungi have been used by Aboriginal peoples.
- 2 Conduct a class discussion on the ethics of native fungi and fungal lore in following scenarios.
  - a A famous chef has decided to use an edible native mushroom in a recipe at their restaurant. They will be charging \$90 a plate.
  - b A large pharmaceutical company has been researching the use of a native mushroom for patients with heart disease. Local Aboriginal peoples have been using this mushroom as a bush medicine for thousands of years.
  - c The local council is planning on conducting land clearing in an area with three native fungal species. There are no written records about the use of these fungi by Aboriginal peoples.
- 3 Visit the Australian National Botanic Gardens website to learn more about native fungi. Choose one species and write a brief report on its distribution, appearance and uses.



Figure 16.13 Native ghost fungi

Shutterstock.com/Petar B photography



Weblink

Australian National Botanic  
Gardens

## Structures

**hyphae** the branching filaments or threads of a fungus that usually live on or below ground

**mycelium** the network of hyphae that together make up the body of a fungus

**spores** fungal reproductive cells released from the gills

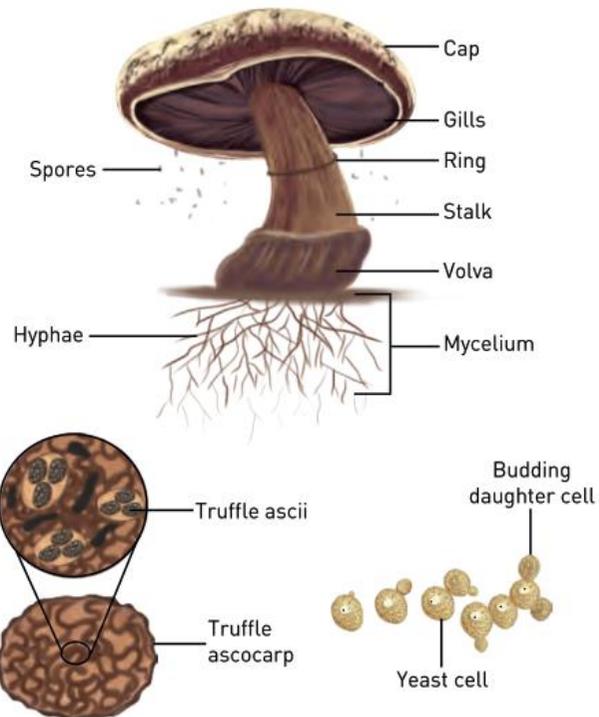
**gills** paper-thin, leaflike structures found below the mushroom cap, containing basidia and releasing spores

**basidia** structures within the gills of a mushroom that make and release spores

Fungi are made up of tiny hair-like structures called **hyphae** that fuse, grow and tangle together to form **mycelium**. The fungi feeds through its mycelium, releasing chemicals to break down nutrients, which it then absorbs.

Some fungi produce fruiting bodies that then release reproductive cells called **spores** into the environment. Mushrooms and toadstools are fruiting bodies that stick out above the ground. The mushroom stalk supports a cap that protects and houses the delicate **gills**.

Spores are made in, and released from, structures called **basidia** that are located in the gills. Compared with plant seeds, spores are much lighter and smaller and can float on the wind for long distances.



**Figure 16.14** The structures of a mushroom, truffle and yeast



Worksheets

Complete the *Fungi find-a-word* worksheet on NelsonNet.

### DID YOU KNOW?

The volva and ring are leftovers from a special structure that protected the baby mushroom when it first emerged.

Truffles are fruiting bodies that never emerge above the surface. Instead, the gills and spores are held in sacs underground. Yeasts are another type of fungus. Unlike mushrooms and truffles, yeasts are microscopic single-celled organisms that do not produce fruiting bodies but instead reproduce by dividing themselves in a process called 'budding'.



LET'S ENGAGE

### MAKING A SPORE PRINT

#### PURPOSE

To make spore prints that can be used for identification, propagation of new species, or as artworks

#### RISK ASSESSMENT



Take care with scalpels to avoid injury. Always dispose of sharps appropriately.

#### MATERIALS

- Fresh mature mushrooms with open caps

- Sterile scalpel
- Paper
- Beaker

#### METHOD

- 1 Carefully cut the stalk of the mushroom as short as possible without disturbing the gills.
- 2 Place the cap, gill-side down, on the paper and cover carefully with a beaker.
- 3 After 6–12 hours, remove the beaker and gently lift the mushroom cap off the paper.

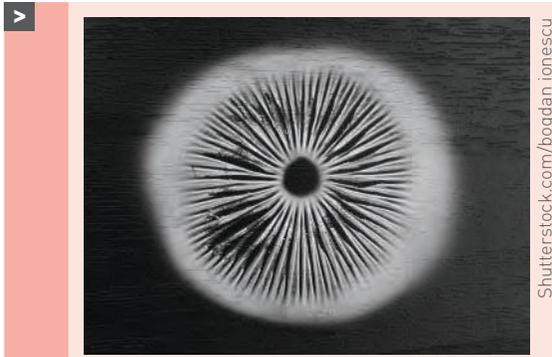


Figure 16.15 Mushroom spore print

### DISCUSSION

- 1 What hygiene measures should we use during this activity if we want to use our spore prints to grow mushrooms?
- 2 Did some mushrooms produce more spores than others? What factors might have influenced this?



## LET'S REVIEW

### LOOKING BACK

- 1 Name some varieties of mushrooms grown in Australia.
- 2 Define the following terms: spore, cap, stalk, gills, hyphae and mycelium.
- 3 Give two examples of fungal fruiting bodies.
- 4 How do spores differ from plant seeds?
- 5 Apart from eating, for what other reasons do we grow fungi?

### FOR YOU TO DO

- 1 Conduct a poll of your class to see who eats mushrooms, how often they eat them and what varieties they have tried.
- 2 Do fungi more closely resemble plants or animals? Construct a table outlining the similarities and differences between fungi, plants and animals.

### TAKING IT FURTHER

- 1 Investigate the different mushroom varieties cultivated in Australia.
- 2 Research one species of mushroom to find out how it is cultivated, where it originates from and how it is used.



Weblink

Mushroom varieties

## 16.3 Production

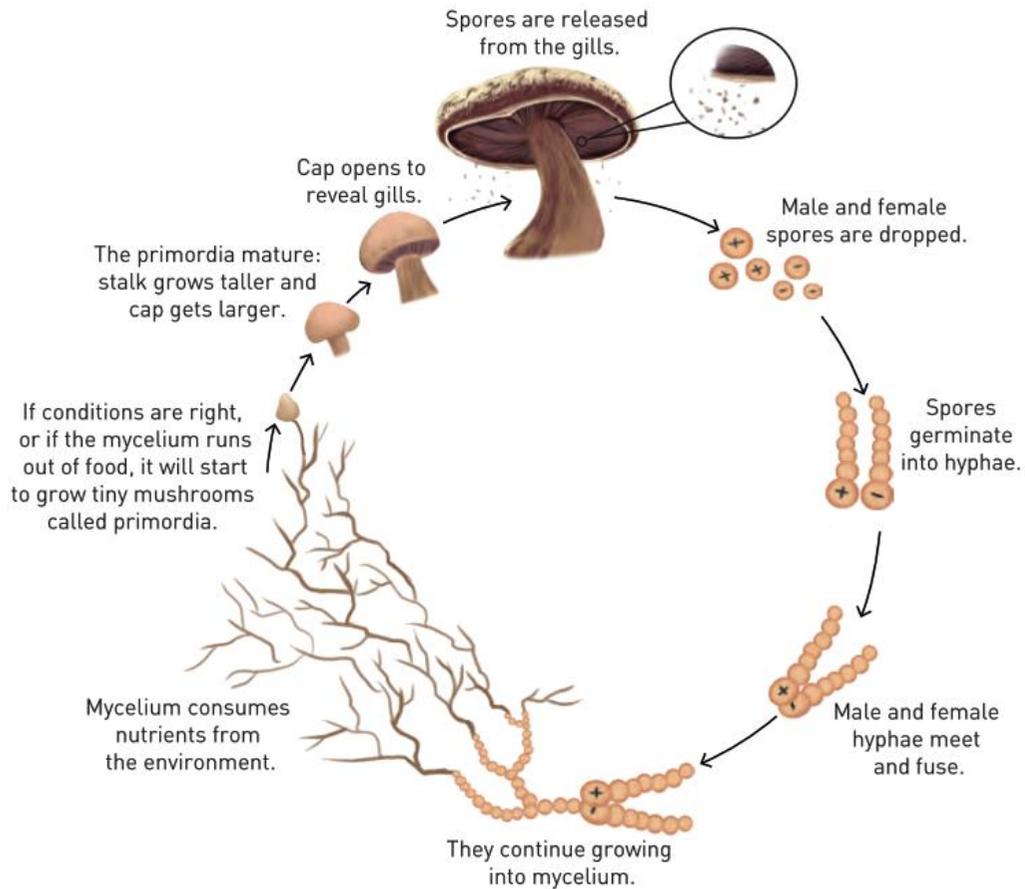
### Cycle

The mushroom production cycle is closely linked to its life cycle. Mushrooms can be grown sexually (through spores) or asexually. Figure 16.16 shows the sexual reproductive process. Mushrooms can also be propagated asexually. If fragments of mycelium are broken off, they can grow and form their own mushrooms. This process is used to multiply the amount of mycelium in growing sheds, allowing growers to produce more mushrooms.



Worksheets

Complete the *Lifecycle of a mushroom* worksheet on NelsonNet.



**Figure 16.16** The lifecycle of a mushroom

## Mushroom production systems

There is a wide variety of modern production systems in Australia, some of which are described in Table 16.3. Some farms are very large and conduct many of their production tasks using machinery and computers, while others are very small and rely heavily on manual labour.

**Table 16.3** Mushroom production systems

Production system	Types of mushroom	How the system works
Sheds	Button, cap, flat, portobello and Swiss brown	Mushrooms are grown all year in compost and peat on shelves inside computer-operated, climate-controlled cells or rooms. Farms can be very large and produce tonnes of mushrooms.
Bags and containers	Oyster, shimeji and other exotic varieties	Mycelium is grown in plastic bags or containers. The containers are opened or moved to a more humid and cooler room to fruit after a few weeks.
Logs	Shiitake	Mushrooms are grown inside holes drilled into freshly cut hardwood logs. Mushrooms can be harvested after six to 12 months.
Wild foraging	Saffron milk cap and slippery jack	Foragers search for wild mushrooms in pine forests during autumn. Careful identification of species is important to avoid poisoning or death.
Truffle farming	Black and white truffles, plus several other species	Oak or hazelnut trees are infected with truffle spores and then approximately ten years later, trained dogs sniff them out for harvesting. White truffles sell for up to \$15 000 per kilogram.



Data scenario

Investigate the best method of production for Phoenix Oyster mushrooms by completing the *Mushroom yields in bags versus buckets* data scenario on NelsonNet.

Shutterstock.com/Videologia



**Figure 16.17** White mushrooms can be grown on shelves in climate-controlled sheds.

## DID YOU KNOW?

Mushroom hats are worn by foragers to spread spores through the forest. Harvested mushrooms are placed, gills down, on the thin mesh brim of the hat. As the wearer walks around gathering mushrooms, the spores drop through the mesh onto the forest floor.

## AG IN FOCUS

### THE DANGERS OF MUSHROOM FORAGING

#### Identify

Many native mushroom species are dangerous and some are deadly.



Foraging is a risky activity and should only be done by trained, competent individuals.

#### Understand

Foraging for wild foods has become popular, with a number of mushroom species becoming regular ingredients in some restaurants.

Between 2014 and 2018, over 300 calls were made to the Poisons Information Centre about suspected mushroom poisoning. Many toxic species look almost identical to common edible species. Amateur foragers may end up with a simple stomach ache or even die, depending on the species they stumble across.

**Table 16.4** Some poisonous mushrooms of Australia

Species	Signs of poisoning
Death cap	Vomiting, diarrhoea, liver damage, kidney failure, coma, death
Yellow stainer	Severe stomach pain, vomiting, diarrhoea, nausea
Green-spored parasol	Severe vomiting and diarrhoea, blue discolouration of lips and tongue, death

Never pick and eat wild mushrooms. Young children and pets should also be kept away. If you suspect someone may have ingested wild mushrooms, seek medical attention immediately.

#### Discussion

- 1 What should you do if you suspect someone has ingested wild mushrooms?
- 2 Why would young children and pets be more likely to fall victim to mushroom poisoning?
- 3 Design a poster or presentation outlining the potential dangers of consuming wild mushrooms.



LET'S ENGAGE

## MAKING MUSHROOM BUCKETS

### PURPOSE

To create reusable mushroom buckets for growing oyster mushrooms

### RISK ASSESSMENT



Take care when using power tools. Only use under the direct supervision of your teacher.

### MATERIALS

- Food-grade buckets with lids
- Electric drill with 0.5 inch drill bit

### METHOD

- 1 Remove the bucket lids and set aside. Drill 10–15 evenly spaced holes in the sides of each bucket.
- 2 Wash the buckets and lids thoroughly with warm soapy water.
- 3 Rinse the buckets in clean water then leave upside down to drain and dry.
- 4 Store the mushroom buckets with lids on.



Melissa Marshall

**Figure 16.18** A completed mushroom bucket

### DISCUSSION

- 1 Discuss the advantages and disadvantages of using buckets over plastic bags.
- 2 Investigate other methods of growing oyster mushrooms. What other containers and systems can be used?



Discover more about how products are made from yeast by completing the NelsonNet worksheet *Yeast in agriculture*

## Yeast production cycle and systems

Yeast production systems are based on fermentation. Yeast organisms use sugar for energy. When they are in oxygen-rich environments, they use cellular respiration to convert sugar and oxygen into carbon dioxide, water and a special molecule called adenosine triphosphate (ATP), which powers their cells. If, however, they are kept in an environment with no oxygen (e.g. in a liquid solution), they use the sugar for fermentation instead. Fermentation uses sugar to produce alcohol (ethanol), carbon dioxide and ATP.



**Figure 16.19** Fermentation of sugar by yeast

Alcohol and carbon dioxide are waste products for yeast but are useful to agricultural industries. Carbon dioxide causes dough to expand and rise in breadmaking. Fermentation of plant sugars in vats produces the ethanol in wine, beer, cider and other alcoholic beverages. Bioethanol, a fuel that can be used as a substitute for petrol, is also produced by yeast fermentation of plant sugars.

### Fermentation vats

Sugar and yeasts are added as a liquid solution to fermentation vats. Stirrers keep the concentration of yeast and sugar and the temperature of the vat even. Cool or warm water is

pumped through a water jacket surrounding the vat, keeping the temperature at the optimum level for yeast fermentation. Once the alcohol has been produced, it can be refined using dehydration (heating to evaporate water) and distillation (separating the alcohol based on its boiling point).

## AG IN FOCUS

### CELLULAR AGRICULTURE

#### Identify

In cellular agriculture, animal and plant products are grown from cell cultures in a lab rather than on the farm. Yeast cultures are used to produce several traditional agricultural products including milk, egg whites and vanillin.

#### Understand

To produce an agricultural product, yeast must first be genetically modified by adding or changing genes in the yeast's DNA. The yeast used to grow egg white proteins must first have the egg white genes inserted into its DNA. The yeast is then fermented in a vat with sugar and produces the egg white protein using the egg white genes.

Lab-grown animal products have a number of advantages. They can be grown without using or degrading land, use significantly less energy and water, and produce substantially lower greenhouse gas emissions than animal enterprises. As the technology improves, cellular agriculture has the potential to provide cheap sources of high-quality protein to developing nations and growing populations. Products of cellular agriculture can be marketed as vegan because they are not made from animals. Food safety is also enhanced because the products never come into contact with animal faeces or other sources of bacterial contamination.

Yeast has also been genetically modified to produce vanillin, or vanilla flavouring. Vanillin is normally produced in factories from petrochemicals or harvested from rainforests. Yeast-grown vanillin not only reduces the use of petrochemicals, it also reduces human impact on delicate rainforest ecosystems.

#### Discussion

- 1 How are cellular agricultural products made?
- 2 How are genetically modified yeasts different from normal yeasts?
- 3 Outline the advantages of cellular agriculture for the production of milk, egg whites and vanillin.
- 4 Some consumers are reluctant to try lab-grown food. Conduct a poll of your class members to determine their attitudes to lab-grown food.
- 5 Analyse the impact of cellular agriculture on animal welfare.



## LET'S REVIEW

### LOOKING BACK

- 1 Construct a flowchart outlining the life cycle of a mushroom.
- 2 What needs to happen for fungi to start producing mushrooms?
- 3 Identify and describe three methods for growing mushrooms.
- 4 How does fermentation differ from cellular respiration?



### > FOR YOU TO DO

- 1 Evaluate different production systems for growing mushrooms.
  - a Compare systems based on the issues of sustainability, production times, financial returns and expenses.
  - b Make a judgement on which system you would choose to use as a mushroom farmer.
- 2 Compare reproduction in plants and fungi. Make sure you consider both sexual and asexual reproduction.
- 3 Investigate fermentation vats used in the production of alcohol. Draw and label a diagram of a fermentation vat, showing how production occurs.

### TAKING IT FURTHER

- 1 Design an experiment to test the effect of sugar concentration on the rate of fermentation of yeast. Hint: can you think of a way to measure how much CO<sub>2</sub> is released?
- 2 Investigate what kinds of edible gourmet mushrooms are foraged in pine forests.

## 16.4 Management

### Environmental management

#### Distribution of enterprises

Mushroom farming began in the railway tunnels under Sydney during the 1930s. Today, large mushroom enterprises are found in or near most capital cities. Small-scale producers often grow exotic varieties and are usually located near cities or major regional centres.

Mushrooms do not need soil and can be grown in very small spaces. Hence, they are perfect for urban areas where they can be cultivated in buildings or sheds then transported quickly to market.

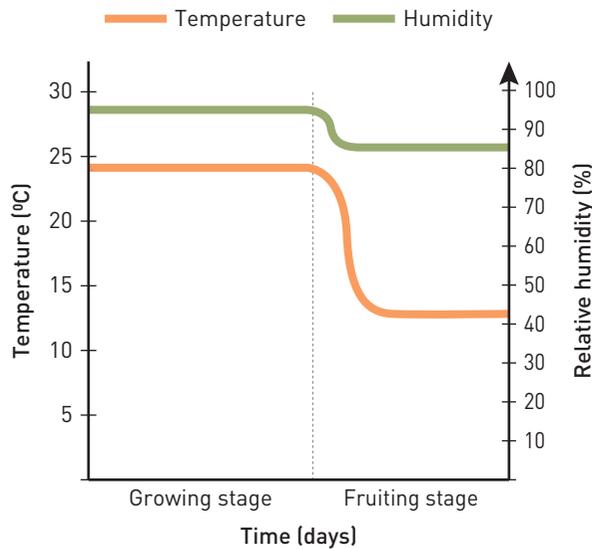
#### Climate

In nature, most fruiting occurs in autumn. *Agaricus* mushroom growers can simulate autumn conditions and shock their mycelium into producing mushrooms by controlling the climatic conditions within growing and fruiting rooms. To induce fruiting, temperature levels are reduced and airflow is increased. This causes both a decrease in carbon dioxide levels (due to the improved ventilation) and a drop in humidity, as can be seen in Figures 16.20 and 16.21. While humidity drops at the time of fruiting, it still needs to be very high compared with outside conditions. This can be difficult to maintain, so large-scale producers monitor fruiting and growing room conditions electronically and use air conditioning and misting to keep the climate just right.

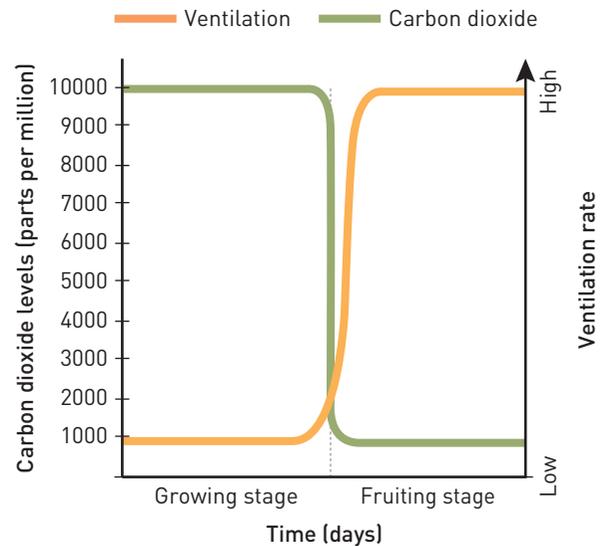


Worksheets

Learn more about the environmental management of mushroom production by completing the worksheet on NelsonNet



**Figure 16.20** Temperature and humidity requirements for white mushrooms



**Figure 16.21** Carbon dioxide and ventilation requirements for white mushrooms

## Enterprise management

### Spawn labs

Many mushroom growers buy their **mushroom spawn** from specialist companies. Spores are collected, germinated on agar plates and then grown in containers filled with sterilised grain. The end result is a white fluffy mass of mycelium that is ready to be broken up and used to grow hundreds of mushrooms.

Spawn production is performed under laboratory conditions. Special filters extract microbes from the air while tools and equipment are sterilised in the same way as surgical instruments. The grain must be pressure cooked before being used, to remove any germs.



**Figure 16.22** Oyster mushroom spawn

Melissa Marshall

#### **mushroom spawn**

mycelium grown on sterile grain, which will be broken up and used to produce mushrooms

### Substrates: food and a home for fungi

**Substrates** are the materials in which mushrooms grow. They are a source of nutrition and a home for the mycelium. Oyster mushrooms grow well in straw or other plant-based organic wastes including coffee grounds and discarded cotton.

White mushrooms are grown in compost. Substrate compost is formulated from a range of ingredients including animal manure, hay, straw and grains. Various supplements are added to ensure mushrooms receive the nutrients they need to grow, including:

- potash for potassium
- ammonium nitrate to provide nitrogen
- gypsum for calcium and to balance the pH.

The compost is mixed and watered regularly to promote the growth of bacteria and fungi, which will break down the ingredients. The compost gets very hot when this is happening,

**substrates** the materials in which mycelium is cultivated. They include composts, straw and various waste products, and are formulated to meet the needs of each mushroom species.

and mushroom farmers know the compost is almost ready when the pile starts to cool down. The compost is then pasteurised, or heated, to kill the bacteria, fungi and any other microbes. If these were left in the compost, they would compete with the white mushroom mycelium in the growing shed.



## LET'S DISCUSS

- 1 What types of businesses and agricultural industries are found in your local area?
- 2 Which of these might produce waste products that can be used as substrate?
- 3 Discuss the benefits of finding local sources of substrates.

## Growing rooms

In shed systems, mushroom substrate is mixed with spawn and then spread over large trays. A casing layer of peat is added on top to retain water and keep the mycelium and compost moist. The room is temperature controlled and water is misted constantly on the beds to provide the best growing conditions.

For oyster mushrooms, bags and containers are left closed during mycelium growth. Once the mycelium has completely covered the substrate, it is time for fruiting.

## Fruiting

Mushrooms start to form if the mycelium becomes stressed or shocked. Growers shock mycelium by changing the temperature, humidity and carbon dioxide levels in the environment.

In mushroom sheds, temperatures are dropped over a few days once the first tiny mushrooms appear. For container and bag systems, mycelia are moved to a fruiting room that is still humid but has good airflow, to reduce carbon dioxide levels.

Many mushrooms will usually appear within a very short time. This is called a 'flush'. The mycelium can often be tricked into producing two or three flushes by repeating the shocking process.

## Harvesting

Even on larger farms, mushrooms are usually cut by hand. Mechanical harvesting is sometimes used for mushrooms that will be used for processing.

### Robotic harvesting

Mushrooms are delicate, and harvesters need to pick the correct size of mushrooms while leaving the smaller ones to continue growing. This makes harvesting expensive.

Robotic harvesters are currently being developed. These robots are able to identify mushrooms that are ready to be harvested and carefully pick only the right ones. Robots are expensive to buy but can work for longer hours



Figure 16.23 Robotic mushroom harvester



WebLink

Investigate robotic harvesting machines for mushroom production.

than humans. Using robots as an alternative to humans also means there is less traffic in and out of the mushroom shed every day, and therefore disease and pest transmission is less likely.

## INDUSTRY IN FOCUS

### GOURMET MUSHROOM GROWER



Credit: Santian Verdugo



Video

Watch Marita Smith producing oyster mushroom spawn in front of a microbial air filter

**Figure 16.24** Marita Smith tending a flush of oyster mushrooms

### Identify

Marita Smith studied organic chemistry and molecular biology before starting her own gourmet mushroom business. She grows edible and medicinal mushrooms, as well as glow-in-the-dark ghost fungi. Marita employs her scientific skills and knowledge to produce spawn, mushroom kits and dried medicinal mushroom products for sale online and at local businesses.

### Discussion

- 1 How have Marita's scientific skills helped her to produce good-quality spawn?
- 2 Why might it be easier to start your own mushroom business than to start a traditional enterprise such as market gardening or beef production?
- 3 Investigate the different types of mushroom spawn available for sale on the Internet.



LET'S ENGAGE

## GROWING PEARL OYSTER MUSHROOMS IN BUCKETS

### PURPOSE

To grow pearl oyster mushrooms and explore the mushroom production cycle.

### RISK ASSESSMENT



Take care to avoid burns when dealing with hot water. Ensure gloves are worn during preparation of the mix and when packing the buckets. Wash hands when finished.

### MATERIALS

- Pearl oyster spawn
- Sugar cane mulch
- Garden lime
- Hot (80°C) water in a large tub
- Pillow cases
- Mushroom buckets
- Methylated spirits in spray bottles
- Surgical tape (micropore)

### METHOD

#### Preparing substrate

- 1 Fill the pillowcases with a mixture of mulch and 1/3 cup of lime. Tie the end of each pillowcase or use a cable tie to seal it.
- 2 Submerge the filled pillowcases in hot water for 2–3 hours to kill any bacteria. Hang them up to dry, drain and cool.

#### Growing mycelium

- 3 Using gloved hands, thoroughly mix one part spawn to five parts mulch on a clean surface. Spray mushroom buckets lightly with methylated spirits before packing them tightly with the mixture. Close the lids and cover the holes with micropore tape.
- 4 Place the buckets in a cool protected position. Monitor daily and mist with water if the mulch is drying out.

#### Fruiting

- 5 As soon as the mycelium has spread through the mulch, open the lid and completely soak the contents in clean water for 6–12 hours.
- 6 Drain the water, remove the tape and replace the lids. Ideally, place the buckets in a fruiting chamber. A small plastic greenhouse placed indoors works well for this purpose. A small humidifier can be placed in the bottom of the greenhouse, or spray mist inside the greenhouse daily to keep the humidity levels high. Alternatively, mist the sides of the buckets and keep them somewhere cool until mushrooms emerge.
- 7 Mushrooms should appear in the next week or two.

### DISCUSSION

- 1 Keep a diary of observations for your oyster mushroom kits. Record any changes you notice.
- 2 Draw an oyster mushroom life cycle in your book.
- 3 Mushrooms often begin fruiting after autumn storms. How did the changes you made to the kits mimic these climatic conditions?

## Records and financial management



### LET'S ENGAGE

### CALCULATING GROSS MARGINS FOR FRESH OYSTER MUSHROOMS

#### PURPOSE

To sell the first flush of your mushrooms then calculate their gross margin per kilogram

#### MATERIALS

- Fresh mushrooms from the oyster mushroom kits
- Electronic scales
- Materials for packaging

#### METHOD

- 1 Research the current market price for oyster mushrooms either online or at the local supermarket. Package and sell your mushrooms for this price to teachers, parents or at a local farmers market.
- 2 Calculate or estimate the variable costs of growing the mushrooms. Because this is the first flush of mushrooms and more mushrooms will eventually be produced, we will divide these costs in half. The rest of the costs will be used to work out the gross margin of a value-added product we will make later in the chapter.
- 3 Complete a gross margin analysis of your mushroom crop. You can

use the template on NelsonNet to assist you.

- 4 Now calculate the gross margin per kilogram of your oyster mushrooms.

$$\text{Gross margin (\$/kg)} = \frac{\text{Gross margin}}{\text{(Number of kilograms of mushrooms sold)}}$$

$$= \$ \underline{\hspace{2cm}} / \text{kg}$$

#### DISCUSSION

- 1 Identify three fixed costs not considered in a gross margin analysis.
- 2 Use the weblink to explore gross margins for other crops, then answer the questions below.
  - a Identify some of the more common variable costs used to calculate these gross margins.
  - b Why are these gross margins not expressed as \$/kg?
  - c In these online gross margins, you will notice that profitability varies depending on the yield. Identify some factors that might influence the yield of your mushroom kits, and explain how these factors might affect your gross margin.



Template

Gross margin template



Weblink

DPI gross margins



### LET'S REVIEW

#### LOOKING BACK

- 1 Identify the major mushroom production areas in Australia.
- 2 Using Figures 16.20 and 16.21, describe the climatic changes that need to occur for mushrooms to fruit.
- 3 Compare substrates used for white and oyster mushroom production.
- 4 Why is a layer of casing added to white mushroom trays?
- 5 Explain what a 'flush' is. How can producers get more than one flush from a crop?
- 6 Why is mushroom harvesting mainly done by hand?
- 7 Identify some of the advantages of using robotic harvesters.





Video

Compost production

### > FOR YOU TO DO

- 1 Watch the video of compost production and construct a flowchart showing the steps involved in making white mushroom substrate.
- 2 Compare how shed and bag systems can be managed to control temperature, humidity, carbon dioxide and ventilation rates.
- 3 Design a fruiting chamber for your next oyster mushroom crop. Use scrap materials from school or home. You will need to design and locate the chamber to control the temperature, humidity and airflow.
- 4 Discuss other areas of mushroom production that could be mechanised. How would robots and specialist machinery be of benefit?

### TAKING IT FURTHER

- 1 Brainstorm ways you could increase the efficiency of your oyster mushroom production or gain a better price for your crop. How could this increase your net profit?
- 2 Your school decides to grow white button mushrooms in addition to your pearl oyster mushrooms.
  - a Identify how the process and materials will differ from those used in the pearl oyster mushroom activity.
  - b Design a system suitable for growing white button mushrooms.

## 16.5 Pests and diseases

### Pests

Flies, mites and nematodes can infect fungi and cause reduced yields and damage to crops.

Fungus gnats are small black flies. They are attracted to humidity and high temperatures and lay their eggs in decaying organic matter, such as mushroom substrates. The larvae eat the growing mycelium. Because the fungi feed through their mycelium, this damage causes smaller mushroom crops.

Fungus gnats are small enough to fit through flyscreen, so are difficult to keep out of growing sheds. Pyrethrin, a natural insecticide extracted from pyrethrum daisies, can be sprayed as a gas into growing rooms to kill adult flies. *Bacillus thuringiensis*, a soil bacterium that produces a natural pesticide, has also been used to kill flies.



**Figure 16.25** Fungus gnat larvae eating decaying material and mycelium

Shutterstock.com/Henrik Larsson

## Diseases

Bacterial blotch causes yellow spots on the caps, reducing the quality and appearance of the mushrooms. The disease is caused by *Pseudomonas fluorescens*, which can live in substrate and casing materials. Splashing water, dirty tools and mushroom flies can spread the bacteria throughout a growing shed. Careful hygiene and biosecurity can help prevent bacterial blotch. Mushroom caps can also be heated with flows of warm air to dry out their surfaces, and water can be treated with bleach to kill any pathogens.

### AG IN FOCUS

#### FIGHTING SHEEP PESTS WITH FUNGI



Shutterstock.com/Alf Mancigli

**Figure 16.26** Barber's pole larvae live in pasture and can infect sheep and other grazing animals.

#### Identify

*Duddingtonia flagrans* is a fungus being used to combat internal parasites of grazing animals.

#### Understand

Research into fungi is helping combat pests and disease in other agricultural industries.

Barber's pole worm is an internal parasite of sheep and cattle. Over the years, the worm larvae have developed resistance to the drenches farmers use to kill them. In some locations, farmers have had to stop farming because they can no longer treat their animals for this pest. Once infected, pastures are affected for a long time.

*D. flagrans* is a fungus that eats some worm larvae. After building its mycelium around a newly hatched worm, the fungus traps and digests it. *D. flagrans* spores are fed to grazing animals, which then pass them out in their manure onto infected pastures.

Studies have shown that *D. flagrans* significantly reduces the number of larvae on a pasture and the number of worms in animals that graze on it.

#### Discussion

- 1 Research the Barber's pole worm online. How does it affect sheep? How does it affect wool and lamb production?
- 2 Explain the advantages of using *D. flagrans* for the control of Barber's pole worms in sheep.
- 3 Visit the Wormboss website and read the information on worm control using *D. flagrans*. Evaluate the effectiveness of the fungus in these trials.
- 4 Visit the Bioworma site and explore how *D. flagrans* can be used for other worms in grazing animals.



Weblink

Wormboss



Weblink

Bioworma



## LET'S REVIEW

### LOOKING BACK

- 1 How do fungus gnats cause damage to mushroom crops?
- 2 Why are these flies so difficult to keep out of growing sheds?
- 3 How can bacterial spot be spread in a mushroom farm?

### FOR YOU TO DO

- 1 Biosecurity involves measures to prevent or control harmful pests and diseases from entering a farm. Make a list of the ways pests and diseases could enter a mushroom farm and give suggestions for methods to reduce these risks.
- 2 Design a poster informing mushroom growers of ways to prevent flies or bacterial spot from infecting their crops.

### TAKING IT FURTHER

- 1 Integrated pest management involves using a variety of methods to prevent and treat pests rather than relying on chemicals. Find examples of the following types of pest control measures used in mushroom farming:
  - a cultural controls (hygiene, management practices)
  - b physical controls (stopping pests from getting near the crop)
  - c biological controls (using other living organisms)
  - d chemical controls (e.g. pesticides).
- 2 Fungi cause several diseases. Research the role of fungi in the Great Famine of Ireland.

## 16.6 Social and ethical issues

### Australia's native fungi: where are they?

Many of Australia's native fungi have died out or become rare since European settlement. Grazing animals have compacted the soil, making it difficult for hyphae to grow and feed. Land clearing has destroyed the habitats of many fungi, and chemicals such as antifungal medicines have reduced the populations of once common species.

Australia and New Zealand have edible and useful species of native fungi. Native wood-eating mushrooms were recognised as edible by Chinese immigrants in both Australia and New Zealand in the 1870s. These mushrooms were then exported from both countries to China.

Some **mycologists** study native fungi, investigating species that may prove to be valuable medicines or food sources. Unfortunately, we have lost species that may have also been useful due to agricultural practices, urbanisation and pollution.



**Figure 16.27** In traditional Chinese medicine, wood-eating mushrooms purify the blood.

Shutterstock.com/Bildagentur Zoomar GmbH

**mycologist** a scientist who studies fungi

## Are mushrooms meat for vegetarians?

Mushrooms have sometimes been called meat for vegetarians because they contain protein and iron. Should vegans and vegetarians rely on mushrooms to provide them with the nutrients usually found in red meat? Compare the nutritional data for lean beef and mushrooms in the table below.

**Table 16.5** Nutritional data for beef and mushrooms

Nutrient per 100 grams	Red meat (beef)	White mushrooms	Oyster mushrooms
Fat (g)	10.0	0.3	0.6
Energy (calories)	211.0	22.0	43.0
Protein (g)	28.0	3.1	3.3
Iron (mg)	2.6	0.5	1.3
Fibre (g)	0	1.0	2.3



### LET'S DISCUSS

- 1 Consider some of the reasons people choose to be vegetarian or vegan.
- 2 Are there environmental or health benefits to avoiding animal products?
- 3 Mushrooms are high in fibre and low in fat. Can you think of any health issues for which they would be helpful?



### LET'S REVIEW

#### LOOKING BACK

- 1 List three practices that have had a negative effect on native fungi.
- 2 Why were wood-eating mushrooms so important in New Zealand and Australia?
- 3 Why are mushrooms often called 'meat for vegetarians'?

#### FOR YOU TO DO

- 1 Compare the nutritional data for red meat and mushrooms. Are mushrooms a good substitute for red meat?
- 2 Calculate how many cups of mushrooms you would have to eat to gain the same amount of protein and iron as you would get from 100 g of steak (1 cup of mushrooms equals approximately 80 g).

#### TAKING IT FURTHER

- 1 Investigate other plant crops that provide high levels of protein and iron.
- 2 Use the Atlas of Living Australia to research native fungi in your area. Choose one fungus and write a short report on its appearance, habitat and distribution.



Weblink

Atlas of Living Australia

## 16.7 Sustainability

### Sustainable practices and methods

#### Sustainable substrates



Video

Watch the *Landline* episode about using waste coffee grounds as a growing medium for mushrooms.

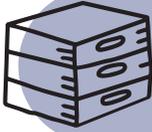
The material we choose to grow mushrooms in can be:

- waste products from other industries
- used to make food rather than be sent to landfill
- sourced from the local area
- sold to gardeners and farmers after use as a soil conditioner.

Examples of possible substrate materials include manures, straw, hay, coffee grounds, cardboard and even old jeans.

#### DID YOU KNOW?

The average Australian throws away over 20 kg of unwanted clothing each year. Most of this ends up in landfill. Some producers are experimenting with using unwanted cotton clothing as substrate to grow mushrooms.



#### LET'S EXPERIMENT

### COMPARING SUBSTRATES FOR OYSTER MUSHROOM PRODUCTION

#### PURPOSE

To test the effect of different substrates on mushroom yield

#### HYPOTHESIS

Which substrate do you think will produce the most mushrooms?

#### RISK ASSESSMENT



Take care to avoid burns when dealing with hot water. Ensure gloves are worn during preparation of the mix, and when packing the buckets. Wash hands when finished.

#### MATERIALS

- Eight mushroom buckets
- Pearl oyster spawn
- Lime
- Surgical tape (micropore)
- A variety of locally available substrates
- Sugar cane mulch

#### METHOD

Use the oyster mushroom bucket production method from Let's Engage on page 460 for this experiment.

- 1 Prepare a variety of substrate mixes using the pillow case, lime and hot water method. Examples of mixes could include:
  - a sugar cane mulch (as a control)
  - b wood chips
  - c shredded old jeans
  - d rice hulls.



- 2 Divide the mushroom spawn evenly between the groups and mix into each substrate.
- 3 For each substrate mix, fill two buckets. Label them and cover the holes with micropore tape.
- 4 Monitor for mycelium growth. Record observations.
- 5 Once mycelium has completely filled the bucket, induce fruiting by removing the tape and soaking for 6–12 hours. Place in a fruiting chamber or somewhere cool and humid.
- 6 Harvest and weigh the mushrooms once they have grown. Record your results.

### RESULTS

- 1 Keep a record of mycelium growth during the experiment.
- 2 Construct a table to record the final yields of each bucket.
- 3 Calculate the average yield for each substrate treatment group.
- 4 Construct a column graph to show substrate group versus yield per bucket.

### DISCUSSION

- 1 Interpret your results. Which substrate produced the most mushrooms? Which performed the worst?
- 2 Which factors did you find hard to control in your experiment?
- 3 How could you improve this experiment?
- 4 Evaluate each of the substrates you used with regards to their sustainability and productivity.
- 5 Can you recommend a solution to oyster mushroom farmers who are seeking the best substrate for their enterprise?

### CONCLUSION

Was your hypothesis correct, incorrect or partially correct?

## Sustainable technology

### Fighting the war on plastics

Researchers have discovered that some fungi will eat polyurethane, a plastic used to make kitchen sponges, foam insulation and glues. After exposing the plastic to ultraviolet light, it is fed to the mycelium, which then consumes it over the next few months.

**DID YOU KNOW?**

Plastic-eating fungi produce mushrooms. Scientists are investigating whether they can be safely eaten.



Video

Find out more about plastic-eating fungi.



Data scenario

Investigate the success of new technology in the production of biofuels by completing the data scenario *Engineering yeasts to make more biofuels on NelsonNet*.

## Sustainable decision-making

### Soil management and fungi health

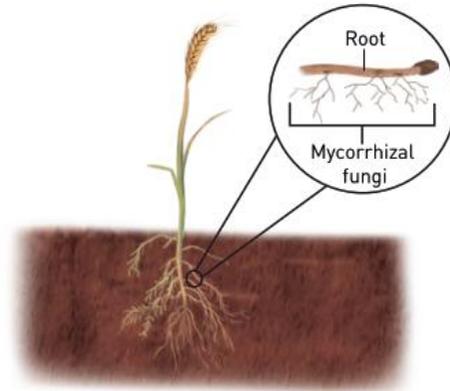
Some fungi live in **symbiosis** with plants. These **mycorrhizal fungi** invade plant roots and send their hyphae out into the surrounding soil. The fungi receive sugar from the plant for their own growth and development, and in return, the plant uses the hyphae as an extended root network, substantially increasing the amount of water and nutrients the plant can absorb from the soil.

**symbiosis** a relationship between two organisms where at least one benefits

**mycorrhizal fungi** live in symbiosis with plants, attaching themselves to roots

The number of mycorrhizal fungi is reduced when we use inorganic fertilisers and cultivate soil. Many farmers still use these methods despite their effect on mycorrhizal fungi and other soil microbes. This is because, in the short term, artificial fertilisers can produce much higher yields and cultivation of the soil can control weeds and help seeds germinate.

More sustainable methods of farming are often expensive to adopt. Special machinery is needed for no-till farming, where seeds are injected straight into undisturbed ground. However, investing in these new practices and reducing the use of artificial fertilisers will encourage mycorrhizal fungi and make farming more profitable and productive over time.



**Figure 16.28** Mycorrhizal fungi living in symbiosis with plant roots



Ensure you are making sustainable agricultural decisions by completing the *Treating fungal diseases sustainably* worksheet on NelsonNet.

## AG IN FOCUS

### MYCORRHIZAL FUNGI AS A BIO-FERTILISER

#### Identify

Mycorrhizal fungi can be used to improve water and nutrient uptake, reduce drought stress and increase the yields of several agricultural crops.

#### Understand

An **inoculant** of mycorrhizal fungi can be applied to plant roots during transplantation, or it can be added to soil or potting mix. Seed treatments, root dips, injections and liquid solutions are also available. These inoculants are called bio-fertilisers because they contain living organisms that increase the nutrients available to plants.

Drought and low soil phosphorus levels are two key challenges for the Australian wheat industry. Mycorrhizal fungi, through their symbiotic relationship with wheat plants, can increase water uptake and make phosphorus and other nutrients more available to plants.

The results of an experiment testing the effect of mycorrhizal fungi on wheat production are displayed in the table below. Wheat seeds were randomly allocated to one of two groups: a control and a mycorrhizal group. The seeds in the mycorrhizal group were sown in pots that had been inoculated with mycorrhizal fungi. The control group seeds were sown in identical pots and identical soil, but without the fungal inoculant. At the end of the experiment, the root length of each plant was measured, and the leaves, flowers and roots were then dried and weighed.



**Figure 16.29** Roots grown with and without mycorrhizal fungi

Alamy Stock Photo/Grant Heilman

**inoculant** a substance introduced to an organism, often to increase its immunity or improve its function, such as a vaccine

**Table 16.6** Effect of mycorrhizal fungi on wheat growth and development at 75 days

Treatment groups	Average dry matter yield (grams)			Root length (cm)
	Leaves	Flowers	Roots	
Control (no mycorrhizal fungi)	2.42	2.65	1.14	431
Mycorrhizal group (wheat plants with mycorrhizal inoculant)	3.37	3.02	1.61	541

### Discussion

- 1 How can mycorrhizal fungi be applied to agricultural plants?
- 2 Explain how mycorrhizal inoculants can help wheat production in Australia.
- 3 Outline what a control is, and why it is important in this experiment.
- 4 Draw column graphs illustrating:
  - a treatment groups and average dry matter leaf yields
  - b treatment groups and root length.
- 5 Explain the significance of increased leaf and root matter for wheat production.



## LET'S REVIEW

### LOOKING BACK

- 1 Why are substrate materials usually sourced locally?
- 2 Outline how fungi can be used to combat the plastic pollution problem.
- 3 Describe the relationship between mycorrhizal fungi and plant roots.
- 4 Identify two ways mycorrhizal fungi are affected by agricultural practices.

### FOR YOU TO DO

- 1 Investigate the current prices of some common substrate materials, including straw and grain.
- 2 Write a report on the importance of mycorrhizal fungi to the horticulture industry.

### TAKING IT FURTHER

- 1 Investigate the use of fungi as a substitute for plastic and leather.
- 2 Research other symbiotic relationships between plants and microbes.



Weblink

Substrate prices



Weblink

Mycorrhizal fungi and the horticulture industry

## 16.8 Marketing

### The market

Almost 97% of Australian mushrooms are sold in the fresh domestic market. Most of the remaining mushrooms enter the domestic processing market, with less than 1% of the total

being exported. Annual consumption of mushrooms per capita in Australia is 2.8 kg. This has increased in recent decades, with the influence of multiculturalism and new varieties entering the market.

The marketing chain of white mushrooms involves several steps, as can be seen in Figure 16.30.

**perishable** likely to go bad or decay quickly

Mushrooms are highly **perishable**, making export difficult. Australian labour costs are higher than other mushroom producing countries, meaning Australian growers find it difficult to compete in international markets. The main overseas buyers of Australian mushrooms are Brunei, Papua New Guinea, Fiji and Nauru.

Demand for mushrooms is seasonal, with consumers purchasing fewer mushrooms and more fruit during the summer months. Because of this trend, growers are often faced with an oversupply problem during the summer. This increased supply and reduced demand forces mushroom prices down.

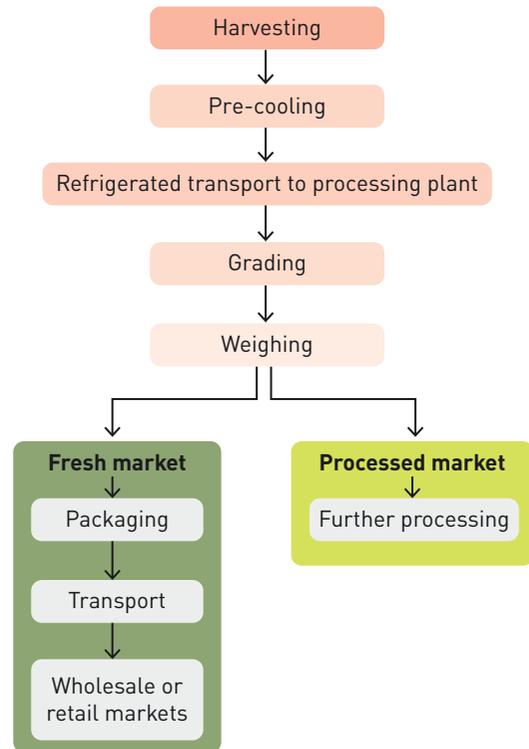


Figure 16.30 White mushroom marketing chain

## Specifications

### White mushrooms

Market specifications are a list of desired characteristics for an agricultural product, and help producers by giving them information about what consumers want. They are also used to grade and determine prices for produce.

For *Agaricus* mushrooms to be graded as Class 1 they need to fulfil a number of criteria, including those listed in Table 16.7.

Table 16.7 Market specifications for white mushrooms

Market specification	Button mushroom	Cup mushroom	Flat mushroom
Cap colour	White	White	White to cream
Diameter	2–3 cm	3–8 cm	Over 4 cm
Appearance of gills	None visible	Pale, immature	Firm, dark
Shape	Round	Round	Flat to slightly round
Evidence of disease	None	None	None

### DID YOU KNOW?

Button, cup and flat are all the same type of mushroom. Buttons are picked earlier and are the least mature. Cups are slightly more developed, and flats are the fully mature *Agaricus* mushrooms.



## LET'S ENGAGE

## GRADING OYSTER MUSHROOMS

### PURPOSE

To grade school-grown oyster mushrooms using market specifications

### MATERIALS

- School-grown or purchased oyster mushrooms
- Market specifications

### METHOD

- 1 Research the appropriate market specifications for oyster mushrooms.
- 2 Grade and sort the oyster mushrooms according to the specifications. Decide on criteria to grade Class 2, 3 and 4 mushrooms.

### RESULTS

Grade Assigned	Number of mushrooms	Percentage of total mushrooms assigned to this grade
Class 1		
Class 2		
Class 3		
Class 4		

### DISCUSSION

- 1 Write a brief report summarising the results of the mushroom grading.
- 2 Identify some management practices that may have affected the quality of your mushrooms.
- 3 What changes would your group make to the production process to increase the percentage of Class 1 mushrooms?



Weblink

Market specs are available at FreshSpecs

## Marketing strategies

### Vertical integration

When a producer owns more than one step of the marketing chain, they have more control of the final product. Production costs are also usually lower.

Vertical integration in mushroom farming is common with many growers making substrate, and processing, packaging and transporting mushrooms to market.

### Value-adding

Most mushrooms are sold fresh and unprocessed. Value-adding in the mushroom industry can include any of the following:

- slicing and packaging
- drying
- fermenting and pickling
- inclusion in pre-cooked, frozen meals
- sales of by-products, including used mushroom compost.



Worksheets

Design a marketing campaign for a gourmet mushroom farmer by completing the *Mushroom marketing* worksheet on NelsonNet

Growers receive a higher price per kilogram of mushroom grown when they value-add. They can also access new markets with these products. Sales of by-products adds an extra income stream from what would otherwise be waste.

### Direct marketing

Many small producers sell their mushrooms directly to the customer, often at local farmers markets or online. When growers sell their product by direct marketing, they receive a larger proportion of the final retail price. Direct marketing often involves vertical integration: the grower processes, packs, transports and sells the product themselves. Growers save money because they do not need to pay other people to do this for them.



Figure 16.31 Drying is a form of value-adding

Shutterstock.com/Jennarong Thana



LET'S ENGAGE

## DRYING MUSHROOMS

### PURPOSE

To dehydrate mushrooms for storage and later consumption

### RISK ASSESSMENT



Take care with knives to avoid injury. Use the dehydrator according to instructions to avoid burns and electrocution.

### MATERIALS

- School-grown or any variety of purchased mushrooms
- Clean sharp knives
- Electric dehydrator or clean old flyscreens
- Airtight jars or ziplock bags
- Weigh scales

### METHOD

- 1 Brush any dirt or soil off the mushrooms.
- 2 Weigh mushrooms and record the results.
- 3 Slice mushrooms finely.
- 4 Place in dehydrator or on old flyscreens in the sun until completely dry.
- 5 Weigh the dried mushrooms again.
- 6 Store in ziplock bags or jars for up to 12 months.

### DISCUSSION

- 1 Calculate the number of kilograms of fresh mushrooms needed to produce one kilogram of dried mushrooms.

$$\text{Number of kilograms (fresh)} = \frac{\text{Weight of fresh mushrooms used (kg)}}{\text{Weight of dried mushrooms produced (kg)}}$$

- 2 Identify the extra costs involved in drying the mushrooms.
- 3 Research the retail price for dried mushrooms online. Set a price for your dried mushrooms and sell them to teachers, parents or the local farmers markets.



- 4 Determine the gross margin per kilogram for dried oyster mushrooms (use the template on NelsonNet to assist you). Remember, you need to halve the variable costs of cultivating the mushrooms because you have already sold half of your mushrooms in their first flush.
- 5 Compare the profitability of fresh oyster mushrooms and dried oyster mushrooms.
- 6 Evaluate the production of value-added products such as dried mushrooms in terms of profitability.



Template

Risk assessment  
template



## LET'S REVIEW

### LOOKING BACK

- 1 Why has per capita consumption of mushrooms increased?
- 2 Less than 1% of Australian mushrooms are exported. Why?
- 3 Outline the roles of market specifications.
- 4 Explain how the following marketing strategies work: value-adding, vertical integration and direct marketing.

### FOR YOU TO DO

- 1 Research the most current statistics on mushroom production at the Australian Bureau of Statistics.
- 2 Conduct a class discussion on the best marketing strategies for small growers versus large growers.
- 3 Brainstorm advantages and disadvantages of vertical integration, value-adding and direct marketing.
- 4 Create an online marketing survey with the weblink provided, or with another survey creator. Use your survey to find out:
  - a when and how consumers buy mushrooms
  - b preferences for different types of mushrooms
  - c the most important factors that influence decisions to purchase mushrooms, including price, freshness and production methods.
- 5 Investigate vitamin D-enhanced mushrooms. Many Australian teenagers are vitamin D-deficient. Investigate the signs of vitamin D deficiency in teenagers and design an advertising campaign aimed at increasing mushroom consumption.



Weblink

Australian Bureau of Statistics

### TAKING IT FURTHER

- 1 Investigate a recent promotional campaign for mushrooms.
  - a Identify the target audience for this campaign.
  - b Describe the campaign: what is the message and how is it being delivered?
  - c Assess the effectiveness of this campaign. Do you think it is an effective way of increasing consumer awareness of, and demand for, mushrooms?
- 2 Create your own value-added mushroom product. Design a promotional campaign aimed at your target audience, involving two methods of communication (e.g. posters, podcasts, television commercial or social media page).
- 3 Research the marketing chain for beer. Construct a flowchart showing all of the steps involved in production, processing and selling beer.



Weblink

SurveyMonkey marketing  
templates

# Let's summarise



Practice quiz

Complete the chapter review test on NelsonNet to review what you've learnt about Fungiculture

## How are fungi linked to other agricultural enterprises?

Fungi help to ensure soil and plant health. Mushroom production is linked to many other agricultural enterprises, both through using different substrates and providing used compost for other growing industries.

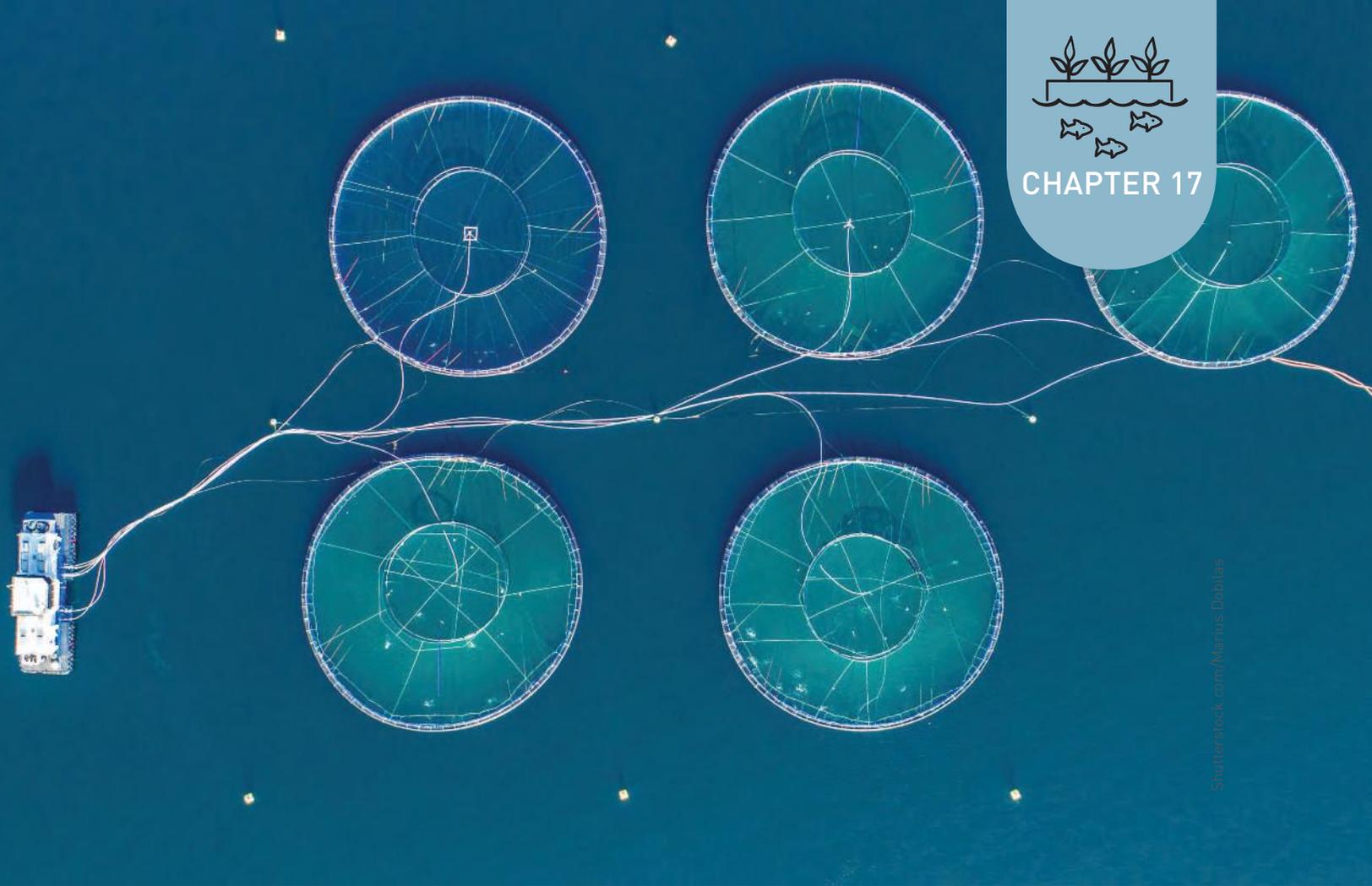
Fungi also cause disease and can be used to control disease in agricultural plants and animals. Use what you have learned in this chapter to create a mindmap explaining all the ways fungi are linked to agriculture. Use the following stimulus words to help.

Mycorrhizal fungi	Yeasts	<i>Duddingtonia flagrans</i>	Recycling
Animal health	Plant diseases	Water and nutrients	Cereal grains
Substrates	Used mushroom compost	Roots	Bread and alcohol

## How do we manage production to make the best mushrooms while looking after the environment?

Mushroom production relies on careful control of the environment and careful management of the production process. To produce the best mushrooms, producers need to understand what consumers want and be efficient in their practices. Copy the following table and use it to recall what you have learned about each topic.

Topic:	Climate control	Hygiene and disease prevention	The right substrates	Market specifications	Finances and efficiency
Why is it important?					
Three ways producers can achieve this					



# Aquaculture

## CHAPTER SUMMARY

A diverse range of species are farmed in aquaculture, from salmon to yabbies. The Australian aquaculture industry has become a world leader for sustainable fish production, and in the last decade, through research and technological advances, has improved water consumption and increased yield. This chapter outlines the many technological advances made in the production and marketing of aquaculture products and how the increase in production over the past twenty years has improved profits for aquaculturists.

**How can we farm fish and other aquatic organisms?**

**How can technology increase aquaculture production?**

**How can aquaculture be undertaken in an ethical and sustainable way?**

# 17.1 Introduction

**aquaculture** the commercial farming of fish, molluscs (e.g. oysters), crustaceans (e.g. prawns) and aquatic plants (seaweeds) in natural or controlled marine or freshwater environments

**freshwater** of or found in freshwater; not of the sea

**terrestrial** growing on land or in the soil; not aquatic

**mollusc** invertebrate of a large phylum, including snails, slugs, mussels and octopuses. They have a soft unsegmented body and live in aquatic or damp habitats, and most kinds have an external calcareous shell.

**Aquaculture** is the farming of fish and other aquatic organisms in dams, ponds, cages or specially constructed tanks. **Freshwater** aquaculture farming was developed around 1000 years ago with the Chinese growing carp. Around 500 BCE, the Romans farmed oysters and fish in Mediterranean lagoons. Australia has its own significant history in aquaculture, with the Brewarrina fish traps, or Ngunnhu as they are known to the local people, demonstrating freshwater culture systems. Until the twentieth century, aquaculture techniques remained largely unchanged.

Like any other **terrestrial** farming system, aquaculture has standard management activities such as feeding, breeding, pest and disease control, and harvesting. This is what sets aquaculture apart from the hunting and gathering methods of fishing, netting and **mollusc** collecting.

Australia has developed a reputation for high quality, safe seafood, produced in environmentally sustainable systems. It targets the high-value species for domestic and export markets. The proximity to the Asian market means Australian aquaculture is competitively positioned.

# 17.2 Functions and anatomy

## Function

### Consumption

Australia produces a range of aquaculture species for human consumption, destined for both the **domestic** and **export** markets. There is a large focus on high-end products, particularly for the export market. The largest group of aquaculture species produced in Australia are the farmed **salmonids**. This is also the most valuable fisheries product. In New Zealand, the largest aquaculture production yield comes from green-lipped mussels. These service both the fresh seafood market and many lines of processing such as canned goods and frozen products.

**Table 17.1** Species grown in Australian and New Zealand aquaculture systems for human consumption

Fish	Crustaceans	Molluscs	Other
Salmonids (Atlantic salmon)	Prawns (tiger, banana)	Oysters	Seaweed
Tuna	Yabbies	Mussels	Kelp
Barramundi	Marron	Abalone	Beta-carotene
Trout	Redclaw	Scallops	
Perch	Mud crabs		
Cod			

**domestic** existing or occurring in a particular country; not foreign or international

**export** goods or services sent to another country for sale

**salmonid** a fish of the salmon family



Worksheets

Introduce yourself to aquaculture with this worksheet.

## Other products

Apart from human consumption, aquaculture species are used in a variety of products. Pearls are harvested for jewellery from pearl oyster production in WA, the NT and Qld. Ornamental (pet) fish including goldfish, koi carp, swordtails and seahorses are raised. Offal associated with processing and on-farm mortalities can be made into pet food and fertilisers. Even pharmaceuticals can be produced from fish; these include fish oil (omega 3 fatty acids), chitin and glucosamine (from prawn shells and other shellfish).

### DID YOU KNOW?

The oyster is a sequential hermaphrodite. This means it changes back and forth from male to female as it grows.

## Anatomy

### External anatomy of fish

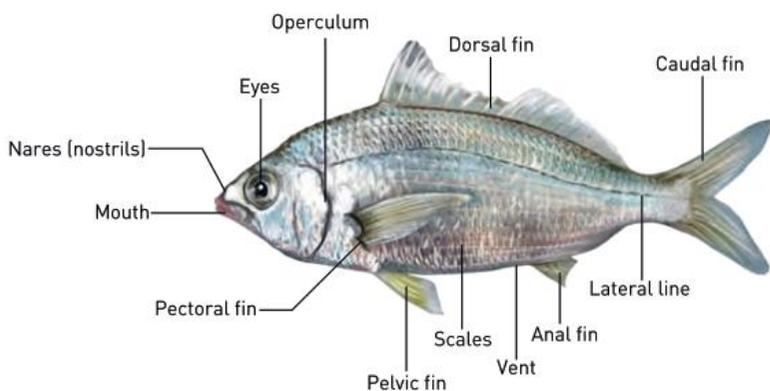
**Table 17.2** Parts and functions of the external anatomy of a fish

Body part	Function
Mouth	Food consumption and swallowing water to pass over the gills for oxygen extraction
Nares	Detection of odours in the water
Eyes	Detecting colour within the water
Scales	Protection from predators, parasites and other injuries as well as a hydrodynamic function to reduce water friction
Operculum (gill covers)	The flexible, bony plate that protects the gills
Gills	The structure that removes the oxygen from water that passes over them to supply the fish
Pelvic fin	Balances and positions the fish
Pectoral fin	Assists the fish with steering, stopping and hovering
Lateral line	Detects vibration to find food and navigate to avoid predators
Dorsal fin	Assists the fish to not roll over onto its sides
Caudal fin	Helps to propel the fish forward
Vent	The external opening for the digestive, urinary and reproductive tracts
Anal fin	Assists the fish to not roll over onto its sides



Worksheets

Explore the *Internal anatomy of fish* with this practical NelsonNet dissection worksheet.



**Figure 17.1** External anatomy of a fish

## External anatomy of yabbies

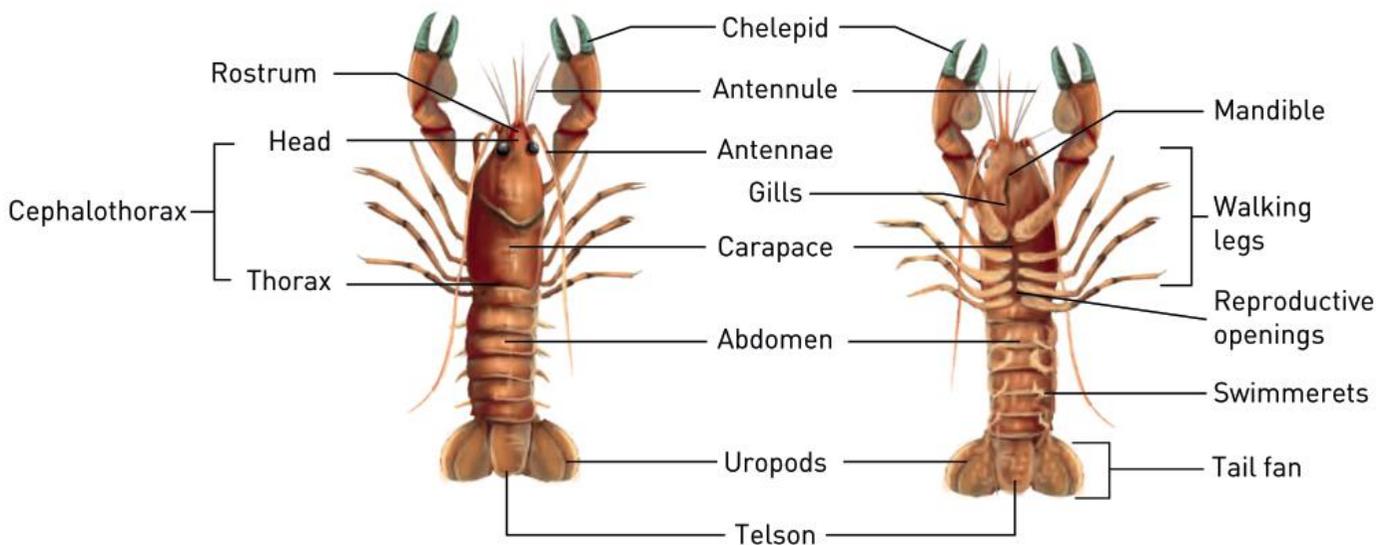
**Table 17.3** Parts and functions of the external anatomy of a yabby

Part	Function
Abdomen	The segmented tail area made up of strong muscles that assist in movement
Antennae	Sensory organs used to touch and taste food and maintain balance
Antennule	Used for tasting food
Carapace	Protective hard shell (exoskeleton) of the cephalothorax
Cephalothorax	Combined head and thorax; contains the heart, gills and stomach
Chelepid	Two large claws used for defence, movement and food handling
Gills	Removes oxygen from water that passes over them
Mandible	Mouth structure used to grind food; maxillipeds surround the mandible and push food into the mouth
Reproductive openings	Males have two protruding genital papillae; females have two oviducts
Rostrum	The hard beak-like structure above the eyes; thought to be for protecting the eyes
Swimmerets	Five pairs of short appendages used for swimming, moving water over the gills and holding eggs and larva
Tail fan	Contains the telson and four uropods; aids in swimming and backwards propulsion when threatened
Telson	Single middle section of the tail fan
Uropods	Two pairs of appendages on the tail fan
Walking legs	Four pairs of jointed legs used for walking, food gathering and moving water over the gills



Worksheets

Review your knowledge about yabbies with the *External anatomy of a yabby* worksheet.



**Figure 17.2** External anatomy of a yabby



## LET'S ENGAGE

## IDENTIFY EXTERNAL PARTS OF A CRAYFISH

### PURPOSE

To dissect or observe the external structures of a crayfish and relate the structure to their function

### RISK ASSESSMENT

Take care when handling dissection equipment to avoid injury. Wear gloves and safety glasses and wash hands thoroughly after completion.



DO NOT use live animals for this practical activity because it may cause distress or harm.

Always refer to NSW Animals in School or other states' webpages to learn more about the use of animals for research purposes in schools.

This practical activity should be conducted using crayfish purchased through a licensed retailer/distributor for human consumption.

### MATERIALS

- Crayfish for observation or dissection
- Dissection kit
- Gloves
- Safety glasses

### METHOD

- 1 Place the crayfish ventral side (stomach) up on the dissection tray.
- 2 Using Figure 17.2, locate and observe the mouthparts.
- 3 Locate the first, second and third maxillipeds (used for manipulating food).
- 4 Locate the mandible underneath the maxillipeds, move it around.
- 5 Locate the two large antennae and smaller antennules.
- 6 Locate the eyes.
- 7 Locate the cephalothorax and rostrum.
- 8 Locate the abdomen and bend backwards and forwards to observe the segments moving.
- 9 Locate the chelipids and gently move each one to determine the range of motion.
- 10 Remove one chelipid and use tweezers to find the connective tissue inside. Pull the tissue to observe the claw opening and closing.
- 11 Locate the swimmerets.
- 12 Locate the telson and identify the uropods on either side.

### DISCUSSION

- 1 For each external structure located, if only observing, touch and manipulate to see how it moves. Discuss how this movement relates to its function.
- 2 If dissecting the specimen, locate, touch and manipulate each structure to see how it moves. Remove the structure from the specimen and observe under a magnifying glass. Discuss how this movement relates to its function.



Weblink

NSW Animals in Schools

## DID YOU KNOW?

Some species of fish change gender depending on their size, age or the need for a dominant male.

## AG IN FOCUS

## COMMON AQUATIC SPECIES USED IN AQUACULTURE

Silver perch (*Bidyanus bidyanus*)

Dreamstime.com/  
Sarayut Watchasit

Freshwater fish

Native to Australia

**System:** Primarily grown in pond culture systems

**Food:** In aquaculture, they are fed commercial fish pellet diets

**Stocking density:** Can be grown successfully at 20 000/ha stocking density

**Optimum temperature:** 23–28 °C

**Market size:** 600–800 g

**Growth:** Market size can be achieved at 18 months

**FCR:** 1.3–2 kg of food to produce 1 kg of fish

**Water:** Dissolved oxygen levels above 3 mg/L; free ammonia levels less than 0.1 mg should be maintained

Rainbow trout (*Oncorhynchus mykiss*)

Shutterstock.com/  
tab62

Freshwater fish

Native to Australia

**System:** Primarily grown in pond culture systems

**Food:** Trout will take artificial pelleted feed and require high protein diets

**Stocking density:** Depends on the volume of the pond, flow, water temperature and fish size

**Optimum temperature:** 10–22 °C. For spawning and egg production 9–14 °C.

**Market size:** 250–350 g

**Growth:** Market size can be achieved in 12 months

**FCR:** 2 kg of feed to produce 1 kg of fish

**Water:** Pond water should be totally renewed every hour; well oxygenated, cool to cold, low suspended solids.

Green-lipped mussel (*Perna canaliculus*)

iStock.com/puhhha

Saltwater mollusc

Native to New Zealand

**System:** Grown extensively in open coastal regions with saltwater

**Food:** Mussels are filter feeders, eating microscopic marine organisms such as plankton

**Stocking density:** Grown in long-line farming. Groups of buoys are held together by long lines, with a series of ropes hanging down where the mussels are attached

**Optimum temperature:** Should not exceed 31 °C

**Market size:** 100 mm

**Growth:** Market size can be achieved in 12–24 months

Murray cod (*Maccullochella peelii peelii*)

iStock.com/marty8801

Freshwater fish

Native to Australia

**System:** Mainly suited to intensive recirculated tank systems, or grown extensively in dams and ponds

**Food:** High protein diets, usually in extruded pellet form

**Stocking density:** 200 fish/ha. Higher in intensive systems 30–40 kg/m<sup>3</sup>

**Optimum temperature:** 24–25 °C

**Market size:** 500–600 g

**Growth:** Market size can be achieved in 12–18 months

**FCR:** 1.5–2 kg of food to produce 1 kg of fish

**Water:** Won't tolerate high salinity; prefers neutral pH between 6–8; dissolved oxygen levels above 3 mg/L

**Barramundi (*Lates calcarifer*)**

Dreamstime.com/Wiksp

Freshwater and saltwater fish  
Native to Australia

**System:** Intensive recirculation tanks used, but pond culture is possible in Northern Australia

**Food:** High protein diets, usually in the form of commercial pelleted feeds

**Stocking density:** 30–40 kg/m<sup>3</sup>

**Optimum temperature:** 26–30 °C

Market size: 500 g

**Growth:** Market size can be achieved in 6–12 months

**FCR:** 1.5–2 kg food per 1 kg fish produced

**Water:** Dissolved oxygen levels between 4–9 ppm; free ammonia levels should not exceed 1 mg/L

**Yabby (*Cherax destructor*)**

Shutterstock.com/Ton Bangkeaw

Freshwater crustacean  
Native to Australia

**System:** Primarily grown in pond culture systems

**Food:** Feed on microbes that break down leaf matter on the pond walls and floors

**Stocking density:** Holding capacity of a grow-out pond for juveniles is 5–10/m<sup>2</sup>

**Optimum temperature:** 22–28 °C

**Market size:** 60–80 g

**Growth:** Market size can be achieved in 12 months

**Water:** Pond water pH should range between 7–8.5. Below 7 can cause moulting and shell hardening problems

**Figure 17.3** Common aquaculture species and their characteristics

## Discussion

- 1 Outline three ways some of these species can be grown.
- 2 Identify some of the water quality issues that can affect production of these species.
- 3 Which common characteristics make a species suitable for aquaculture production?
- 4 Which of the above species would be suitable for growing in your region? Explain why.

## DID YOU KNOW?

You can tell male and female mussels apart by the colour of their flesh. Mature male mussels have creamy white flesh while mature females have apricot-coloured flesh.



## LET'S DISCUSS

- 1 Discuss other species suitable for aquaculture in your region and evaluate whether it is suitable in a school environment.



Worksheets

Learn more about an aquatic species you would like to grow with the *Choosing the right species* worksheet.



## LET'S REVIEW

### LOOKING BACK

- 1 What is aquaculture?
- 2 Describe four different commercial uses of aquaculture products.
- 3 List five economically significant fish in aquaculture today.
- 4 List five other economically significant aquatic species in aquaculture today.

### FOR YOU TO DO

- 1 Conduct a fish dissection to identify external and internal structures.
- 2 Research and draw a labelled diagram of an oyster. Use your diagram to conduct a dissection of an oyster and locate the main structures.
- 3 Research how green-lip mussel spat is harvested for commercial production to sell to grow out farmers in New Zealand.



Video

Watch a fish dissection video to assist.

### TAKING IT FURTHER

- 1 Investigate one common fish species commercially produced in Australia and create a research poster highlighting the following facts:
  - common name
  - scientific name
  - image
  - physical description (adult size length and weight, colour)
  - common diet
  - primary predators
  - common production systems used
  - markets available.
- 2 Research how mussels and oysters feed in their natural environment then build a model to demonstrate your understanding.

## 17.3 Production

### Cycle

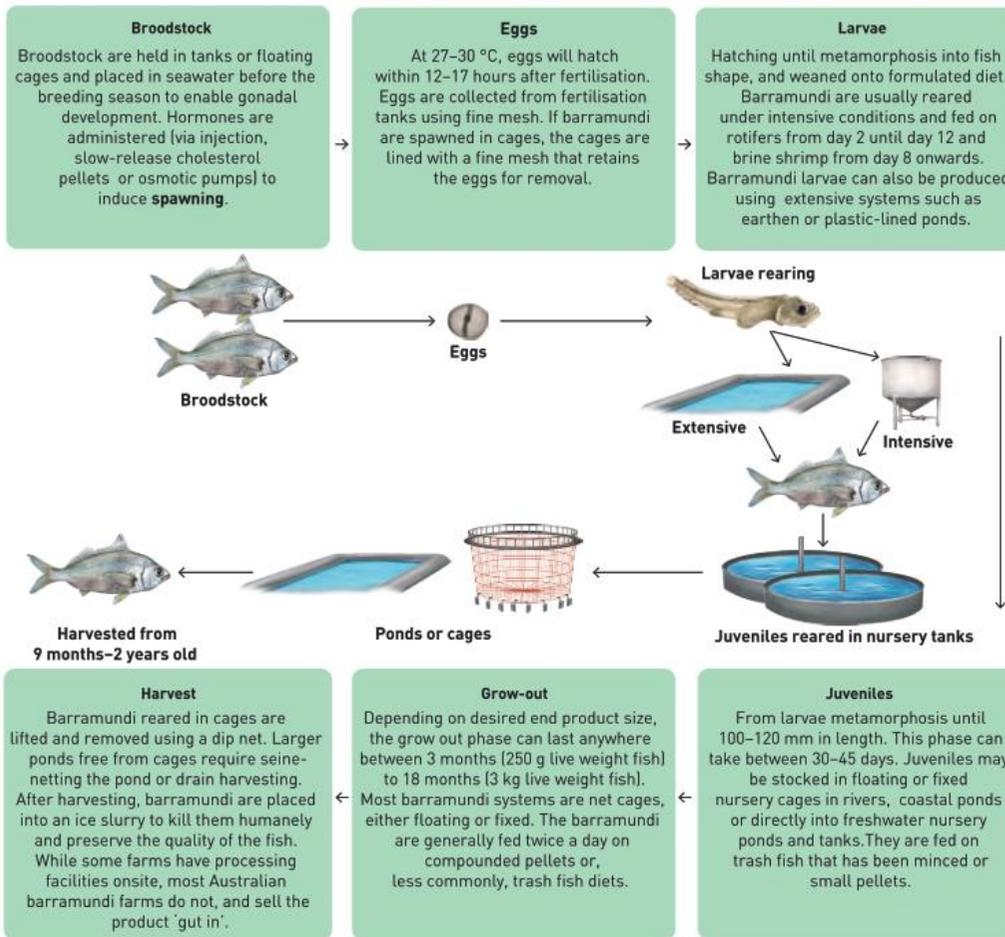
**broodstock** a group of mature individuals used in aquaculture for breeding purposes

**incubate** maintain at a favourable temperature and in other conditions to promote development and hatch

**hatcheries** places that produce fingerlings for sale to the public and for stocking public waters

Production cycles in aquaculture are unique to each species and growing system. Most cycles begin with breeding juveniles from **broodstock**. Fertilised eggs are **incubated** and hatched in **hatcheries** under controlled conditions in most species. Tiny larvae are then fed and cared for until they reach juvenile sizes ready for growing out. Some farmers buy stock from hatcheries and grow out to marketing size. At this stage they are called fingerlings. Others have breeding and hatching facilities on site. Some species, especially fish, will be moved to a nursery pond, tank or cage, before being graded and moved to the final grow out system to reduce competition from larger fish. Once the aquaculture species reaches market size, grading will occur based on size and/or weight and individuals ready for market will be harvested and sold to retail outlets or processors.

## Production cycle of barramundi



**spawn** the release or deposit of eggs



Watch the Barra Boom *Landline* episode. What systems does Australia's biggest producer of barramundi use?

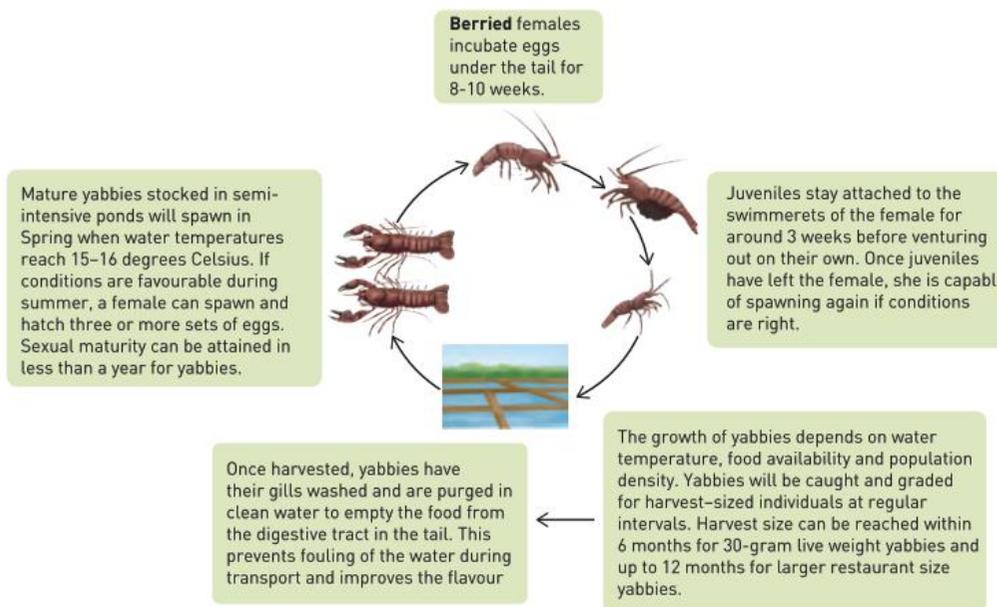


Explore the aquaculture systems used in Victoria with the Murray Cod *Landline* episode.

**Figure 17.4** Production cycle of a typical barramundi farm in Australia

## Production cycle for yabbies

Unlike fish, where hatcheries are used to produce juveniles for farmers to purchase and grow out, the complete lifecycle of the yabby is usually conducted onsite by the producer. Commercial yabby farming in Australia is generally undertaken in **semi-intensive**, especially designed ponds.



**semi-intensive** aquaculture with medium stocking rates where farmers provide some feed for the animals and there are some artificial controls on the environment for the aquatic species

**berried** bearing eggs

**Figure 17.5** Stages of production in semi-intensive yabby culture

## DID YOU KNOW?

Female yabbies can produce between 100–500 eggs per brood depending on their size.

## Systems

Aquaculture is one of the fastest growing agricultural sectors across the world for food production. Such systems can be classified as either intensive or extensive production systems.

### Intensive aquaculture

These types of systems rely on full, or almost full, control of environmental conditions through technology in artificial tanks at very high stocking rates. Farmers using intensive systems must have a thorough understanding of the species grown so that temperature levels, water quality, stocking densities, and feeding quality and quantity promote optimal growth while also reducing stress, disease and mortality. Intensive systems can produce high yields during peak and non-peak times of the year. However, these systems can have high start-up costs and require much more labour and specialised knowledge.



Getty Images/Bloomberg

Figure 17.6 Intensive aquaculture system

### Extensive aquaculture

These systems are more basic than intensive aquaculture systems. Less effort is put into the husbandry of the species grown and there is little to no environmental modification. Extensive systems are usually conducted in natural waterways such as rivers, lakes, bays and seas where water quality is determined by the water body. Fish and other cultured species are contained within their habitats by cages, mesh enclosures or attached to especially designed poles or structures in the case of oysters and mussels. Start-up of these systems costs relatively less than intensive systems, but because the product is susceptible to the elements, site placement is essential when planning these ventures. Water quality can be difficult to control. Species chosen for extensive aquaculture, such as prawns, mussels, salmon and seaweed, are generally very hardy and often do well at high density.



## LET'S DISCUSS

- 1 Discuss how the soil, topography and natural waterways of an area could affect the choice of aquaculture system used.



## LET'S ENGAGE

## DETERMINING THE SEX OF A YABBY

### PURPOSE

To determine the difference between male and female reproductive structures of yabbies

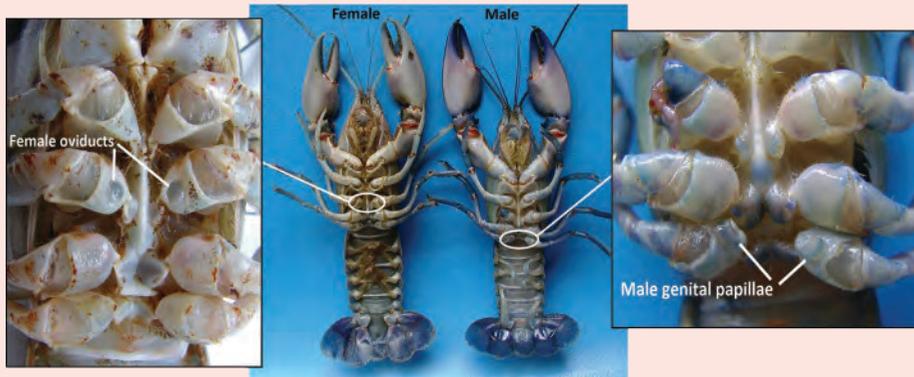
*Always refer to NSW Animals in Schools or other state or country webpage to learn more about the use of animals for research purposes in schools. Stress should be minimised during any practical activity using animals where possible.*

### MATERIALS

- Yabbies

### METHOD

- 1 Pick up yabby safely by the carapace and turn over to see the underside.
- 2 Look at the base of the third last set of walking legs for two small transparent discs (female), or on the base of the last set of walking legs for two penile protrusions (male). Refer to the photos below for assistance.



**Figure 17.7** Female (left) and male (right) yabby anatomy

### RISK ASSESSMENT



- Wash and sanitise hands thoroughly before and after handling
- Use correct handling technique to safely pick up the animal.

### DISCUSSION

- 1 Determine whether the yabby is male or female and explain how you came to that conclusion.

© Rob McCormack, Australian Aquatic Biological



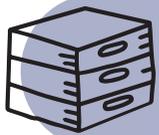
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NSW Animals in Schools



Video

Watch a video demonstration about safe handling of yabbies.



## LET'S EXPERIMENT

## MONITORING AQUATIC ANIMALS IN AQUACULTURE

### PURPOSE

To compare the growth rates of male and female yabbies

*Always refer to NSW Animals in Schools or other state or country webpage to learn more about the use of animals for research purposes in schools. Stress should be minimised during any practical activity using animals where possible through safe and minimal handling.*

### HYPOTHESIS

What effect do you think sex (independent variable) will have on growth rate (dependent variable)?

### MATERIALS

- Two tanks (equal size, same set-up and running on the same biofilter system and water)
- Same number of male and female yabbies (amount will be determined by stocking density appropriate for the system size)



Weblink

NSW Animals in Schools



Template

Risk assessment template



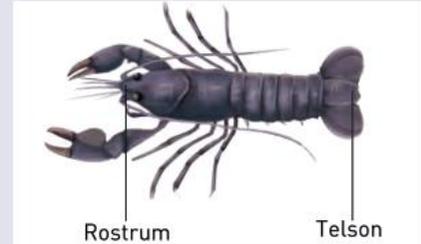
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Instructions to build a simple recirculating aquaculture system

- Yabby food.
- Kitchen scales
- Plastic sheet with a 1 cm grid printed on it.

### METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Set up recirculating system aquaculture system with two tanks in unison, or a bought fish tank with a divider down the middle.
- 3 Add identical hides to each tank for protection (shade cloth folded on top of itself and placed on the bottom).
- 4 Sex the yabby stock into male and female groups using the instructions in the previous Let's Engage activity.
- 5 Weigh and measure each group and record average start weight and lengths.
- 6 Add stock to the tanks (six to ten medium-sized yabbies per 100 L of water).
- 7 Feed yabbies the same amounts daily, on formulated pellets.
- 8 Weigh and measure weekly.
- 9 Record results.



Measure yabby from telson to rostrum on the overhead plastic grid by placing the telson alone one line and counting the number of squares to the rostrum

**Figure 17.8** Technique for measuring yabbies with little stress

### RESULTS

- 1 Construct a table to record average weights and lengths for males and females.
- 2 Construct stacked line graphs showing the average growth rate (weight and length) for male and female yabbies.

### DISCUSSION

- 1 Analyse the data to determine which group of yabbies grew the fastest. Can you think of why this might be the case?
- 2 What problems did you encounter in conducting this experiment? How did you overcome them?
- 3 Assess this experiment in terms of standardisation, randomisation and repetition. How could you improve on this experiment next time?
- 4 Design an experiment to determine the effect of feeding yabbies different percentages of protein in their diet.

### CONCLUSION

Was the hypothesis stated correct, incorrect or partially correct?

## AG IN FOCUS

### EARLY AQUACULTURE IN AUSTRALIA

#### Identify

The World Heritage-listed Budj Bim traps were built by the Gunditjmara people to manage eels in Lake Condah and nearby Darlots Creek. These traps are among the earliest examples of aquaculture in Australia. Historical and archaeological evidence

shows that the land-based eel farming system supported a large settled Aboriginal community in the area through both food and trade. Fishing and aquaculture production has been an important cultural and economic part of Aboriginal communities and is a vital element of connection to traditional country.

## Understand

The traps are a series of earthen canals, graded ponds and basalt dam walls that run for some 35km around the lake. The Gunditjmara people manipulated water levels to encourage young eels from Darlots Creek to swim into holding ponds in low lying areas. Smaller eels could move between ponds through spillways, while larger eels would become trapped and could be harvested for food. The system increased the range and availability of eels for much of the year.

Budj Bim is considered to be the earliest and possibly the largest land-based aquaculture venture in Australia but the age is not known for certain. Some historians date it to be as old as 6000 years, with the last modifications made around 200 years ago.

Other significant Aboriginal aquaculture sites include the Brewarrina fish traps, also known as Baiame's Ngunnhu.

## Discussion

- 1 Who built Budj Bim and for what purpose?
- 2 Describe how Budj Bim was designed to catch and grow eels.
- 3 Compare Budj Bim to modern day extensive aquaculture systems. Identify similarities and differences between the two.
- 4 Investigate the Aboriginal fish weirs and dams at Brewarrina in NSW. Compare these to the Budj Bim system, explaining the similarities and differences.



Fairfaxphotos/The Age/Justin McManus

Figure 17.9 Aerial view of Budj Bim



Weblink

Find out more about the history of Indigenous aquaculture by visiting AIATSIS.



## LET'S REVIEW

### LOOKING BACK

- 1 What are broodstock?
- 2 Compare and contrast extensive and intensive aquaculture systems and discuss the advantages and disadvantages of each system.
- 3 How are oysters and mussels grown?

### FOR YOU TO DO

- 1 Create a diagram to represent the production cycle for farming barramundi from broodstock spawning (egg laying) through to harvest. Include key life stages throughout the process.
- 2 Create a diagram to represent the production cycle for farming yabbies in a semi-intensive pond system from broodstock through to harvest.



### > TAKING IT FURTHER

- 1 Research the production cycle of an aquaculture species of interest. Create a flow diagram to represent this process from breeding to the consumer.
- 2 Research how green-lipped mussels are farmed. Make a list of the similarities and differences between how these molluscs are produced and how fish are farmed.

## 17.4 Management

### Environmental management

#### Distribution of enterprises

The aquaculture industry is largely based in regional Australia, while New Zealand's aquaculture industries mainly rely on coastal waters. Locations are generally based on the species being produced, with the tropical areas of Australia producing pearl oysters, prawns and barramundi and the southern regions growing cold-reliant species such as abalone and salmon.

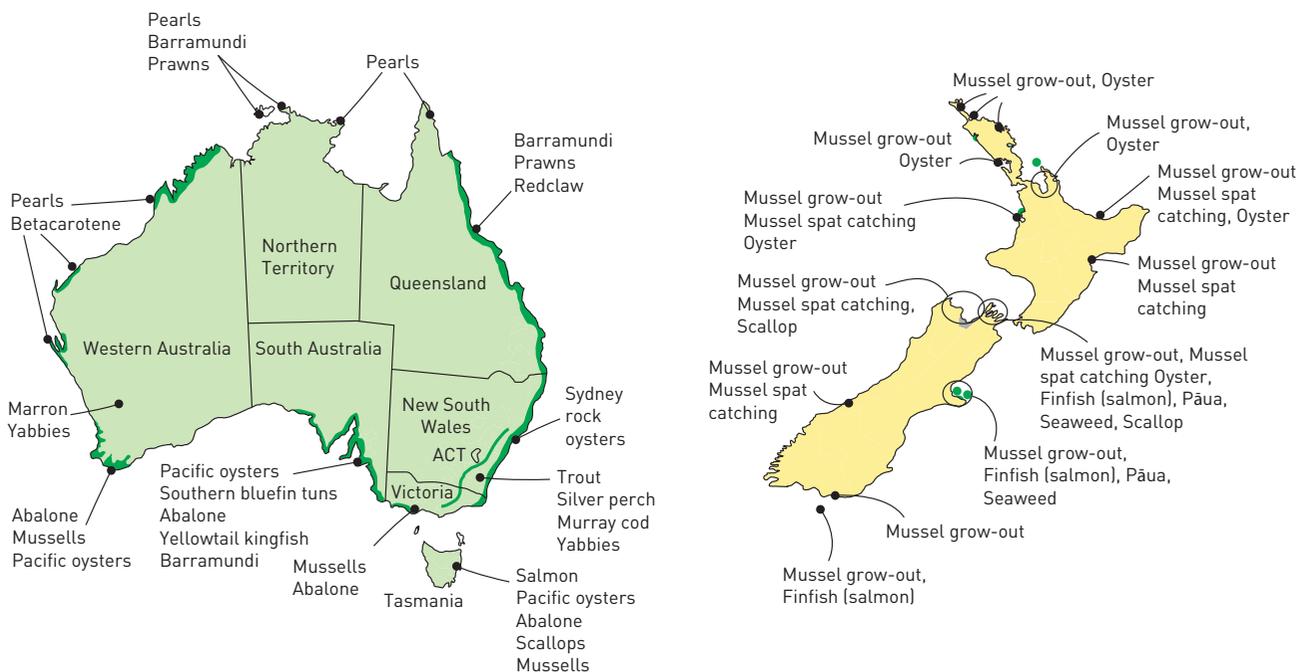


Figure 17.10 Distribution of aquaculture enterprises in Australia and New Zealand

#### Water quality

Intensive, semi-intensive and extensive aquaculture systems all must have a regular supply of clean water and the right temperature ranges for the species being grown. Water quality determines the stocking rates and productivity of the system. The maximum weight of aquaculture species a dam or tank can support is called its **carrying capacity**. This also depends on factors such as the species grown, food available and the size of the water body.

Dissolved oxygen levels are one of the most important parameters of water quality because oxygen is vital for all the organisms living in the water. This is not usually a problem in extensive systems, but in intensive systems water circulation is required to keep the levels

**carrying capacity** the maximum population size of the species that the environment can sustain indefinitely

acceptable. Aerators or increasing water flow can increase dissolved oxygen to achieve this. In extensive systems, pumping water from the bottom of the pond or dam and spraying it back onto the surface can also assist. The first sign of oxygen deficiency is dead fish or fish coming to the surface to gasp for air.

There are a range of environmental factors that determine acceptable water quality for aquaculture, including:

- pH range (level of acidity or alkalinity – sudden changes in pH can cause stock deaths)
- turbidity (how muddy or clear the water is)
- salinity levels (saltiness or amount of salts in the water)
- dissolved nutrient levels
- concentrations of contaminants such as heavy metals or chemicals from spraying
- presence of toxic nitrogenous waste materials.

**Table 17.4** Examples of ideal water quality ranges for select species

Water quality parameter	Barramundi	Silver perch	Yabbies
Temperature (°C)	26–30	23–28	22–28
pH	7.5–8.5	6.5–9	7.5–8.5
Turbidity (secchi depth)	30 cm	20–60 cm	30–45 cm
Salinity level (ppt)	0–36	2	<4
Nitrite (mg/L)	<0.1	<0.1	<4
Ammonia (mg/L)	<0.1	<0.1	<0.1
Dissolved oxygen (mg/L)	>4	>4	>4.5



## LET'S DISCUSS

- 1 How might water quality affect the taste, smell and appearance of aquaculture products?



## LET'S ENGAGE

### WATER QUALITY TESTING – pH

#### PURPOSE

To determine the pH of the aquaculture water sample

#### MATERIALS

- pH papers
- Water sample for testing

#### METHOD

- 1 Use the online template to conduct a risk assessment before conducting this activity.
- 2 Take a pH strip and dip the coloured squares into the sample water.
- 3 Leave the strip in the water for five minutes.

- 4 Remove the strip and match its colours against the colour chart to determine pH.

#### DISCUSSION

- 1 Interpret the results for your system.
- 2 Identify any factors that may be contributing to your test results (you may need to research some of these).
- 3 Research other ways for farmers to test water pH. How do pH test strips compare to these methods in terms of accuracy, expense and ease of use?
- 4 Investigate ways to alter the pH of tank water.



Template

Risk assessment template



LET'S ENGAGE

## WATER QUALITY TESTING – NITRITES

### PURPOSE

To determine the level of nitrites in the aquaculture water sample

### MATERIALS

- Aquarium nitrite test kit
- Water sample for testing

### METHODS

- 1 Use the online template to conduct a risk assessment before conducting this activity.

- 2 Follow the instructions on the testing kit.

### DISCUSSION

- 1 Interpret the results for your system.
- 2 What could you do to make this test more valid and accurate?
- 3 If the nitrite results were too high for a system, how could a farmer change the system to help reduce the nitrites in the water?



Template

Risk assessment template



Worksheets

Ensure you test your water for electrical conductivity and turbidity. You can find practical worksheets on NelsonNet.

## DID YOU KNOW?

The presence of nitrite indicates possible over-feeding, too many animals in the system or inadequate biological filtration.

## Enterprise management

### Breeding

The aquaculture industry usually consists of three areas:

- hatcheries
- nurseries
- grow out facilities.

Farmers may own one or all parts of the production line, depending on the species cultured and the expertise required to ensure profitable success at each stage.

In the early days of aquaculture, the juvenile stock was sourced from wild populations and grown out to harvest size. With increased research and technology, the aquaculture industry can now control breeding and, in some cases, induce breeding to be a year-round occurrence. The most common aquatic species cultured have large hatchery facilities producing juveniles for nursery and grow out farmers to purchase.

## AG IN FOCUS

### BREEDING IN INDUSTRY

#### Identify

Different species have different breeding processes, each of which requires specialised knowledge to ensure year-round production is possible.

#### Understand

##### Breeding of silver perch

Sexually mature silver perch broodstock are often induced to spawn using an injection of the human chorionic gonadotropin (HCG) hormone. After the injection of HCG,



pairs of males and females are moved to covered tanks with string aeration and a consistent 25 °C temperature. Spawning will take place here once the hormone has taken effect. Natural fertilisation will take place. Up to 125 000 eggs per kg of the female's body weight can be produced during the spawning.

### Breeding of black tiger prawns

Most prawn species are produced in hatcheries. Some use pond-reared mature spawners, others collect broodstock from wild-caught spawners in coastal waters. Spawners that are gonadally mature can spontaneously spawn when they are transferred to the hatchery facilities. Others will require methods to induce spawning. This can be achieved through the use of eyestalk ablation (the removal of one or both eyestalks). Prawn eyes have specialised glands that produce hormones to control reproduction. Removing one of the eyestalks reduces the levels of a hormone that prevents reproduction, allowing them to mature faster and release more eggs. This can make egg production more predictable and efficient.

### Discussion

- 1 Compare spawning techniques for silver perch and prawns.
- 2 Research the breeding techniques used for one more aquatic species of your choice. Make a list of similarities and differences between the researched species and the two in this case study.
- 3 Prawns have a very simple nervous system and whether they feel pain or not is unknown. Discuss whether eyestalk ablation should be conducted to induce spawning due to animal welfare concerns.

## Feeding

Growth, reproduction and the general health of fish and other aquatic animals are mostly dependent on having an adequate supply of food in terms of both quality and quantity. The nutrient and energy requirements of the aquatic species grown will determine the ratio, amount and frequency of feeding to meet the production goals of the farmer.

Fish and other aquatic animals are usually fed one or more of the following types of feeds.

**Table 17.5** Types of feeds used in aquaculture

Feed types	Sources	Advantages	Disadvantages
Natural feeds	<ul style="list-style-type: none"> <li>• Aquatic animals and plants that can be grown in ponds and dams.</li> <li>• Produced through helping natural growth using fertilisers.</li> </ul>	<ul style="list-style-type: none"> <li>• Low cost – naturally grows in a pond with some encouragement.</li> <li>• Always available, fish can feed when they like.</li> </ul>	<ul style="list-style-type: none"> <li>• Less control over food source – anything that affects the growth of the feed affects the stock growth.</li> <li>• May not meet the nutritional requirements.</li> </ul>
Supplementary feeds	<ul style="list-style-type: none"> <li>• Usually agriculture by-products such as wheat and rice bran.</li> <li>• Used commonly in semi-intensive systems to complement the natural feed sources.</li> </ul>	<ul style="list-style-type: none"> <li>• Cheaper than artificial feeding.</li> <li>• Easy to access.</li> </ul>	<ul style="list-style-type: none"> <li>• It has not been formulated to meet specific nutritional needs of the cultured species.</li> </ul>

Feed types	Sources	Advantages	Disadvantages
Trash fish	<ul style="list-style-type: none"> <li>Cheap fish and fish offcuts that are not generally consumed by humans.</li> </ul>	<ul style="list-style-type: none"> <li>Suitable for species that do not accept artificial diets.</li> </ul>	<ul style="list-style-type: none"> <li>May not meet nutritional needs.</li> <li>Need a large quantity of trash fish to improve the growth of cultured fish species.</li> <li>Must be kept in a refrigerated environment that can be expensive to run and maintain.</li> </ul>
Live food organisms	<ul style="list-style-type: none"> <li>Very small plants and animals fed live to the cultured species. Bred and grown specifically for the system. Rotifers, artemia, copepods, microalgae.</li> <li>Used especially during the larvae stage of fish development.</li> </ul>	<ul style="list-style-type: none"> <li>Suitable for larvae stages of growth for species that do not take artificial feeds.</li> </ul>	<ul style="list-style-type: none"> <li>Expensive in both time and money to produce.</li> <li>Specialist skills required to grow in large numbers.</li> </ul>
Artificial feed	<ul style="list-style-type: none"> <li>Specially made diets to meet the nutritional needs of the cultured species grown. Can be pellets, powders or moist or semi-moist feeds.</li> </ul>	<ul style="list-style-type: none"> <li>Meets the specific requirements of the cultured species, ensuring maximum growth and development.</li> <li>Available when environmental conditions are not favourable.</li> </ul>	<ul style="list-style-type: none"> <li>Can be costly compared with natural feeds.</li> </ul>

### DID YOU KNOW?

Fish are very efficient at converting food into growth. For every kilogram of feed they consume, Atlantic salmon can grow 1 kg of flesh. Compare this with chickens which require 1.8 kg of feed for every kilogram of flesh.

## Records and financial management

### AG IN FOCUS

#### GROSS MARGINS

##### Identify

Farm gross margins can compare the performance of enterprises that have similar requirements for labour, land and machinery. A gross margin refers to the total income received from an enterprise, minus the enterprise's variable costs, such as fingerlings, feed and chemicals.

## Understand

Compare the gross margins of two pond-based finfish farms below.

**Table 17.6** Economic performance of an average pond-based barramundi farm

Average return (income) (A)	\$8.90
<b>Variable costs</b>	<b>\$/kg</b>
Fingerlings	0.27
Feed	3.11
Labour	1.42
Process/pack/freight	0.04
Electricity	0.33

**Table 17.7** Economic performance of an average pond-based silver perch farm

Average return (A)	\$5.49
<b>Variable costs</b>	<b>\$/kg</b>
Fingerlings	0.15
Feed	2.48
Labour	1.42
Process/pack/freight	0.04
Electricity	0.33

## Discussion

- 1 Calculate the total variable costs and then the gross margin for each farm.
- 2 Identify which farm is more profitable per kilogram.
- 3 If the example barramundi farm produced 200 kg of fish in January, and the silver perch farm produced 350 kg, what is the total income for each farm? Which farm produces more profit? Explain why.
- 4 Discuss factors other than profit that may influence a farmer's decision on what species to grow.



Template

Gross margin template

## INDUSTRY IN FOCUS

### FISH FARM MANAGER

#### IDENTIFY

Fish farm managers are responsible for the breeding and rearing of fish for market. Farms can breed their own fish by hatching eggs from adult broodstock or can buy in juveniles and rear them before selling on to purchasers.

A fish farm manager's daily role involves managing and maintaining fish habitats, taking care of stock health and welfare and feeding the fish either by hand, or through automated machinery. This job also involves:

- calculating suitable feeding regimes for stock based on age and growth rate
- planning breeding programs
- understanding and adhering to environmental legislation
- maintaining stock records
- ensuring water supply is of sufficient quality
- handling fish for spawning, grading and harvesting
- selling and marketing fish.

Fish farm managers usually split their time between working indoors and outdoors while managing stock, staff and paperwork. It is not essential to have a degree from university for this position if you have enough practical experience, but a university or TAFE degree in agriculture, applied chemical or biological sciences, aquaculture, fisheries studies or marine sciences is highly sought after.

## Discussion

- 1 Outline four daily duties of a fish farm manager.
- 2 What qualifications does a person require to become a fish farm manager?
- 3 Why do you think it is important for a fish farm manager to understand environmental legislation?



**Figure 17.11** Fish farm manager performing daily duties



## LET'S REVIEW

### LOOKING BACK

- 1 Name three species commercially grown in your state.
- 2 What three industry areas is aquaculture broken up into?
- 3 Explain the term 'carrying capacity'.
- 4 Identify which feeds are best suited to the following stages of growth:
  - a barramundi larvae
  - b juvenile barramundi
  - c barramundi in grow-out stage before harvesting.
- 5 Why is dissolved oxygen important for water quality?
- 6 Describe the first signs of oxygen deficiency in a farm dam.

### > FOR YOU TO DO

- 1 Take water quality measurements each week for the term and record pH, temperature, electrical conductivity and nitrites. Create a graph at the end for each and discuss any trends you can see.
- 2 Research aquaculture facilities in your local region. Make a map showing the species grown and types of systems used.

### TAKING IT FURTHER

- 1 Use Excel or a similar program to create a spreadsheet for keeping records of water quality testing in your aquaculture system.
- 2 Survey local aquaculture facilities and determine the most popular feeds used and where they source juveniles from (either bred onsite or bought in).



Worksheets

Use the NelsonNet worksheets to assist you to take these measurements.

## 17.5 Pests and diseases

### Pests

Farmed aquatic animals may be eaten by predators, such as birds and other fish, particularly if they are in extensive systems. There are several options available to reduce this type of predation on an aquaculture facility, including:

- exclusion – physical barriers such as fences and nets to stop the pests getting into the ponds
- deterrent – electronic devices used to produce loud noises that scare away predators
- hiding – providing a means for the cultured species to hide from predators, such as increasing turbidity of the water or using some form of cover
- traps – catching the pests before they affect the stock.

Not all pests prey on aquaculture species – others compete for resources or damage the water quality of an open waterway extensive system. These pests can include:

- weed or algae blocking sunlight to the bottom
- dead animals fouling the water quality
- carp and speckled livebearers that degrade water quality and can create turbidity
- Asian green mussels clogging seawater intake pipes
- mosquito fish that attack the fins of native species grown causing damage to the product
- sea lice causing gill congestion and skin damage.

### Diseases

Aquaculture systems are susceptible to diseases because large amounts of juvenile stock are being brought in regularly and animals are often kept at high stocking rates. Diseases can also enter extensive aquaculture systems directly from the wild.

Examples of disease in aquaculture include:

- vibriosis in seabass, snapper and shrimp larvae
- enteric redmouth in rainbow trout and salmonids
- streptococcosis in crayfish, rainbow trout
- white spot disease in prawns and other crustaceans
- epistylis in yabbies
- white spot (Ich) in silver perch.



Video

Explore how pests and diseases can affect Australian aquaculture production by watching the South Australian oyster *Landline* episode.

Diseases can be prevented by quarantining new stock, maintaining water quality and appropriate stocking rates, and providing animals with good nutrition.

## AG IN FOCUS

### WHITE SPOT SYNDROME VIRUS

#### Identify

White spot syndrome virus (WSSV) is a highly contagious viral infection caused by *Whispovirus*. It affects decapod crustaceans including prawns, crabs, lobsters and yabbies.

#### Understand

Infected animals may stop eating, become lethargic and swim differently. Their shells may become loose with numerous white spots on the inside surface and may also become discoloured. Movement of infected animals and contaminated water can cause the disease to spread. Birds and other crustacean predators that feed on infected animals can also spread the disease.

Australia was considered WSSV-free until an outbreak was recorded in November 2016 in south-east Queensland. Within four months of the initial outbreak, seven prawn farms along the Logan River, Queensland, were infected.

Infected properties undergo treatment to ensure the virus is destroyed as quickly as possible to minimise further spread. Treatment includes adding chlorine to growing ponds, water channels and settlement ponds. These water sources are then drained, dried out and cleared of all sediment. This is the largest aquaculture animal disease emergency the Queensland government has had to respond to, spending around \$4.4 million on controlling the spread of the disease.

Australia has many biosecurity measures in place to prevent these types of diseases from entering the country. Bringing infected seafood into the country is prohibited and imported foods are tested in quarantine before passing through. Live aquatic animals are also quarantined at the border to ensure they are disease free. Prawns intended for human consumption are not to be used as fishing bait because they can be a source of transmission into open waterways.

The source of this particular outbreak remains unknown.



Shutterstock.com/Trieu Tuan

**Figure 17.12** Prawns infected with white spot syndrome virus

#### Discussion

- 1 Describe what WSSV is and how it is spread.
- 2 Outline the biosecurity measures in place to prevent the disease coming into Australia and the measures taken when detected.
- 3 Discuss the effectiveness of the biosecurity measures outlined.



## LET'S REVIEW

### LOOKING BACK

- 1 Name three pests of aquaculture species.
- 2 Name three diseases of aquaculture species.
- 3 Apart from eating aquatic animals, what other effects can pests have on aquaculture systems?
- 4 How can a disease be introduced into aquaculture systems?

### FOR YOU TO DO

- 1 Research three biosecurity measures:
  - a Australia has in place to prevent serious pests and diseases from entering the country.
  - b aquaculture farmers can put in place to prevent serious pests and diseases from entering their systems.
- 2 Research the protocols for farmers who detect notifiable pests or diseases on their farm.
- 3 Research why it is illegal to use European carp for stocking dams in New South Wales.

### TAKING IT FURTHER

- 1 Design and build an exclusion or a hiding system for the aquaculture species and system on your farm. Examples could include yabby hides made from shade cloth or nets to go over the pond.
- 2 Create a biosecurity awareness poster for aquaculture farmers to increase awareness of simple procedures they could use to prevent serious pests and diseases.

## 17.6 Social and ethical issues

### Fishmeal and fish oil products

Fishmeal and fish oil (F&FO) made from small wild fish to produce specially formulated diets for aquaculture farming is a hotly debated and complex topic.

Fishmeal can be made from almost any type of seafood but is generally manufactured from wild-caught, small marine fish that have a high percentage of bones and oil. Production of fish meal is seen as a major contributor to over-fishing and risks pushing wild stocks beyond replacement numbers. Some areas of the world have seen a large increase in the production of fish meal and this is hurting local fisheries, causing them to collapse.

Aquaculture production is expected to increase, but catch from wild fisheries is expected to remain static or decrease. Aquaculture puts direct pressure on wild fisheries instead of being a form of relief as a net contributor to fish supplies. Those against using F&FO made from wild stock for aquaculture diets argue that the food conversion ratio is inefficient with more than 6 kg of wild fish required to produce 1 kg of farmed fish. Supporters of the use of F&FO believe that focusing solely on feed conversion ratios is misleading. They argue the wild fish being used are usually small and bony and not in demand for human consumption, and therefore there is no direct competition in this area. Processing these fish into F&FO allows production of high-quality healthy fish that are increasingly in demand for human consumption.

Feed accounts for the largest input costs for aquaculture, and the prices of fishmeal and fish oil are increasing. As a result, alternative protein sources are being investigated to produce a new feed source at a competitive price without compromising on the nutritional make-up. Alternatives include advanced plant-based products such as fermented soybean protein concentrate, algae and insects.



Shutterstock.com/premkh

**Figure 17.13** Powdered fishmeal

## The use of antibiotics in aquaculture

Antibiotics are used to treat diseases caused by bacteria. More commonly however, they are used to prevent diseases before they occur. The type and amount of antibiotics used in aquaculture depends on the farming practices, national laws and government enforceability. Preventing diseases by treating the water or fish before the disease occurs is profitable because it prevents loss and allows fish to grow quickly.

Antibiotic use in aquaculture in Australia is allowed but authorities have called for the industry to cut down on use. The World Health Organization has raised alarm over the overuse of antibiotics in humans and animals because it is considered the leading cause of the rise in antibiotic-resistant bacteria.

While only a few antibiotics are approved for aquaculture, some of these are also used to treat human disease.

Another major problem is the importation of products containing antibiotic residues. In some countries clean water is limited, and farmed fish are exposed to animal manure and human waste. To prevent the spread of bacteria, some foreign aquaculture producers use unapproved antibiotics in their fishmeal and this seafood can be imported into Australia. Australia has Imported Food Testing Guidelines including regular testing for antibiotic residues.



### LET'S REVIEW

#### LOOKING BACK

- 1 What is fishmeal and fish oil made from?
- 2 Explain why fishmeal is seen as an ethical problem.
- 3 Outline two major concerns surrounding the use of antibiotics in aquaculture.

#### FOR YOU TO DO

- 1 Investigate alternative protein sources for fish food. Why haven't alternative food sources been widely adapted if fishmeal is considered unsustainable?
- 2 Research and compare the nutritional content of fish meal and a plant-based protein meal such as soy or a selection of insects (you can find information on the nutritional value of insects in Chapter 14 Bees and other insects).



### > TAKING IT FURTHER

- 1 Some environmentalists claim that farmed salmon are the battery hens of the sea. Conduct a class debate on this topic.
- 2 Investigate your states legislation relating to the welfare of aquatic animals.
- 3 Consider the positives and negatives of using antibiotics in aquaculture. Conduct a classroom debate discussing the issue from a farmer's perspective and a consumer's perspective.

## 17.7 Sustainability

### Sustainable practices and methods

#### Effluent disposal

Aquaculture waste water, or **effluent**, contains high levels of nutrients such as ammonia and phosphorus. If released into the environment, untreated effluent can lead to algal blooms and eutrophication (see Chapter 3 Farm resources and technology, Ag in Focus).

There are government regulations that control the disposal of effluent. Some cost-effective methods include:

- settlement basins where solid wastes settle to the bottom and floating wastes can be skimmed off the top
- biofiltration, where filter beds of beneficial bacteria extract and detoxify dissolved chemicals
- mechanical drum filters with microscreens which remove solids

Aquaponics, where plants are grown in recirculated aquaculture water, has the potential for treating effluent water from commercial aquaculture.

### Sustainable technology

#### Recirculation technology

This technology is based on the principle of reusing part or all of the water in the production system. Recirculation can be used for any aquatic species grown in aquaculture, such as fish, molluscs and crustaceans. Because water is becoming a limited resource in many regions, recirculation technology is seen as an environmentally sustainable solution to this agricultural problem. The limited use of water as an input makes it cheaper and easier to remove the nutrients excreted because the volume of discharged water is much lower than that of traditional fish farming. The nutrients from the system can be used as fertilisers on land-based farming or for biogas production.

Traditional methods of aquaculture, from Aboriginal peoples with fish traps through to many of the extensive systems practised today in open waterways and outdoor dams, depend on external conditions such as water temperature, oxygen levels and water turbidity. In a recirculated system, these factors can be partly or completely controlled. Controlling the environmental conditions such as water temperature, dissolved oxygen levels and amount of daylight allows a farmer to provide optimal conditions for the growth, development and health of the animals. Having stable, consistent conditions can result in reliable growth patterns that enable producers to predict the time to market size.

**effluent** liquid waste or sewage discharged into a river or the sea



Worksheets

Build your own aquaponics system with the worksheet on NelsonNet.



Video

Find out more about how fish can assist with growing vegetables.



Data scenario

Investigate the effect of *Genetically modified salmon on growth rates* with this data scenario.

## Sustainable decision-making

After decades of wild fisheries being the primary source of seafood supplies, wild stocks have been considerably overfished and some species are now endangered or extinct. Aquaculture is seen by some as a solution to alleviating the stress placed on these stocks by consistently supplying the seafood market with fresh disease-free supplies. Aquaculture also has a place in restocking natural waterways and replenishing fish stocks. However, aquaculture can also have detrimental effects on natural waterways through the accidental introduction of invasive species into an ecosystem. In extensive systems that are cultured in open waterways, escaped fish pose a short-term threat through increased competition with native species for limited resources. Long-term threats have more serious consequences. When introduced species interbreed with wild species, they can disrupt the genetic variability of the species, making them more prone to infection and diseases.

### AG IN FOCUS

#### THE USE OF GENETICALLY MODIFIED SALMON

##### Identify

AquaAdvantage Salmon was the first GM animal to be approved for human consumption by the US Food and Drug Administration in 2015. It is a fast-growing salmon, genetically engineered to grow to market size in half the time of conventional Atlantic salmon. This salmon contains a growth hormone gene found in Pacific Chinook salmon and a fragment of DNA from the ocean pout. When combined, the DNA fragment acts like an 'on' button to enable this salmon to grow year-round instead of seasonally like other salmon.

##### Understand

This transgenic Atlantic salmon was developed by a Canadian biotech company called Aquabounty Technologies over 20 years ago. In the past 20 years, the company has conducted vast research that has determined that, under certain conditions, the fish is safe to eat, represents no risk to the environment and raises no ethical concerns surrounding animal welfare. However, even with the vast research behind the GM salmon, there are many restrictions placed on the production of this animal; most notably, it can only be grown in land-based facilities with physical barriers preventing it from reaching the ocean. Other precautions include the fact that all the GM salmon are female and sterile, so they could never breed with wild stock if released.

##### Discussion

- 1 What are the short-term impacts of using GM salmon?
- 2 What are the long-term impacts of using GM salmon?
- 3 Discuss as a class how use of GM salmon could affect the sustainability of the enterprise.
- 4 Would you, as a farmer, recommend using GM salmon? Explain why.



## LET'S REVIEW

### LOOKING BACK

- 1 Explain what effluent discharge is and discuss why it is a problem.
- 2 Explain how a recirculation system works and how it can help manage water consumption.
- 3 Explain why aquaculture stock escaping into natural waterways can be a sustainability issue.

### FOR YOU TO DO

- 1 Research how a biofilter works and the range of materials that can be used for increasing surface area for bacteria to live.
- 2 Aquaponics is a food production system that combines aquaculture with hydroponic practices. Research how aquaponics systems are built and list the advantages of combining these two systems of food production.

### TAKING IT FURTHER

- 1 Build a biofilter for an aquaculture system. Experiment with a range of materials for creating surface area.

## 17.8 Marketing

### The market

Aquaculture has been the fastest-growing agricultural protein sector over the past 30 years and now represents nearly half of the total global fisheries production (70 million tonnes per year). Since 2002–03, the gross value of Australia aquaculture production has increased by 12% to over \$1 billion per year.

**Table 17.8** Annual aquaculture harvest for the top 16 countries.

Rank	Country	Annual aquaculture harvest (million metric tonnes)
1	China	58.8
2	Indonesia	14.4
3	India	4.9
4	Vietnam	3.4
16	Australia	0.24

Australia has earned an international reputation for the production of safe, sustainable and very high-quality seafood. Most of the value from Australian production comes from high-value species, including salmonids, oysters, pearl oysters and tuna. Commercially in Australia, there are over forty aquatic animals produced, the top five (in order of production values) include salmonids, tuna, oysters, pearl oysters and prawns.

Australia exports a significant amount of high-end fish species that Australian consumers are often unwilling to pay for. The export market for Australian aquaculture production shows an increasing demand for native species. The Asian markets are the highest importers of seafood products, and Australia is well positioned to take advantage of this.



Worksheets

Find out about local consumer behaviour regarding seafood with the *Seafood consumption survey* worksheet.

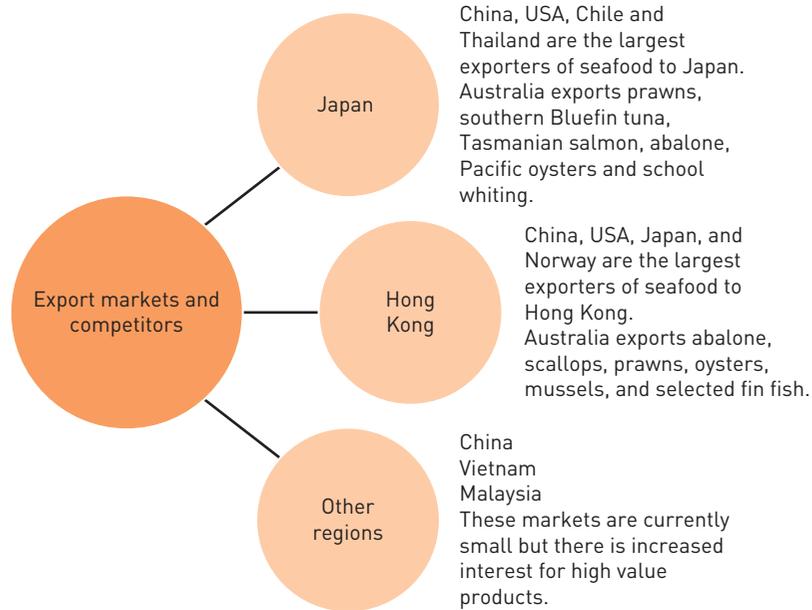


Data scenario

Examine *Aquaculture production in Australia*.

## DID YOU KNOW?

China dominates aquaculture, growing a whopping 61% of the world's farmed seafood. If you add in the rest of Asia, the percentage increases to 91%.



**Figure 17.14** Current export markets for Australian aquaculture products and its competitors

**net importer** a country that imports more than they export of a product

Australia is considered a **net importer** of seafood products with imported amounts remaining steady over the past decade. Seafood imports are largely made up of lower-value products such as frozen fish fillets, prawns and canned fish. Low production and labour costs in South East Asian countries make it difficult for Australia to compete with lower-end products. These products are predominantly imported from Thailand, New Zealand, Vietnam and China.

## Specifications

In the aquaculture industry, market specifications are specific to each species and the market in which they are being sold. Most species have size or weight criteria to ensure that there is enough of the consumable protein available when prepared in a restaurant. Other criteria include condition, flavour and grading.

The market specifications for barramundi are listed in Table 17.9 based on a number of fish being sold in a box together.

**Table 17.9** Market specifications for barramundi sold in Australia per box

Feature	Specification	Standard quality grade
Size (g)	400–600	No more than two fish out of grade per case and fish within 50g of specifications
	600–800	No more than one fish out of grade per case and within 60g of specifications
	800–1000	No more than one fish out of grade per case and within 80g of specification
	1+, 2+ & 3+	Nil tolerance out of grade
Flavour/taste		No obvious earthy or other undesirable flavour permitted

Feature	Specification	Standard quality grade
Smell		Fish has no obvious smell No offensive or spoilage odour evident
Physical deformities	All size categories	None present
Scale loss or skin damage	Size: 400–600	No obvious scale loss/skin damage on more than two fish per case
	Size: 600–800	No obvious scale loss/skin damage on more than one fish per case
	Size: 800–1000	No obvious scale loss/skin damage on more than one fish per case
	Sizes 1+, 2+ & 3+	Nil tolerance on obvious scale loss/skin damage on fish

The restaurant market specifications for yabby production are below, based on a number of yabbies being sold in a box together.

**Table 17.10** Market specifications for yabbies sold in Australia per box.

Feature	Specification	Note
Size (g)	30–40 40–50 50–70 70–90 90+	The market or consumers prefer larger sized yabbies in the market grades: 50–70 g, 70–90 g and 90+ g
Flavour/taste/smell		<ul style="list-style-type: none"> <li>Yabbies <b>purged</b> prior to sale can improve taste and appearance of flesh, improve survival rate during transport and attract a higher price</li> <li>No regulation enforcing purging, this is voluntary</li> <li>No obvious smell or spoilage smell present</li> </ul>
Physical damage		<ul style="list-style-type: none"> <li>No heavy staining (light, uniform colours preferred)</li> <li>Two claws of similar size preferred</li> <li>No tail blisters present</li> </ul>

**purged** emptying of the stomach and digestive tract

## Marketing strategies

Aquaculture marketing chains are complex. They can be very short with retailers and consumers purchasing directly from producers that process fish or other aquatic species onsite, or they can be long. An individual fish or animal could change hands many times before the final product is sold to consumers. There are generally four market options for seafood:

- restaurants – chefs who value-add through preparation and serving to consumers
- food-service industry – catering businesses value-add by preparing it for consumers to eat
- fishmongers or retailers – sell directly to the consumer with little preparation, mostly only filleting and cleaning
- chain retailers – for example, Woolworth and Coles, which sell with little preparation, straight to the consumer. Some chain retailers have small fishmonger sections to value-add to the product for increased profit.

Value-adding is the process of changing a product from its original or raw state to a more valuable product. For example, changing whole live trout into smoked trout fillets that will receive a higher price per kilogram. There are several advantages of value-adding to products, including generating higher profit to the producer or processor, creating safer products, preserving high-quality characteristics and extending shelf life. Value-adding can take many forms in the aquaculture industry, the most common being filleted fish, frozen and canned seafood products and ready-to-eat meals. Each of these value-added products appeals to consumer demands for safe products that maintain their quality and are convenient.



## LET'S REVIEW

### LOOKING BACK

- 1 List three countries Australia exports aquaculture products to and name the products.
- 2 List three countries Australia imports seafood products from and the types of products.
- 3 What are market specifications?
- 4 What is value-adding? Name three value-added products that can be made from aquaculture.
- 5 Outline the four markets available to aquaculture producers.

### FOR YOU TO DO

- 1 Create a pie chart representing the top four countries, total aquaculture harvest and include the rest as 'other' on the chart.
- 2 Find examples of value-added aquaculture products. Compare their prices to the raw product price in retailers. Evaluate the price differences in terms of extra ingredients and labour costs.
- 3 Design and conduct a survey to determine how many products in the fresh and frozen sections of the local supermarket are products of Australia and how many are imported. Calculate the percentages of each.
- 4 Create a simple marketing chain for an aquaculture product of your choice.

### TAKING IT FURTHER

- 1 Create a poster demonstrating the market specifications for an aquaculture species of your choice.
- 2 Compare the costs of prawns sold in the local supermarket, local versus imported. Account for the difference in price. Conduct a survey to determine which product people would normally buy and their reasons for this.
- 3 Investigate one other seafood product that is promoted as either sustainably or humanely produced. Analyse the marketing promotion used to advertise the product.
- 4 Use data collected from the Australian Bureau of Statistics to create a graph displaying Australia's exports and imports of fisheries products in recent history.



WebLink

ABS

# Let's summarise

## How can we farm fish and other aquatic organisms?

Aquaculture has taken the title of the fastest growing protein farming industry over the past three decades. There are now around 600 aquatic species commercially produced in a range of aquaculture systems around the world.

Copy and complete the table below, discussing the farming system and management techniques (such as food, breeding process and water preferences) for each species.

Species	Farming system	Management
Barramundi		
Yabby		
Silver perch		



Practice quiz

Complete the chapter review test on NelsonNet to review what you have learnt about aquaculture production.

## How can technology increase aquaculture production?

Technology has been essential to the increase in aquaculture production around the world, resulting in more intensive farming enterprises and allowing larger amounts of fish to be farmed in smaller artificial places. Create a mind-map to discuss at least four technologies that have helped contribute to the increase in aquaculture production. Some possible technologies to discuss are listed in the table below.

Recirculation technology	Effluent disposal	Breeding technology	Genetically modified fish
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## How can aquaculture be undertaken in an ethical and sustainable way?

The expansion of aquaculture as an industry has placed a strain on local ecosystems and the strive to produce high-quality products with reasonable profits have led to some unsustainable practices. The industry has begun putting in place practices to prove that large-scale aquaculture is possible without placing unacceptable demands on the environment.

Using your knowledge from this unit, complete the table below.

	Intensive	Common to both intensive and extensive	Extensive
Environmental issues			
Solutions			
Ethical issues			

# glossary

**accuracy:** how close a measurement is to a true or correct figure

**active ingredient:** the specific ingredient or substance that causes the desired outcome using the chemical

**ad lib:** available to feed all the time

**aggregate:** the material or structure formed from a mass of fragments or particles loosely compacted together

**algae:** photosynthetic plants without stems, roots or leaves and ranging in size from single-celled to multi-celled organism

**anemometer:** an instrument used to measure wind speed

**annual:** a plant that completes its lifecycle within one growing season

**antibiotics:** chemicals that kill certain microorganisms, mainly bacteria

**aquaculture:** the commercial farming of fish, molluscs (e.g. oysters), crustaceans (e.g. prawns) and aquatic plants (seaweeds) in natural or controlled marine or freshwater environments

**arachnid:** a type of arthropod with only two body segments and four pairs of legs

**arthropod:** (jointed-legs) the largest grouping of organisms in the animal kingdom, includes insects and arachnids

**awn:** a hair-like spine that grows on a wheathead. Some wheat species are awn-less.

**bacteria:** single-celled microscopic organisms

**bale:** a bundle of cotton fibre, tightly compressed and secured with twine

**basidia:** structures within the gills of a mushroom that make and release spores

**Beaufort wind force scale:** measures wind speed according to what conditions look like at sea or on land

**berried:** bearing eggs

**binocular:** vision or sight using both eyes, allowing for depth perception

**bioaccumulation:** the increase in concentration of a chemical in organisms as we move up the food chain

**biofuel:** fuel made from living things

**boll:** the seed-bearing part of the cotton plant in which the fibres are formed

**boundary:** limitations placed on a farm, including physical, financial, cultural and legal

**brooder:** a heating device used to simulate conditions under a sitting hen

**broodstock:** a group of mature individuals used in aquaculture for breeding purposes

**calibrate:** to correct a measuring device by comparing it with a standard to ensure accuracy

**capillary action:** the spontaneous flow of a liquid into a narrow tube or porous material that does not require the force of gravity

**carbon footprint:** the total greenhouse gas emissions caused by an individual or activity

**carcase:** the body of the animal after removal of head, feet, hide and internal organs

**carrying capacity:** the maximum population size of the species that the environment can sustain indefinitely

**cashmere:** the quality wool fibre produced by goats

**cellulose:** an insoluble substance that is the main part of plant cell walls

**cephalopod:** a mollusc, such as a squid, octopus or nautilus

**chlorosis:** leaves of typical green colour turn pale and yellow

**climate:** the average conditions of Earth's atmosphere based on records taken over at least a 30-year period

**cloaca:** the body cavity of a hen or rooster containing the ends of the digestive, reproductive and urinary tracts

**clutch:** the number of eggs laid on consecutive days

**colostrum:** the special milk produced in the first few days after calving, containing essential immune-fighting antibodies that protect the calf until they can produce their own

**compaction:** the process by which the pressure on soil causes the material to stick together and pore spaces to be squeezed together

**copepods:** small or microscopic aquatic crustacean found in both fresh and salt water

**cotton:** a soft white fibrous substance that surrounds the seeds of the cotton plant

**cotton gin:** a machine that quickly and easily separates cotton fibres from their seeds

**crossbreed:** the product of crossing two different breeds

**cultivar:** a plant variety that has been specifically developed for a market

**cultivate:** to work the soil and prepare it for planting

**decomposer:** an organism, especially a soil bacterium, fungus, or invertebrate, that decomposes organic material

**decomposition:** the state or process of rotting; decay

**degradation:** the physical and chemical decline in soils

**dew point:** the atmospheric temperature below which water droplets begin to condense and dew can form

**dicotyledon:** plants that, among other traits, have a pair of special leaves called cotyledons that emerge from the seed. These cotyledons contain a food source for the newly emerged seedling.

**disease:** any condition that produces a change in the normal functioning of an organism

**domestic:** existing or occurring inside a particular country; not foreign or international

**domestic market:** the goods grown and sold within a country

**domestication:** the process of selecting and changing organisms to best suit the needs of humans and bring them under human control

**drought:** a prolonged period of abnormally low rainfall, leading to a shortage of water

**dry:** not pregnant or lactating

**dry matter:** the material remaining as food after water is removed; the required nutrients are contained in the dry matter

**dual-purpose:** sheep used for two different purposes, such as meat and wool production

**ecosystem:** an area containing interacting living things and their non-living environment

**effluent:** liquid waste or sewage discharged into a river or the sea

**eluviated horizon:** the dissolved or suspended material within the soil that has been transported to this layer by the flow of water

**emitters:** small holes that discharge water from pipes

**erosion:** the wearing away of material and the movement of weathered material by various agents such as wind, water and gravity

**erucic acid:** a monosaturated omega-9 fatty acid considered toxic to humans and livestock in high concentrations

**eutrophication:** when there is an excessive amount of nutrients in a body of water, it can result in extreme algal growth, called an algal bloom

**evaporation:** the process of turning from liquid into vapour

**export:** goods or services sent to another country for sale

**extensive enterprises:** usually involve less inputs and labour for a given area

**extensive farming:** aquaculture systems with low stocking rates where fish and other aquatic animals feed on organisms that naturally live in their environment and there are low levels of environmental control

**extensive industry:** growing animals or plants over large areas of land, and aquaculture with low stocking rates

**fallow:** land that has been cultivated but left unseeded for a period of time between growing seasons

**fertilisation:** the fusion of male and female sex cells to produce an embryo

**fibrous roots:** multiple roots that come off the base of the stem of a monocot plant seed and branch out in all directions

**finishing:** a period before slaughter when animals are fed high energy and/or protein feeds to improve weight gain and carcass quality

**flukicide:** an insecticide used to kill or reduce the numbers of flukes

**freshwater:** of or found in freshwater; not of the sea

**fungi:** organisms including rots, mildews and moulds that lack chlorophyll and possess threads (hyphae)

**gene marker:** a mapped segment of DNA which is associated with a gene for a particular trait or characteristic

**germination:** the sprouting of a seed to produce a seedling

**gills:** paper-thin, leaflike structures found below the mushroom cap, containing basidia and releasing spores

**glucosinolate:** compound found in canola and other plants in the *Brassica* family associated with the hot and bitter taste in mustard

**gradient:** incline or slope of the land

**greasy wool:** wool shorn straight from the sheep

**greenhouse effect:** the warming effect of the Earth due to greenhouse gases in the atmosphere and solar radiation

**groundwater:** water located underground or in rocks

**hatcheries:** places that produce fingerlings for sale to the public and for stocking public waters

**herbaceous:** plants with little or no woody tissue, usually grown in one season

**herbicide resistance:** the ability of a plant to withstand application of a particular herbicide

**homogenised:** the process of breaking up the fat particles in milk so the milk does not separate

**humidity:** the amount of water vapour in the atmosphere

**humus:** a stable product in soil formed through the breakdown of organic matter

**hybrid:** an organism bred from crossing two different varieties, breeds or species

**hybrid vigour:** the improved performance of a crossbred species compared to the average performance of its parents

**hydroponics:** the process of growing plants without soil, most commonly in water

**hyphae:** the branching filaments or threads of a fungus that usually live on or below ground

**imports:** products brought into one country from another country

**in vitro:** outside a living body; for example, in a test tube or laboratory

**insemination** the placement of semen into female reproductive system to achieve pregnancy

**incubate:** maintain at a favourable temperature and in other conditions to promote development and hatch

**incubator:** a device used to optimise conditions for hatching fertile eggs

**inflorescence:** a flower head that consists of individual flowers arranged in cluster

**inoculant:** a substance introduced to an organism, often to increase its immunity or improve its function, such as a vaccine

**inorganic particles:** unrelated to organic matter or organic life, not animal, vegetable, or a chemical compound that contains carbon

**input:** anything brought onto the farm to be used in an enterprise

**insect:** a particular type of arthropod, with a body composed of three body parts, three pairs of legs and a pair of antennae

**intellectual property:** relates to creations and knowledge, including the thoughts and ideas behind inventions and ways of doing things

**intensive animal farming:** systems that usually involve a high stocking density of animals on small areas of land

**intensive farming:** the use of a controlled environment to produce large amounts of product in a smaller area than extensive farming

**invertebrate:** an organism without a backbone

**irrigation:** applying water to the land for growing plants and crops

**joining:** the process of placing the males (rams) in with the females (ewes)

**lactose intolerant:** an inability to process lactose, the key carbohydrate found in dairy

**leaching:** loss or draining away of substances, usually in water

**lint:** the raw fibre from the cotton plant that is pressed into bales at the cotton gin

**linters:** short cotton fibres that stick to seeds after a first ginning

**litter:** poultry bedding material, often composed of sawdust, rice hulls or straw

**lodging:** when crops bend lower in the stem, causing the plant to fall to the ground

**macronutrients:** chemical element (e.g. potassium, magnesium, calcium) required in large amounts for plant growth

**marbling:** the amount of intramuscular fat (fat within the muscle belly)

**microbial fermentation:** the breakdown of feedstuffs by microbes, in the absence of oxygen

**microclimate:** the climate in a very small area, which can vary greatly from the overall climate of a larger area

**micron:** the measurement used to describe the fibre diameter of wool

**micronutrients:** chemical elements or substances required in trace amounts for the normal growth and development of plants

**microorganisms:** the simplest form of living being and are so small they can only be seen with the aid of a microscope; including bacteria, fungi, protozoa, algae and viruses

**mollusc:** invertebrate of a large phylum, including snails, slugs, mussels, and octopuses. They have a soft unsegmented body and live in aquatic or damp habitats, and most kinds have an external calcareous shell.

**monocotyledon:** plants that have only one seed leaf and whose seeds contain endosperm to provide nutrients for the seedling

**monocular:** vision or sight using one eye or lens

**monoculture:** a crop or planting consisting of a single species or variety

**moult:** the loss and replacement of a chicken's feathers, usually associated with shortening of day length; egg production ceases until moulting has finished

**mushroom spawn:** mycelium grown on sterile grain, which will be broken up and used to produce mushrooms

**mutton:** meat from sheep which are over 12 months old and have incisors in wear (it takes about a month for them to show wear)

**mycelium:** the network of hyphae that together make up the body of a fungus

**mycologist:** a scientist who studies fungi

**mycorrhizal fungi:** fungi that live in symbiosis with plants, attaching themselves to roots

**mycotoxin:** toxic substances produced by fungi

**necrosis:** death of plant cells, leaves can turn black

**nematode:** elongated, cylindrical worms also called roundworms

**net importer** a country that imports more than they export of a product

**nomadic:** the tendency to wander from place to place

**oestrus:** another term for heat; when a sheep can get pregnant

**oocysts:** small capsules containing the reproductive cells of protozoal organisms

**organic matter:** the matter that has come from living organisms

**ornamental fish:** usually attractive, colourful fish of various characteristics, kept as pets in confined space such as an aquarium or garden pond

**output:** anything produced by the farm

**palatable:** tasty – palatable foods are readily eaten

**parent material:** the rock that lies beneath the subsoil that weathers to form soil

**pasteurised:** treated with heat to destroy bacteria

**pathogen:** a bacterium, virus or other microorganism that can cause disease

**ped:** the unit of soil structure

**penicillin** an antibiotic, or medicine, used to treat bacterial infections, made from *penicillium* mould

**perennial:** a plant that lives for more than two years without needing to be re-sown

**perishable:** likely to go bad or decay quickly

**peri-urban:** areas that are the dynamic interface between cities and rural areas

**permeability:** the ability of a substance to allow another substance to pass through it

**pH:** a figure expressing the acidity or alkalinity of a solution

**phloem:** transports sugars around the plant

**plant spacing:** the space between the growing plants

**platyhelminth:** flatworms that are unsegmented, soft-bodied invertebrates

**poll:** an animal born naturally with no horns

**pore:** the space between soil particles, usually containing air or water

**power take-off (PTO):** a device that supplies power to operate a tractor implement

**precipitation:** rain, snow, sleet, or hail that falls to or condenses on the ground

**process:** actions or activities that convert inputs into outputs

**protozoa:** single-celled organisms with many animal-like features but are not considered animals

**purebreed:** an animal with parents of the same breed

**purged:** emptying of the stomach and digestive tract

**range:** a measure of spread of data, indicating the difference between highest and lowest values

**refuge:** safe or sheltered area

**relative humidity:** the amount of water vapour present in air, expressed as a percentage of the amount needed for saturation at the same temperature

**return on investment:** the income received after paying for something

**rhizobia:** nitrogen-fixing bacteria living in symbiosis with legumes

**rotifers:** any microscopic animal of the phylum rotifera, found in fresh and salt waters

**row spacing:** the space between the rows

**ruminant:** an animal with four stomachs

**Safe Operating Procedure (SOP):** a document that provides step-by-step instructions on how to safely complete an activity

**salinity:** the accumulation of salt in soil or water

**salmonid:** a fish of the salmon family

**selective breeding:** a system where plants or animals with desirable traits are chosen to produce offspring with these characteristics resulting in new breeds or varieties over time

**semi-intensive:** aquaculture with medium stocking rates where farmers provide some feed for the animals and there are some artificial controls on the environment for the aquatic species

**shattering:** when wheat seeds are easily detached and fall out of the wheat head

**shearing/shorn:** the process of removing the wool from the sheep

**shot and sprung:** when grain seeds germinate within the wheat head

**sodic soils:** contain a high level of sodium ions that cause the soil to lose its structure and rapidly disperse in water; structurally unstable; limit the movement of air and water through the soil

**soil acidification:** a process whereby the soil pH decreases and becomes increasingly acidic

**soil horizon:** the layers parallel to the soil surface, whose physical characteristics differ from the layers above and beneath

**soil profile:** a vertical section through a soil from the surface to the underlying parent material

**soil structure:** the arrangement of soil particles in a soil

**soil texture:** the proportions of sand, silt and clay in a soil

**solar radiation:** the many forms of electromagnetic radiation, including light and heat energy that come from the sun

**spawn:** the release or deposit of eggs

**spores:** fungal reproductive cells released from the gills

**squares:** developing cotton fruit

**squatter:** farmer who occupies land without legal ownership

**standard deviation:** a measure of spread of data

**staple:** a cluster of wool fibres

**stocking density:** the number of animals in a given area; for example, per m<sup>2</sup>, per hectare, per km<sup>2</sup>

**stocking rate:** the average area available to each animal in a production system usually expressed as the number of animals per hectare

**substrates:** the materials in which mycelium is cultivated. They include composts, straw and various waste products, and are formulated to meet the needs of each mushroom species.

**swarming:** when a queen and worker bees leave an overcrowded hive to find a new home

**symbiosis:** a relationship between two organisms where at least one benefits

**taproot:** a main root that descends from the base of the stem on a dicot plant seed as a primary root and produces numerous branches. Taproots often store sugars and starches.

**target weight:** the live weight an animal needs to reach to be sold to a particular market

**temperature:** the degree or intensity of heat present in a substance or object

**terminal sire:** used over different breeds of crossbred ewes with the aim to improve carcass traits

**terrestrial:** growing on land or in the soil; not aquatic

**textiles:** a type of cloth or woven fabric

**three-point linkage:** a method of securely attaching a tractor implement via three points of contact

**tick-worry:** a general state of unhappiness and distress in cattle due to tick infestation

**tillage:** the turning over and preparation of soil for planting crops

**topography:** the shape, slope and contour of the Earth's surface

**trash fish:** fish that have little or no market value as human food but are used sometimes in the production of fish meal

**trellising:** supporting growing plants with stakes or wires to grow up

**vaccine:** a substance prepared from the disease-causing agent or a synthetic substitute; used to provide immunity against one or several diseases

**variety:** plants that have different genetics but are still the same species

**vegetative state:** the growth stage of a plant that occurs after germination but before flowering, when the plant produces most of its leaves

**vernalisation temperature:** a period of cold days required for a plant to initiate flowering

**vertebrate:** an animal possessing a spine or vertebral column

**viruses:** parasitic, non-cellular organisms

**waterlogging:** a condition where the soil is saturated with water, depriving plant roots of oxygen

**weather:** the daily changes in the atmosphere in precipitation, temperature, wind, pressure, cloud cover and other factors

**weathering:** the breakdown of rock to form the mineral fraction of soil

**windbreaks:** natural or artificial barriers used to reduce and redirect wind

**windrow:** a long line of material raked by hand, machinery or the wind

**withholding period:** the minimum period of time from when a chemical was applied to when an area can be accessed, or a plant or animal can be processed and/or consumed

**xylem:** transports water and mineral nutrients around the plant



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