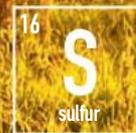
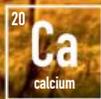


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CENGAGE Learning

DYNAMIC AGRICULTURE

YEARS 7–10 4TH EDITION

LISLE BROWN
ROBERT HINDMARSH
ROSS MCGREGOR





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DYNAMIC AGRICULTURE YEARS 7–10 4TH EDITION

LISLE BROWN
ROBERT HINDMARSH
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Introduction

This appealing new edition of *Dynamic Agriculture* addresses effectively the entire revised NSW Years 7–10 Agriculture Technology syllabus.

As with previous editions of *Dynamic Agriculture*, this new text has been written with the understanding that students' enjoyment of agriculture is enhanced by hands-on experience. The book is packed with a broad range of practical skills, activities and questions to cater for a range of abilities. Margin questions throughout the text enable students to review the content. Agricultural terms and key words are highlighted at the beginning of each chapter and throughout the text. They also appear in an end-of-book glossary so students can search for terms alphabetically. The chapter review sections contain extension, research and assessment material including information and communication technology (ICT) activities. Questions and activities within this section are classified according to the cognitive demand on the student (according to Bloom's revised taxonomy).

A suite of resources for each chapter is provided on the accompanying NelsonNet teacher website. The worksheets provide students with revision, consolidation, practical and skill-based activities for a range of abilities. The videos enable students to review processes on the farm and provide a valuable discussion tool within the classroom. Please note that complimentary access to NelsonNet is only available to teachers who use the accompanying student book as a core educational resource in their classroom. Contact your sales representative for information about access codes and conditions.

This lively, accessible book draws junior agriculture students into the subject and enables them to develop knowledge, understanding and skills to participate in the dynamic world of modern agriculture.



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About the authors

Lisle Brown

Lisle Brown has 36 years of agricultural teaching experience including 29 as Head Teacher of Agriculture at the selective James Ruse Agricultural High School. Lisle has extensive experience in syllabus development as an active member of junior and senior agriculture syllabus committees and in the setting and marking of the Higher School Certificate (HSC) examination.

Lisle's teaching career was recognised by the NSW Association of Agriculture Teachers (NSWAAT) with the 2008 J.A. Sutherland Award for significant contribution to the teaching of agriculture in NSW.

Robert Hindmarsh

Bob Hindmarsh has had a 33-year teaching career in more than 15 schools, ranging from selective agricultural high schools to comprehensive schools. In this time he introduced agriculture into the curriculum of two schools and worked from scratch to establish viable farms in both schools. He has been Head Teacher of Agriculture at a large selective agricultural high school and a developing comprehensive high school as well as a deputy principal and principal in comprehensive schools.

He has published several books on agriculture and been an active member of both the junior and senior agriculture syllabus committees. He has been part of the examination committees for the HSC and School Certificate-level for Agriculture as well as an established marker for the HSC exam.

As a past president of NSWAAT, he has provided support to a range of teachers in various locations across the state as well as being part of an effective team of dedicated agriculture teachers.

Ross McGregor

Ross McGregor has had over 35 years of agricultural teaching experience, including the last five years as Head Teacher of Agriculture at Hurlstone Agricultural High School. Ross has extensive experience in teaching, HSC exam setting, HSC marking and syllabus development. He has a keen interest in cattle showing.



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How to use this book

The **words to know** list at the beginning of each chapter presents the student with a glossary of bolded new terms introduced within the chapter. These terms also appear in an alphabetical glossary at the end of the book.

CHAPTER 4
AGRICULTURE IN THE AUSTRALIAN ECONOMY

Words to know

consumers people who buy and use a product to satisfy their needs or wants (e.g. people buying fruit and vegetables to eat)

domestic market for sale within Australia

manufacturing industries those that produce manufactured goods (e.g. cars, machinery, clothes)

mining industries those involved in extracting valuable ores and minerals from the ground and then selling them (e.g. gold, coal, bauxite, iron)

service industries those that provide services to people (e.g. banks lend money, stock and station agents assist with buying and selling animals)

tariff a tax imposed on imported or exported goods to affect trade

technology the practical application of knowledge such as the use of machinery, computers and/or techniques for undertaking agricultural practices (e.g. the machinery and the method used to grow a wheat crop)

value adding further processing of a product so that it can be sold for a higher price

Margin question sets contain comprehension-style questions to enable students to revise what they have read and learnt. Each question set is placed directly adjacent to the relevant text.

- 8 Explain how the agricultural sector of the economy is a consumer.

Connect boxes enable students to find out extra information beyond their textbook. Connect boxes are to relevant websites, such as the National Farmers' Federation, NSW Department of Primary Industries and CSIRO. The URL for each connect is available on the teacher website.

connect

National Farmers' Federation

The voice of Australian farmers

The **end-of-chapter review** contains lots of different ideas for activities, research and extension. The shading on the question number

indicates the level of thinking required. Light shaded numbers indicate lower order thinking (Understanding) with shading increasing up to the highest order thinking (Evaluating and Creating).

Things to find out

- List as many different advertisements for poultry products (chicken, eggs, fast foods) as you can find in the media (television, newspapers, magazines, junk mail) over one week.
- Go to the **Dairy Australia** website.
 - What is the function of this organisation?
 - Why do they use a logo to promote milk products?
- There has been a steady increase in the percentage of pigs sold direct to processors, usually on consignment. On what basis is payment made?
- Evaluate the methods used to promote egg marketing in your state.
- How does MLA promote the increased use of red meats?
 - Critically evaluate if the promotion of red meat has been successful.
- 'Agriculture traditionally is a system that exploits the environment with little consideration to long-term consequences.' Critically evaluate this statement.
 - Visit the **AWB** website. What is the function of this organisation?
 - Under the menu item 'About AWB' read the overview of the industry and summarise it so that you can present an oral or written report to your class.

Things to do provide students with a range of interesting activities to undertake, which include tasks such as drawing, constructing, observing, experimenting and surveying.

Things to find out challenge students to research information for themselves by visiting farms or other establishments, websites and other sources of information.

Extension activities extend students beyond what is presented in the text.

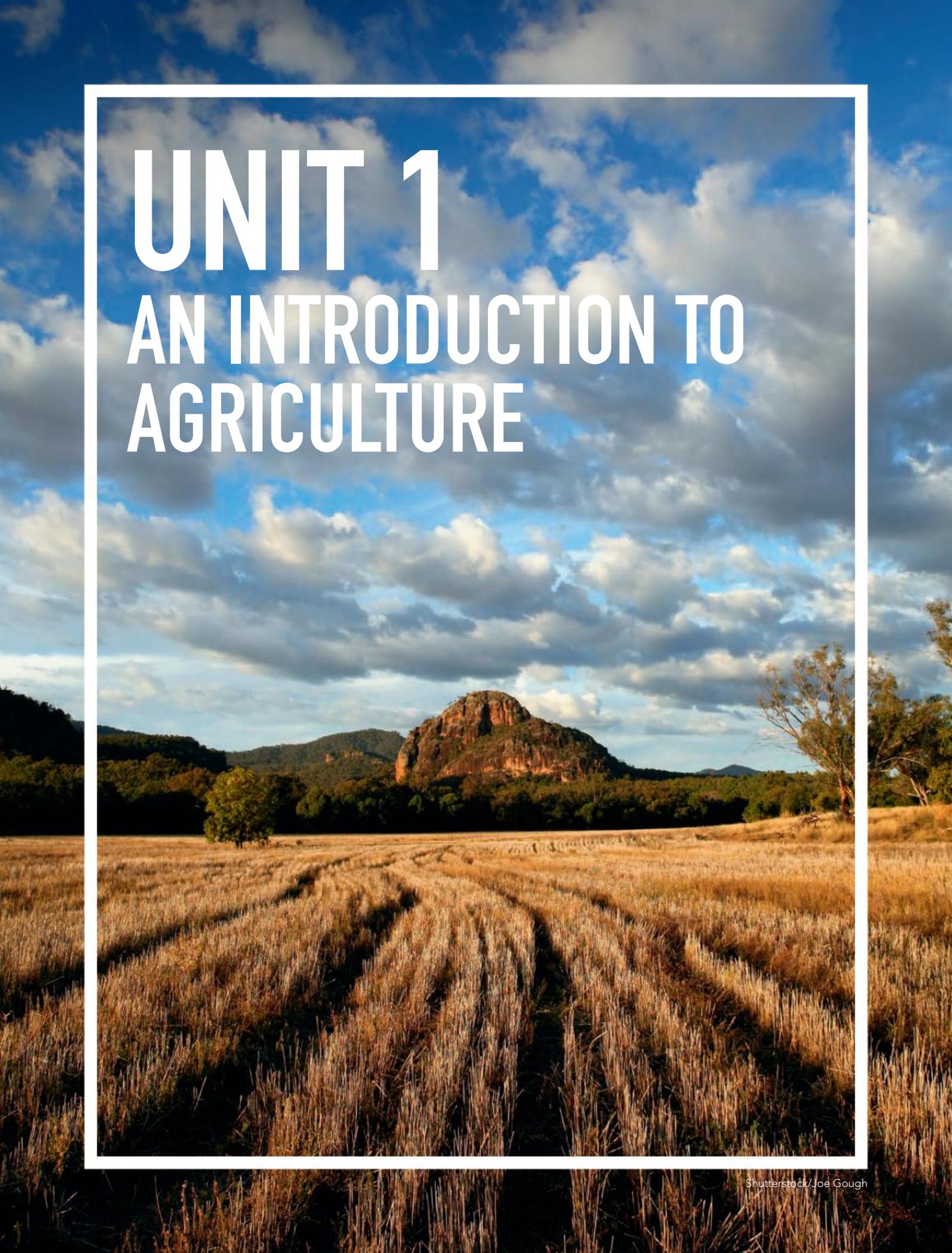
Test yourself sections provide students with helpful revision-style questions relevant to the material addressed in the chapter.

The **NelsonNet** teacher website provides extra material including worksheets and videos with footage of farms, farming and farm practices.

Pages that have videos associated with them are indicated with this blue icon in the footer: .

UNIT 1

AN INTRODUCTION TO AGRICULTURE



CHAPTER 1

THE BEGINNINGS OF MODERN AGRICULTURE

Words to know

agronomist a person who studies and experiments with various crop plants and pastures, assessing their growth, sustainability and economic potential in agriculture

animal husbandry the practices involved in raising and managing the welfare of farm animals

breed society an organisation that maintains a register of animals that breed true to type and outlines standards relating to appearance that must be met for that particular breed

buyer a person who purchases agricultural products or produce

crossbreeding using different breeds of similar genetic makeup to produce a hybrid

crossmating the result of cross mating animals of different breeds or species

dairy farmer a person who keeps cattle for milk and milk products

domestication the process of selection and breeding of wild plants and animals into cultivated and tamed species

dual purpose an animal that serves more than one purpose (e.g. meat and milk production)

farm manager a person who makes decisions related to the financial and practical operations of the farm

geneticist a person who studies how characteristics (genes) of plants and animals are inherited

grazier/pastoralist a farmer who raises livestock (e.g. sheep or cattle) that graze on pasture for the purpose of an income or hobby

horticulturalist a person who oversees operations involving the cultivation of plants for research or commercial use

inbreeding a method of breeding closely-related animals

livestock agent a person who buys and sells animals on behalf of other people

market gardener a person who grows fruit, vegetables and/or flowers for sale

orchardist a person who establishes, cultivates and manages fruit trees

pedigree a recorded outline of the parentage of an animal

poultry farmer a person who raises fowl for meat or eggs

soil scientist a person who studies the origin, management and use of soils

veterinarian (vet) a person who studies and treats the diseases and injuries of domestic animals

Introduction

Agriculture – raising crops and animals to provide food, fibre and other material – is a very old human activity. It includes growing fruit, vegetables and other types of plants for food and shelter, and raising animals such as cattle, sheep, pigs, chickens and goats for food, clothing and even transport. Agriculture also includes all the things we do with the products from the land. For example, fruit and vegetables are available as fresh products or can be frozen or tinned. Some of these products are shown in Figure 1.1.

How agriculture developed

Our ancestors were hunters and gatherers who moved from place to place in search of food. Between 9500 BCE and 8000 BCE, people had begun to settle in one place and form communities in some regions of the world. They began to cultivate plants and to tame and raise animals.

One very early area of agriculture was in south-western Asia, near the Tigris and Euphrates rivers – the location of modern-day Iraq. Another area was the Nile Valley in Egypt. In both these places evidence suggests that wheat was the most important crop. Early settlements in South America depended on the farming of maize (corn), while in Asia the common crop was rice (in China it was millet). In Egypt, evidence points to the early farming of sheep and goats, while the pig was very important to farmers in ancient China.

Domesticated animals

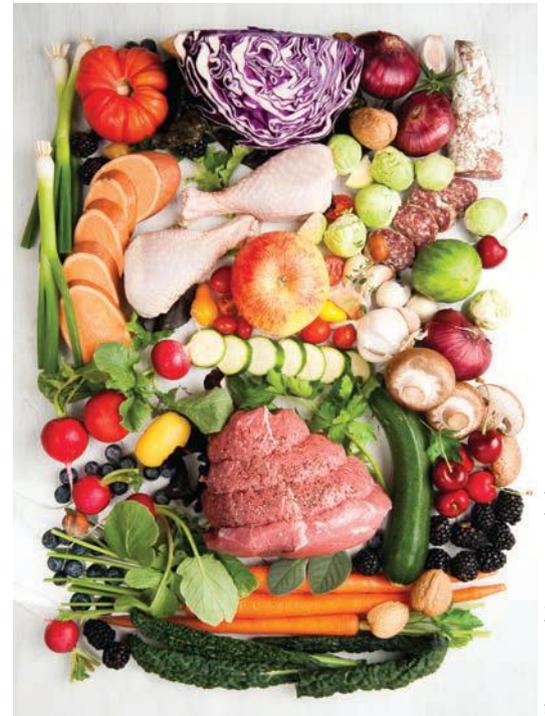
The **domestication** of animals – taming them for use on farms – occurred in different countries at different times, and in each of these countries various forms of **animal husbandry** developed. Not all animals were domesticated. People chose animals to domesticate for a number of reasons:

- they could supply products of value to the community
- they were easy to handle in captivity
- they were capable of growing and reproducing in captivity.

Today, farm animals are the source of many vital products for everyday life:

- food, such as meat, milk and eggs
- other raw materials, such as wool and hides
- cheap transport in many instances and a source of power for cultivation (e.g. water buffalo used to plough rice paddies)
- fertiliser, from animal waste, such as poultry manure
- energy, from burning the gas (methane) produced by rotting animal waste
- pest control, such as cats to discourage rodents
- controlling and guarding other animals, such as working sheep and cattle dogs, and alpacas that protect sheep from foxes.

Of course, domestic animals are used for pets and for recreational pursuits, such as showing, eventing and racing for horses, and rodeos for cattle and horses.



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Figure 1.1 Agricultural products



Figure 1.2 Ancient agriculture

- 1 Define 'domestication'.
- 2 List three reasons for the domestication of animals.

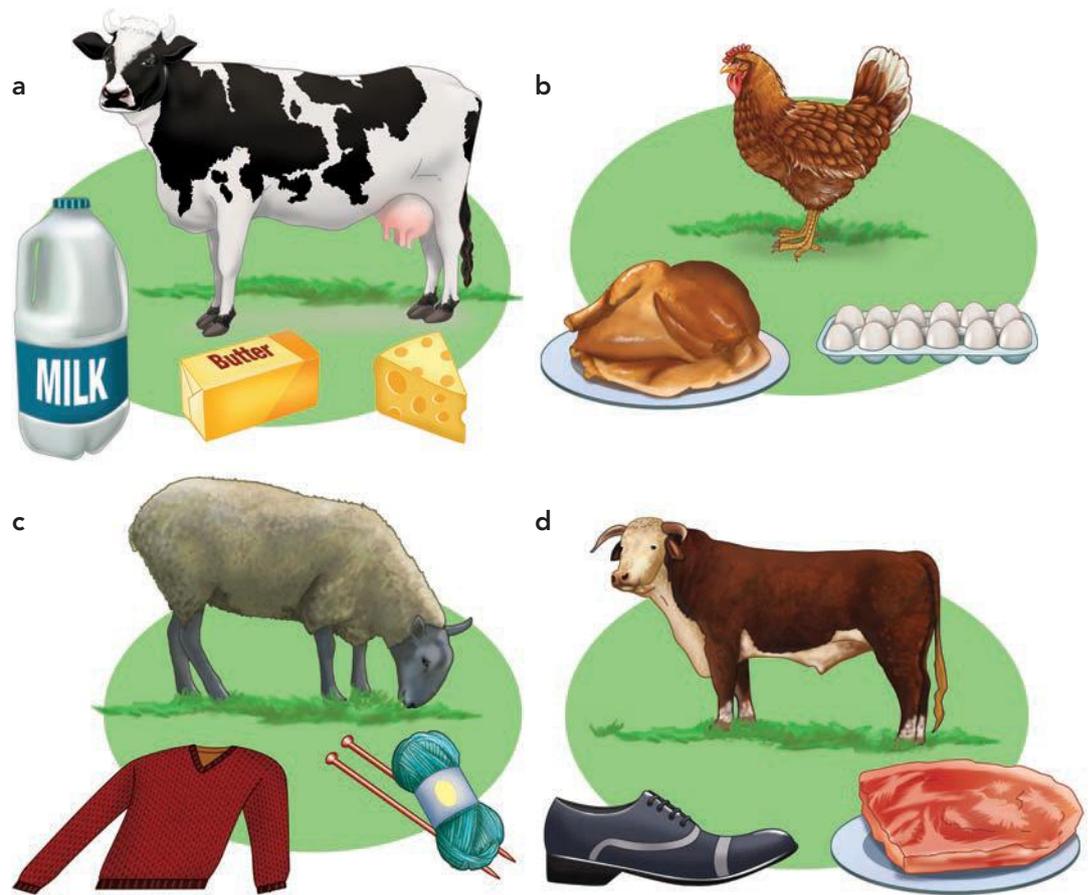


Figure 1.3 Animal products from **a** dairy cattle, **b** chickens, **c** sheep and **d** beef cattle



Figure 1.4 A Bezoar goat

Goats

Goats were one of the first animals to be domesticated – even before cattle. Domestic goats probably originated in western Asia from the Bezoar goat (*Capra aegagrus*, Fig. 1.4) and were raised to supply meat or milk, as well as to serve as beasts of burden. As goats were introduced into areas more fertile than their homelands, they developed rapidly and farmers selected for distinct meat or milking breeds. Today, more importance is attached to the production of fibres such as mohair and cashmere (Fig. 1.5).

Cattle

Cattle were one of the first animals to be domesticated. They were used as sources of meat and milk. In later times they were used as beasts of burden, helping to cultivate the land and to carry loads. Modern domesticated cattle are divided into two main groups: European cattle, whose scientific name is *Bos taurus* – for example, Angus and Charolais – and Indian cattle, whose scientific name is *Bos indicus* – for example, Brahman and Zebu. (It is important to know and use scientific names because the ordinary or common names for many animals can be different in different countries). The Auroch is the ancestor of both European and Indian breeds of



Figure 1.5 A Cashmere-type goat

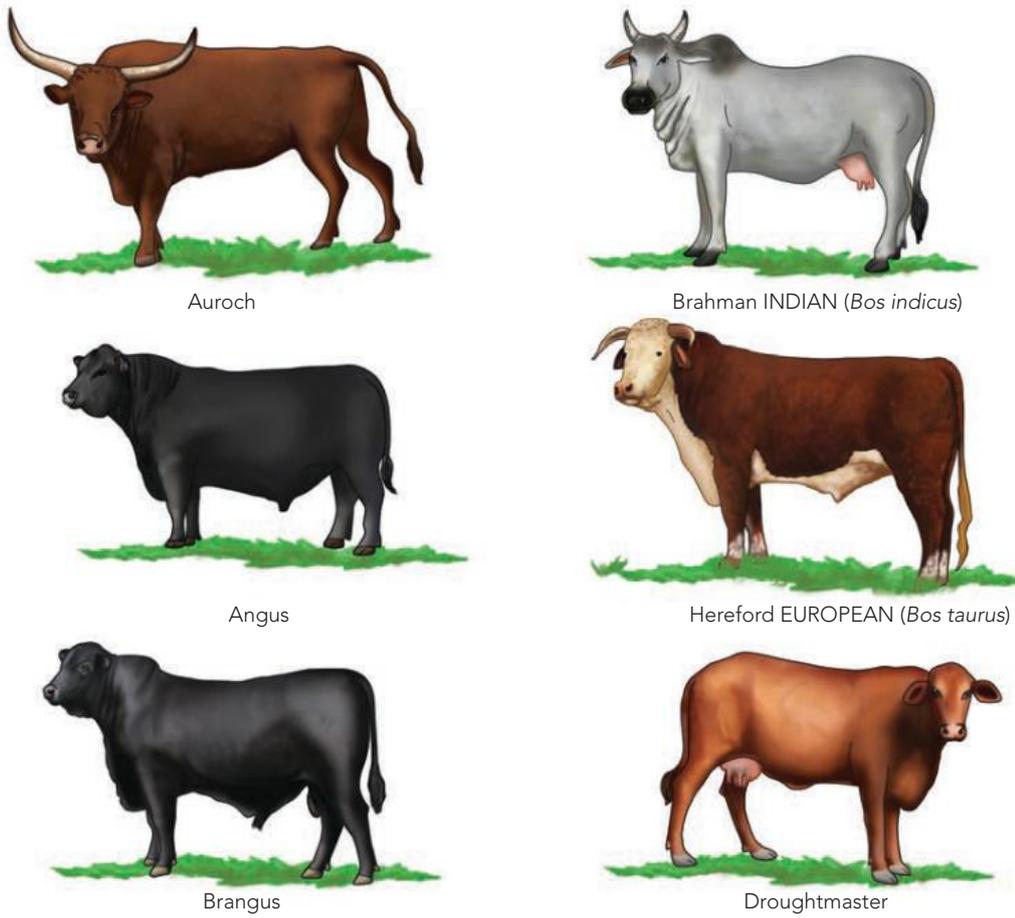


Figure 1.6 Cattle breeds. Hybrid breeds such as the Droughtmaster are obtained by crossing distinct cattle breeds.

cattle, as shown in Figure 1.6. There are also **hybrids** of these animals produced by **crossbreeding**. Figure 1.7 indicates the world distribution of these cattle types.

There were no cattle in Australia before the arrival of the First Fleet in 1788. Among the livestock carried with the fleet were seven cattle needed to provide the settlers' dairy products. By 1796, the colony had 229 cattle, most of them wild.

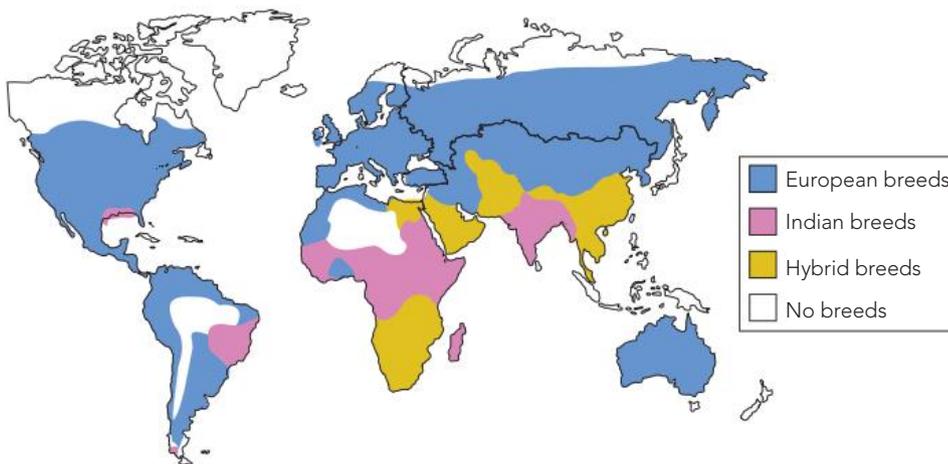


Figure 1.7 World cattle distribution

Sheep

Wild sheep were once found in the more mountainous regions of Asia and Europe. There were three kinds of wild sheep in the Old World: the Urial, the Moufflon (Fig. 1.8) and the Argali. Sheep were possibly domesticated around 10 500 BCE, when they competed with people for the cultivated crops of early farms. These sheep provided hides for the building of shelters, wool for warm clothing, meat and milk. Some of their features can be seen in more modern breeds.

There are now several hundred breeds but only a few breeds are of great importance to the world's sheep industry. The Merino probably originated in Asia Minor, and from there spread to North Africa and then to Spain. In Australia, the Merino was developed into a form adapted to the Australian environment and is by far the most important breed in this country.

The production of meat from sheep is a more recent development. Because of the many possible uses for sheep, several breeds have been developed to cater for the specialised needs of consumers, such as carpet wool and meat.

Pigs

Pigs were native to northern Europe and China, and were one of the later animals to be domesticated (around 7000 BCE) although archaeologists have found evidence that there was a loose farming association between humans and pigs dating to 11 000 BCE. Pigs are foragers and scavengers and probably became familiar with people through raiding community garbage dumps and village stockpiles of food.

The existing domestic breeds probably descended from three sources: the European wild pig (*Sus scrofa*), forms of the Asiatic wild pig of India, and breeds from Indonesia. Pigs eat both plant material and meat and have always been regarded as efficient converters of food to meat.

Poultry

The modern breeds of poultry have descended from the Red Junglefowl (*Gallus gallus*) (Fig. 1.9), a breed still found in India. Evidence suggests that this animal was first domesticated around 5400 BCE.

The ancient Egyptians, Greeks, Chinese and Romans commonly kept hens. The original hens were producers of both meat and eggs – they were **dual purpose** animals. They were also used for the sport of cock fighting, which is no longer acceptable in Australia and many other countries, but its practice led to the spread of this animal across the world. Continual breeding has led to a separation of the features relating to the production of meat and eggs. We now have a lighter-weight egg producer, and a heavier bird for meat production.



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Figure 1.8 The Moufflon, a primitive sheep breed



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Figure 1.9 A male Red Junglefowl (*Gallus gallus*)

The development of animal breeds

Breeds as we know them today were not always in existence. They arose because of economic need or demand for a certain type of product, or as the result of a long-term system of breeding.

Robert Bakewell (1725–1795), an Englishman, realised he could increase the size and production levels of most farm animals by using a particular method of animal breeding. His success was largely due to two factors:

- he had a definite aim in mind and bred for this consistently
- he selected the most suitable animal to breed, regardless of the relationship between the animals. This meant that closely related animals such as brothers and sisters were often bred. This method of breeding is termed **inbreeding**.

Bakewell improved the quality of the Shire horse, Longhorn cattle (Fig. 1.10), the Berkshire pig (Fig. 1.11) and Leicester sheep.

His work also inspired others of the time, such as Benjamin Tompkins and John Galliers, who developed the Hereford breed of cattle.

As the number of animal breeds began to increase, there was a need to develop a set of breed standards. In this way **buyers** could be assured that animals were purebred and had an acceptable appearance recognised by fellow breeders. This led to the formation of various **breed societies**. Each society has certain standards of excellence for their breeds and these standards are published in the form of score cards. Animals that meet the required standards are recorded into the society's *herd* or *stud book*. The standards required vary from breed to breed. With pigs and cattle, the animal's dam (mother) and sire (father) should already be registered; with sheep, nine generations of ancestors have to have been entered into the stud book before an animal can be listed.

In this manner the animal is registered along with its **pedigree** or breeding line. This also shows that the animal is purebred. Breed societies maintain the quality of the breed concerned and allow progressive qualification of animals up to purebred status. The societies also promote the welfare of the breed by sponsoring shows and providing information and general advertisements for the breed.

Cultivated crops

Crop plants would have originated from simple wild forms of local herbs and grasses. For example, millets have a long history of cultivation in China and common plants, such as the radish, were cultivated by the Egyptians in the time of the pharaohs. But many of the plants that form the basis of modern pastures and forage crops in developed countries originated elsewhere. For example, maize originated in what is now Mexico, and spread north and south along trade routes. By the time the Spanish reached South America, maize was the staple food of the Inca empire, centred on what is now Peru. Paspalum comes from South America, while kikuyu is a native of the uplands of eastern Africa. The ryegrasses are essentially natives of the temperate areas of Europe and Asia. This pattern repeats itself for vegetables. Spinach originated in Asia and was introduced into Europe by Arab traders in the 13th century; cauliflowers probably originated in the Mediterranean area. These plants would have been cultivated and undergone various forms of

- 3 Explain the reason for the domestication of goats, sheep, poultry, pigs and cattle.
- 4 Explain why the poultry industry has become so intensive.
- 5 Outline the work of Robert Bakewell.
- 6 On what basis did he develop his breeding method?
- 7 What is the function of a breed society?
- 8 What is required before an animal is registered in a stud or herd book?



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Figure 1.10 A Longhorn steer



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Figure 1.11 A Berkshire pig



Figure 1.12 The origin of some of the world’s plants

breeding over thousands of years of agriculture to produce the plant varieties that we are familiar with today. Figure 1.12 indicates the origin of some common plants.

Australia and countries in North America and Europe are more than 80 per cent dependent upon food-producing crops that originated outside their region.

These developed countries export produce, but seek the genetic material to improve or develop new varieties, breeds or cultivars from the original sources in developing countries. The world’s poorest nations, as a group, account for 96 per cent of the world’s genetic resources.

Crops as exports

Grain, mainly wheat, was a major export from early Egyptian civilisations. Later Egyptian farmers exported wheat to the Greek and Roman empires which in turn supplied grapes, figs and olives from organised farms to the rest of the Mediterranean world. Agriculture gradually spread to England and, under the influence of the Romans, large-scale farms were established there.

As civilisations exchanged agricultural products some emerged as excellent trading goods. When the North African Moors ruled Spain, from around 700 CE to 1492 CE, they introduced sugarcane and other subtropical products. The Americas supplied corn, tomatoes, tobacco and potatoes to the European market, while several countries fought to control the spice markets in the East Indies.

Why is agriculture important?

Agriculture is important to many countries, including Australia, for three main reasons.

- 1 Plant and animal products are necessary to meet the needs of society in terms of food, fibre and shelter materials.
- 2 Many people in different businesses depend upon farmers to support them. Farmers order materials and equipment from suppliers and gain advice from a variety of industry bodies. Many businesses also sell agricultural products. Stock and station agents and supermarkets sell farm produce to the non-agricultural sector of the community.
- 3 Agriculture may provide a significant part of the country's national income. Agriculture provides jobs for many people – the people who live on the land (such as **market gardeners, poultry farmers, dairy farmers, graziers** or **pastoralists, farm managers** and **orchardists**) as well as those who do something with the products that come from the land. Scientists and many professional people help farmers produce products – such people include **agronomists, horticulturalists, veterinarians** and **geneticists**. Many other people have jobs helping to harvest, process or sell products from the farm. These include the shearer who removes wool from the sheep, the buyer, the **livestock agent** who buys and sells livestock on behalf of other people, the butcher who sells meat from the carcass, the juice-bar owner who makes drinks from fresh fruit and dairy products, the greengrocer who sells plant products (fruit and vegetables), and the cheese maker and the baker who sell processed goods.

Agriculture has achieved increasing levels of productivity. Over hundreds of years, the farm labour provided by people has increasingly been replaced by the more effective use of artificial fertilisers, pesticide use, increased selective breeding of plants and animals and increased levels of automation and technology.

In recent times a number of issues have arisen:

- the role of farm subsidies, government policy and international trade barriers
- the use of genetically modified products to increase productivity
- the importance of animal welfare
- the maintenance of effective agricultural pest and disease control programs to guard against infectious diseases
- the use of farming land for purposes other than farming or grazing, such as mining or housing development, which reduces the amount of land for agricultural production
- the impact of climate change and the generation of greenhouse gases
- the effects of water pollution including ground water pollution
- growing crops for biofuels, thus reducing the amount of crops grown for food and increasing the chances of shortages of food
- the loss of soil productivity due to erosion, increased levels of acidity and salinity.

Many of these issues have arisen from environmental concerns such as the effect of human activities on the environment, mining and its effect on agricultural production systems, urbanisation pressures, increasing consumer awareness around animal welfare in agricultural production systems and consumer-driven demand for organically developed produce. Community desire for the development of sustainable agricultural practices is also strengthening.

connect

Management of the land by Aboriginal communities

Read the article and watch the video track, listen to the audio and answer the questions.

- 9 In your notebook, draw a table listing the following products and where they originated: tobacco, potato, corn, grapes, wheat and sugarcane.
- 10 List three jobs performed by people to assist farmers to make farms more productive.
- 11 Identify three issues of importance to agricultural production systems today.

Chapter review

Things to do

- 1 Create a table to divide the following group of people into those who have jobs on a farm and those who have jobs off the farm:
grazier, carpet retailer, shearer, veterinarian, florist, farmer, weaver, agronomist, fruit picker, baker, animal transport driver, auctioneer, stockman, juice-bar worker, orchardist, **soil scientist**, food technician, hay baler, mechanic, leather goods retailer, accountant, fencer, consultant
Write the headings 'People on the farm' and 'People outside the farm' in your notebook and list the jobs under the appropriate heading.
- 2 Using a suitable website or search engine to obtain information, construct a timeline showing major developments that have had an impact on agriculture over the last 2000 years.
- 3 Divide the class into groups. Each group is to grow a plant from seed. Use plants such as maize, lettuce, barley, sunflower or radish. Each week record what the plant looks like. Show the changes over time until the plant matures by drawing diagrams or taking photographs with a digital camera.

Things to find out

- 1 Visit your library or use a search engine online and write a short assignment on one of the following topics.
 - a Describe how the plough developed from ancient times.
 - b Identify several breeds of cattle and name their country of origin.
- 2 Choose one farming activity now performed by tractor and describe how this activity was performed before the tractor was invented.
- 3 Write a short essay on what you think will happen in regard to animal breeding and the type of animal that may become domesticated.
- 4 Listen to the discussion on climate change and its effects at the [Climate change and agriculture](#) website. Summarise the key points.

connect

Climate change and agriculture

Extension activity

- 1 Choose an ancient civilisation that you have studied in History (Egyptian, Greek, Roman, Aztec, Mayan, Chinese, Indian) and write a half-page description of the agriculture that civilisation developed. Use a search engine, such as Google, and search for 'history of agriculture'.
- 2 Explain why many businesses in country towns depend on the farming community for their economic survival.
- 3 Analyse the impact of either environmental or economic pressures on farming practices in your local area.
- 4 Research the origins of one of these breeds: Murray Grey or Illawarra cattle, Polwarth sheep, Australorp chickens, Australian cashmere goats or Kelpie dogs. Create an A3 poster, with images, on how and why your chosen breed developed.

- 5 Imagine you are an Australian animal farmer and you wish to develop a new breed of any animal of your choice. What characteristics do you want in your new breed? What current animal characteristics do you want to do without? What current breeds will you use to try to create your new breed and why?

✓ Test yourself

- 1 Write answers to the following.
- Define 'agriculture'.
 - Outline how agriculture started.
 - Summarise the two broad categories of people who work in agriculture.
- 2 Discuss five issues that are having an impact on agricultural production systems in Australia.
- 3 Use a search engine or visit the [Breeds of livestock](#) website. Identify the origins of one of the following breeds of modern-day animal: sheep, cattle, poultry or pigs, and then answer the following questions.
- Why was this animal bred for use on a farm?
 - What breeds arose during the domestication of this animal?
- 4 Identify four crops that have originated from the Americas and evaluate the importance of these crops to Australian agriculture.
- 5 Analyse why agriculture is important in Australia.

connect

Breeds of livestock

CHAPTER 2

THE HISTORY OF AUSTRALIAN AGRICULTURE

Names to know

William Farrer (1845–1906), developed a rust-resistant variety of wheat that could be planted in many areas of New South Wales

William Lowrie, Professor (1857–1933), Director of Agriculture in South Australia and principal of Roseworthy Agricultural College in 1887; his research indicated the need for superphosphate to be added to Australia's soils

John and Elizabeth Macarthur (1767–1834) and (1766–1850), founders of Australia's wool industry

Samuel McCaughey (1835–1919), introduced the 'wrinkly-skinned concept' into Australian Merino sheep breeding

HV McKay (1865–1926), improved on the design of the stripper developed by Ridley so that it completed the threshing, winnowing, sieving and bagging as the machine went along. By 1934 the McKay family firm had developed the Sunshine Harvester.

George and Frederick Peppin Englishmen who settled in the Riverina area in the 1850s and developed a large-framed Merino suitable for the western plains of New South Wales

John Ridley (1806–1887), designed and built the stripper for harvesting wheat; it removed the grain in one operation, by means of sharpened prongs, then threshed and winnowed the grain

James Ruse (1760–1837), Australia's first farmer to produce enough food for his family and have some left to sell

Maria 'Granny' Smith (1799–1870), an orchardist who first recognised and cultivated an edible green apple that was named after her

RB and CH Smith invented the stump-jump plough in 1876

Headlie Taylor (1883–1957), held the patent for the Header Harvester concept and joined the McKay family firm to develop the machine that evolved into the Sunshine Harvester

Introduction

Australian agriculture has developed in several major stages marked by periods when certain forms of agriculture have been popular. Each stage grew from the discoveries and developments of an earlier stage. Today these stages are easily recognised, forming the historical basis of the dynamic contemporary Australian agricultural scene.

When the first white settlers arrived from England 200 years ago, the countryside was very different from what they were used to. The land was covered by eucalypt trees and other native plants and was the habitat of animals such as the kangaroo and wallaby, never before seen by Europeans. The Aboriginal occupants had arrived in Australia thousands of years before the white settlers and had formed many tribal groups throughout Australia. They had developed skills in gathering food from native plants and in hunting the native animals to provide their food, shelter materials and medicinal needs. By moving location according to seasonal availability they maintained a varied and abundant food supply. In grassland areas they burnt off the grasses and shrubs to encourage new and vigorous growth and ensure a supply of animals for meat. They found many sources of protein – kangaroos, possums, fish, lizards, snakes, birds and shellfish – and they obtained starch from fern roots. The early colonists looked to known European sources of food and so they experienced problems such as scurvy, unknown to the Aborigines, who used native currants and sea lettuce to prevent such complaints.

Settlement by the white colonists brought a critical change in land development in Australia. Agriculture has continued to develop over the centuries. There have been some significant changes in the last 10–15 years:

- consumer demand for organically produced goods and a heightened awareness of animal welfare practices
- government policies, such as regulations about live animal exports
- technological advances and innovation, such as GPS systems in tractors and farm machinery
- environmental constraints related to climate change
- international trade agreements and marketing systems.

Today there are fewer farms; those that contribute most to agricultural production have become very large. Agriculture has become increasingly export oriented over the past two decades with a trend to exporting more processed products, such as wine and cheese, rather than the primary products, such as grapes and milk.

- 1 List the main areas of change in agriculture in recent years.

Stage I: The early farmers

The First Fleet brought a range of plants and animals that had been successfully domesticated in Europe but the voyage was long, and much of the livestock and food supply had been used up or lost during the journey. An unexpected result was that the plants and animals that did reach Australia were very healthy, free from many of the diseases that exist in Europe, as the long voyage had acted as a form of quarantine.

On arrival, Governor Phillip needed to quickly establish an agricultural system to feed his community. The majority of people on board the ships were convicts who had been deported from England. The convicts and their soldier guards had little agricultural knowledge and no farm machinery, so most of the clearing and farm work was done by hand (Fig. 2.1).



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

Figure 2.1 Giant tree

- 2 Why did the colony need to become agriculturally self-sufficient?
- 3 Where was the first farming area in New South Wales and was it successful?
- 4 What were the main problems encountered on the first farms?
- 5 Who was James Ruse and why is his work important?

The first farm was at Farm Cove – now the site of the Royal Botanic Gardens in Sydney. Unfortunately, after many hardwood trees had been cleared, the soil was found to be infertile and rocky. The crops grown (mainly wheat) were not suited to the Australian climate and many of the livestock escaped into the bush. This first farming venture was doomed to failure. The colonists then explored other areas and finally established crops, such as corn, wheat and potatoes, in areas around Rosehill and Parramatta. As early as 1792, the fertile soils of the Hawkesbury and Nepean areas were being worked, and by 1795 the colony was basically managing to feed its population.

Early farmers suffered from the effects of both drought and flood, so food production was never stable and food was either scarce or over-supplied. The key agricultural figure to emerge from this period was **James Ruse**. Born in Cornwall, England, in 1760, he had arrived as a convict with the First Fleet. Within a year of his arrival Ruse had earned his freedom, and by 1790 he had shown that people could survive by farming the land, without requiring food from the government. He established a successful farm (Experiment Farm) at Parramatta, and later other farms in the Hawkesbury area, at Bankstown, and finally at Macquarie Fields. He died in 1837. Farms extended into many other areas of Australia during the 19th century (Fig. 2.2).

These early farmers were often innovative in their work. **Maria Smith** and her family came to Australia in the mid-19th century. In England, she and her husband had been farm labourers who could not read or write, but they developed their own orchard near what is now the suburb of Ryde in Sydney. Towards the end of her life, Smith noticed an apple tree that had sprung up from discarded seeds on her farm. She cultivated this tree and seedlings from it; the Granny Smith apple has only increased in popularity since then.



State Library of Victoria, H2013.44

Figure 2.2 An early settler's home c. 1885

Stage II: The wool industry

The first sheep were brought to the new colony by Governor Phillip in 1788. They were intended for meat production and had distinctive large, fat tails. They came from the Cape of Good Hope in South Africa. **John Macarthur** was an important figure in the establishment of Australia's wool industry. Although he started breeding sheep from a mixed flock, he quickly brought Merino sheep into the colony. Because of political problems he was later forced into a nine-year exile in England, taking with him samples of Merino wool and managing to establish market outlets in Europe at a time when wool was in demand. Upon his return to the colonies, he brought a small flock of well-bred Merino sheep. Subsequently

Macarthur continued to develop overseas interest in Australian wool and his wife, **Elizabeth**, managed his properties here while he was busy overseas in this business. Macarthur became a leader in the wool industry and spent the last years of his life at Camden Park, New South Wales, where he died in 1834.

While Macarthur was establishing overseas markets to which wool could be exported and sold for good prices, the crossing of the Great Dividing Range west of Sydney in 1813 opened the way to an abundance of well-grassed, lightly timbered lands. Many farmers (or 'squatters', as they were first called) developed large sheep properties on these open lands.

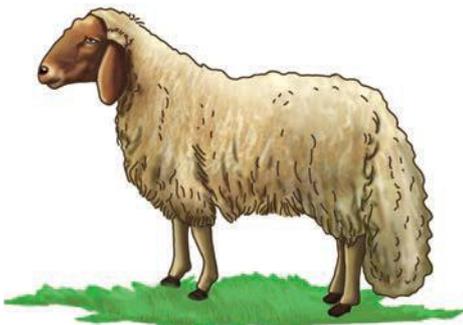


Figure 2.3 A fat-tailed sheep



Coo-ee Historical Picture Library

Figure 2.4 Wool – transport from Queensland to Moree, New South Wales



Frank Hurley, National Library of Australia, an23503990

Figure 2.5 Wool shearing shed in Gilgandra, New South Wales

For these settlers there were no roads, few developed watering points, no shops and the presence of often-hostile conditions; local Aboriginal peoples often retaliated against the forced takeover of their lands. The ‘squatters’ who stayed were usually given a licence or lease of land by the government of the time. Transport long remained a problem (Fig. 2.4).

The development of the Australian wool industry was at first rapid and unplanned. World market prices fell in the period 1840–50, and gold discoveries in areas of New South Wales and Victoria limited development when men left farms for the goldfields and labour became scarce. By 1891 the colonies’ sheep numbers had climbed to more than 1 million, with 60 per cent of the sheep located in New South Wales. Droughts that lasted for several years lowered this number and set the stage for several cycles of increase and decline in sheep numbers over the following decades.

The original Merino sheep, while producing excellent quality wool, was small-framed and not well suited to the dry climate of the country’s inland. This was remedied when the brothers **George** and **Frederick Peppin** bred a large-framed, coarser-woolled Merino suitable for the Western Plains region. Then, between 1890 and 1906, **Samuel McCaughey** introduced a wrinkly-skinned sheep from the United States into Australia (Fig. 2.6). The wrinkled skin provided a greater surface area on which to grow wool. Unfortunately, these sheep were neither tolerant to droughts nor easy to shear. While the breed later declined in popularity, the wrinkled nature of the skin still occurs in some of our present-day strains of sheep, increasing the likelihood for fly strike to occur as flies can lay eggs in the wrinkled folds in the skin.



Champion rams. Photograph by Charles Kerry Studio. Tyrrell Collectin, Powerhouse Museum, Sydney

Figure 2.6 Wrinkly-skinned sheep

- 6 Why were John and Elizabeth Macarthur important to Australian agriculture?
- 7 Why were the Macarthurs successful in establishing the wool industry?
- 8 Why did the wool industry expand rapidly after 1813?
- 9 Describe some of the changes that have occurred in the Merino breed since the sheep was introduced into Australia.

Stage III: The wheat industry

The first Australian wheat crop was harvested at Parramatta in 1789. As the number of people in the colony increased, so too did efforts to expand wheat production. For a long time the major problem lay in transporting the grain from the farms to a suitable market site.

As people moved further inland (often seeking gold and later remaining as farmers), the area sown to wheat increased. Then, development of a rail network across New South Wales made it easier to store and move wheat. By 1913 large areas of land were under cultivation for wheat production (Fig. 2.7) and output increased as fertilisers were used (especially superphosphate).

Many people were responsible for assisting in the development of the wheat industry, which peaked in the 1930s. In 1876, the brothers **RB** and **CH Smith** had developed the stump-jump plough.



State Library of South Australia, B 56053

Figure 2.7 Clover thrashing at Woodside, South Australia



Figure 2.8 Strippers collecting lucerne, Canning Downs station, Warwick, Queensland, 1894



Figure 2.9 Ridley's stripper

-
- 10** What was one major problem encountered during the early development of the wheat industry?
- 11** What enabled farmers to increase wheat production?
- 12** Why were the following people important?
- a John Ridley
 - b The Smith brothers
 - c Professor William Lowrie
 - d William Farrer
 - e HV McKay

This implement could bounce over rocks or small stumps, allowing easier preparation of fields for the sowing of crops. **John Ridley** developed a stripper that not only stripped the ears off the plant, but also used beaters to knock the wheat heads into a box (Figs 2.8 and 2.9). **HV McKay** developed this stripper into a machine that sieved and bagged the wheat as well. In 1916, **Headlie Taylor**, who held a patent for the Header Harvester, joined the McKay family firm to make the Header Harvester by 1922. The main addition was the moving cutter blade. This concept evolved into the Sunshine Harvester in 1934.

Professor William Lowrie demonstrated that many Australian soils were phosphorus-deficient and this led to the use of superphosphate. **William Farrer** developed a variety of wheat called 'Federation' – an early-maturing, rust-resistant type that could live in dry soils. This development overcame many of the problems early wheat farmers had suffered and led to an expansion of the areas planted to the crop.

Stage IV: Pasture development

During the 19th century, many machines were developed to make land preparation, mainly for wheat growing, easier. Additionally, several plant varieties were improved through breeding, increasing their productivity. Oats and many varieties of ryegrass were developed and improved. The discovery of subterranean clover at Mount Barker in South Australia meant that grazing animals could more easily obtain the building blocks for making protein products such as milk, wool and meat. Because clover is a legume (see Chapter 23), it can supply nitrogen to grasses grown in combination with it. The grass–legume pasture combination formed the basis of a pasture revolution, accelerating the grazing industry for both beef and sheep. This period, consolidated in the 1930s and 1940s, saw the Australian meat industry develop in both tropical and temperate areas of Australia.

The development of effective refrigeration systems on ships allowed the export of beef and sheep carcasses and stimulated local production. A further boost to the beef cattle industry came with the introduction of Brahman cattle into Australia in 1933. This breed, originally developed from Indian cattle, was imported from the United States.

Stage V: Technology

Since the 1980s, Australian agricultural production systems have been geared towards the use of modern technology and the incorporation of new scientific discoveries. To improve production efficiency and to lower costs (especially of labour), farms became bigger and many new types of large machines were used to prepare the land, and to grow and harvest the crops. This also meant that farming became capital-intensive (that is, large amounts of money were needed to buy machinery).

-
- 13** What major industry developed during the pasture phase of Australian agriculture?
- 14** Why are legumes an important type of plant?

Farmers also diversified their production as they sought to avoid the problems associated with unstable markets. New techniques were widely introduced, such as embryo transfer, sexed semen (allowing farmers to determine the sex of their calves), pregnancy testing of animals (using ultrasound technology) and robotic milking of dairy cattle.

Genetic research has led to the genetic sequencing of some plants and animals to improve productivity and pest resistance; for example, in the development of citrus rootstock or the development of a bio-insecticide, which is an insecticide containing viruses or bacteria specific to the organism it infects and kills.

Gene sequencing in chickens, turkeys and cattle has assisted in the development of new breeds or enhanced levels of production. By understanding the genetic map of an animal or plant, genes may be added or removed to affect body shape, levels of productivity or enhance product quality.

The use of computer technology was introduced initially for budgeting and financial records but rapidly expanded to the whole farm management record keeping and simulation programs.

An example of recent technology developments is the use of global satellite positioning combined with video imaging to help farmers apply fertilisers and herbicides only to the areas of their crops that need them. Another is the advance in communications that give farmers better access to both technical and market information, thus enabling them to make more informed management decisions. Remote cameras allow farmers on large properties to inspect structures such as bores to see if water is flowing for cattle and sheep without having to physically drive out to check these structures.

Access to advanced telecommunications will drive the adoption of new technologies and practices. The efficiency of infrastructure (roads, ports, railways) will be improved through the adoption of new technologies. This will in turn enhance the effectiveness of Australian agriculture markets.

Challenges of a labour shortage have been met through replacing labour with technology.

- 15 What are the main features of the high-technology phase of agriculture in Australia?
- 16 Give some examples of the technology that is used today. Explain how technology is influencing farmers of today.
- 17 Describe an example of recent technology that has enabled farmers to make better decisions.



Shutterstock/mihalec

Figure 2.10 Modern machinery: a combine harvester

Stage VI: Marketing and exporting of Australian products

By the mid- to late 1980s, farms were increasingly run on business principles. Today it is important not only to produce efficiently, but also to be able to market the product. Marketing is no longer seen as delivering the output gained from a farm to the local market; more importance is attached to exporting Australia's rural products overseas. This means a large amount of time and money is being invested in examining and developing markets for plant and animal products outside Australia. The quality of the export product is being upgraded and the requirements of overseas countries, based on their culture and traditions, are also being taken into account.

New products are being grown and exported from Australia, and potential future industries are in their infancy – notably those relating to our native plants. Australia produces much less food than many other countries but it is still able to export

18 What are two things that are being done to develop export markets for agricultural products?

over half of its agricultural production. Australia is a leading supplier to world markets of beef and dairy products, wheat, barley and sheep meat. This has led to the establishment and continued development of free trade agreements with key growth markets in the local region such as Asia. Australian farmers can be limited in their production due to lack of money for investing in their farms; to help overcome this issue, investment from overseas companies has become increasingly important for developing Australian agricultural operations. Many trade agreements have been formed and in many instances countries have cooperated with Australia in agricultural research and development; for example, China.

Stage VII: Sustainability and technology

connect

Myrtle rust

Read the article.

connect

Supporting sustainable farming

Watch the video clip and answer the questions under 'Things to think about'.

While meeting the requirements of markets continues to influence Australian agriculture, the need for sustainable practices and the further application of technology have emerged as major influences on the agricultural industries.

There are several major issues arising within agricultural production systems from trying to balance environmental, economic, personal, social and political factors:

- maintaining the quality of natural resources; for example, soil and water quality, to maintain productivity
- managing climate variability and change over time
- managing water supplies and availability
- dealing with pests and diseases from overseas – biosecurity risks; for example, Myrtle rust, bird flu and foot-and-mouth disease
- developing a knowledge of and adjustment to legislative changes in relation to natural resource management
- developing an awareness of food security where a population has access to a sufficient quality and quantity of food
- responding to consumer concerns in relation to genetically modified products, animal welfare concerns and a growing demand for organically produced commodities.

Adaptation to climate change is occurring at three levels:

- 1 at the farm level, farmers may change planting times of crops or select new varieties of plants or animal breeds on their farms
- 2 at the government level, through scientists in research institutions developing new genetic strains such as drought-tolerant wheat strains
- 3 at the industry level, there may be a shift in the location of types of farm production systems, such as the movement of wine growers to more southerly locations in Australia where it is cooler.

Along with the general community, farmers have realised that they must look after their farms and the environment to make sure future generations will be able to live productive and healthy lives. Farmers have become involved in programs such as Landcare and Total Catchment Management. They have adopted whole-farm planning techniques to better manage their farms and to curb the degradation of soil, water and biological resources.

19 Define 'biosecurity'.

20 List the main factors influencing farm sustainability.

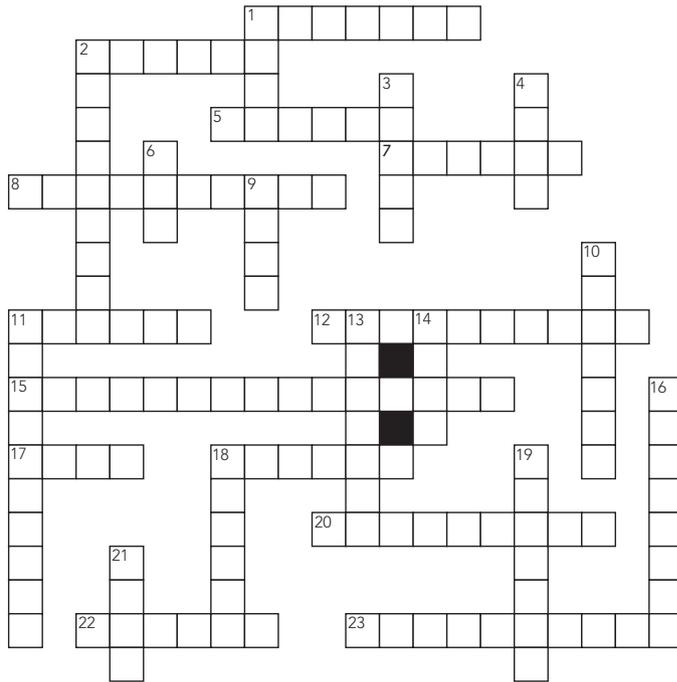
21 Outline how farmers are managing the influence of changes in climate on farm production.

22 Why have farmers become involved in programs such as Landcare?

Chapter review

Things to do

1 Copy and complete the crossword using the list of clues.



Clues across

- 1 A factor that always affects agriculture
- 2 A breed of sheep
- 5 A machine developed to cultivate the soil (it could jump obstacles)
- 7 Farmers need to pay more attention to this type of market
- 8 The location of James Ruse's first farm
- 11 A successful wheat breeder
- 12 The first settlers of this land were called by this name
- 15 Another term for a mixed farm
- 17 The first successful farmer
- 18 An important type of pasture plant
- 20 A concentrated form of farming
- 22 Along with grass, forms the basis of a pasture
- 23 Natural or artificial source of plant food

Clues down

- 1 An important export product of the colony
- 2 A founder of the Australian wool industry
- 3 An important plant in the history of Australian agriculture for many years
- 4 _ _ _ _ wood trees had to be cleared by the early farmers
- 6 A type of sheep brought to Australia because of its _ _ _ tail
- 9 The name given to a group of animals that pulled heavy loads on wagons
- 10 The eating of grass by animals
- 11 The name of an important variety of wheat
- 13 A breed of tropical cattle introduced into Australia
- 14 An extensive network that opened up the wheat growing areas
- 16 A name given to many early farmers
- 18 The person who demonstrated that Australian soils lacked superphosphate
- 19 An unpopular breed of sheep named after its skin type
- 21 Discoveries of this metal limited the number of people working on the land

2 Copy and complete the wordsearch using the list of words.

- Aboriginal
- Brahman
- Diversified
- Farrer
- Federation
- Grazing
- Intensive
- Legume
- Lowrie
- Macarthur
- McCaughey
- McKay
- Merino
- Parramatta
- Plough
- Ridley
- Ruse
- Smith
- Subterranean
- Tractor

P	T	E	X	M	U	I	N	T	E	N	S	I	V	E	T	D	P
E	I	D	Q	I	S	O	P	Q	H	U	A	G	E	W	E	F	R
M	S	F	T	R	U	Y	A	K	C	M	U	A	S	I	S	Q	E
U	P	E	K	O	N	G	Y	L	Y	M	T	R	F	S	B	M	R
G	P	D	G	E	A	N	L	P	O	T	I	I	R	I	R	S	R
E	L	E	D	A	E	I	F	R	A	S	S	G	T	V	A	Y	A
L	O	R	W	W	N	Z	F	M	M	R	L	P	N	U	H	E	F
Z	U	A	R	I	A	A	A	T	E	P	A	D	Z	S	M	L	R
C	G	T	T	M	R	R	R	V	M	W	X	E	L	E	A	D	Y
I	H	I	G	C	R	G	I	C	H	W	C	A	K	D	N	I	E
W	M	O	S	A	E	D	S	Z	L	I	N	J	R	X	D	R	H
Z	T	N	P	R	T	Q	X	U	U	I	D	J	G	C	S	L	G
C	P	H	T	I	B	A	R	T	G	T	P	E	D	I	Q	O	U
U	O	X	T	A	U	L	S	I	T	R	A	C	T	O	R	W	A
G	K	Y	S	T	S	W	R	U	Y	T	T	H	Z	E	Z	R	C
Q	B	L	W	N	Y	O	S	L	H	T	I	M	S	J	B	I	C
F	E	S	U	R	B	I	R	T	P	L	X	F	A	Y	F	E	M
Y	M	A	C	A	R	T	H	U	R	H	M	M	E	R	I	N	O

Things to find out

- 1 Go to your local library or visit a website to locate information on the possibilities of farming one of the following and examine how one of these industries operates.
 - a Kangaroos
 - b Emus
 - c Native plants.
- 2 Account for why horses have been replaced by machines.
- 3 Figure 2.11 illustrates early farmers at work in the fields.
 - a What do you think the people are doing?
 - b What machinery replaced horses and labourers on farms to improve the efficiency of harvesting? How were these machines powered?
 - c What powers this tractor-like machine?
 - d What could the purpose of the other machine be?
 - e How would the bags of grain be removed?
 - f What modern equipment has since replaced these older machines?
- 4 Now look at Figure 2.12.
 - a What activity is the person performing?
 - b What machine performs a similar function today?
 - c How is the modern machine carried around the fields?
- 5 Go to the [Australian Farm Institute](#) website. Use the search function for 'Trade', then select an article on trade. Explain the effect of the issues described in this article on farming today.
- 6 Create an A3-sized poster with pictures and information on an aspect of Australian agricultural history.

V.A.N. Hood Collection, State Library of Victoria, H36531/18/88



Figure 2.11 Wheat harvesting in the Wimmera, Victoria, 1909

J.H. Harvey Collection, State Library of Victoria, H91.300/985



Figure 2.12 Early farming

connect

Australian Farm Institute

+ Extension activity

- 1 Choose one of the agriculturalists in the 'Names to know' list at the start of the chapter. Find out more about this person and produce a 'Person to know' poster that shows some more details of their life and achievements in agriculture.
- 2 Select an issue confronting farmers in Australia from those listed in the text under sustainability and research the effect of this factor on the sustainability of agricultural production.

✓ Test yourself

- 1 In your notebook, copy out and match the descriptive statements with the correct stages of Australian agriculture.

Stage of Australian agriculture	Descriptive statements
I: The early farmers	Satellites and global positioning technology have enabled farmers to more accurately apply fertilisers to areas of their crops that are deficient in nutrients. Farmers have realised that they must look after the environment to ensure future generations are able to farm.
II: The wool industry	Transporting grain was a major problem that was overcome with the expansion of the railway network. Production was improved with the development of the stump-jump plough, header harvester and the use of superphosphate fertiliser.
III: The wheat industry	The first attempts to grow crops in the new colony were at Farm Cove, which is now the Royal Botanic Gardens in Sydney. By 1790 James Ruse had shown that people could survive by farming the land without requiring food from the government.
IV: Pasture development	John Macarthur brought the first Merino sheep to Australia and helped establish overseas markets for wool. The crossing of the Great Dividing Range in 1813 allowed the development of large sheep-grazing properties.
V: Technology	The discovery of subterranean clover at Mount Barker in South Australia led to the development of better grass–legume pastures that allowed more grazing of sheep and cattle, especially for meat production. Refrigerated transport allowed the export of meat from Australia.
VI: Marketing and exporting of Australian products	Farm production became more focused on the requirements of the markets being supplied. New products were produced to export from Australia, including those making use of native plants.
VII: Sustainability and technology	Technology was used to improve production efficiency and lower the costs of production, especially by reducing the labour required. Farms became more diversified to avoid problems with unstable markets.

- 2 Outline examples of how recent technological innovations are improving farm productivity.
- 3 Discuss how agricultural enterprises can adjust to changing climatic patterns.
- 4 Why do farms tend to become larger over time?

UNIT 2

AGRICULTURE IN AUSTRALIA

CHAPTER 3

AGRICULTURAL PRODUCTION AREAS IN AUSTRALIA

Words to know

alluvial soil deep, fertile transported soil deposited by a stream, usually in a flood plain

crop rotation the process of growing different crops, including pasture, from one year to the next on the same piece of land

deficient used to describe a soil lacking a particular nutrient or element

enterprise an individual activity on a farm that can produce an income; for example, raising beef cattle, growing wheat

improved pasture generally refers to the use of introduced species of pasture grasses, legumes or a combination to enhance pasture production

infertile a soil lacking, or deficient in, one or more nutrients or elements that cannot sustain significant plant life as a result

legume a type of plant (bearing a pod) which also 'fixes' or converts nitrogen into a form usable by the plant through the action of specific bacteria living in its roots; examples include clovers, peas, lucerne and broad beans

road train a prime mover (truck) with up to three trailer units used for transporting sheep or cattle to market or agistment (a location where livestock are moved to and rent is paid by the farmer for better feed)

station a large property used for grazing (sheep or cattle)

Introduction

It is the climate that determines which agricultural industries can be efficiently run in any area, although soils and topography may also have important effects. Australia can be divided into four main agricultural areas, based on climate:

- 1 the temperate region
- 2 the subtropical region
- 3 the tropical region
- 4 the arid and semi-arid region

These regions are shown in Figure 3.1 and discussed in detail in the following sections.

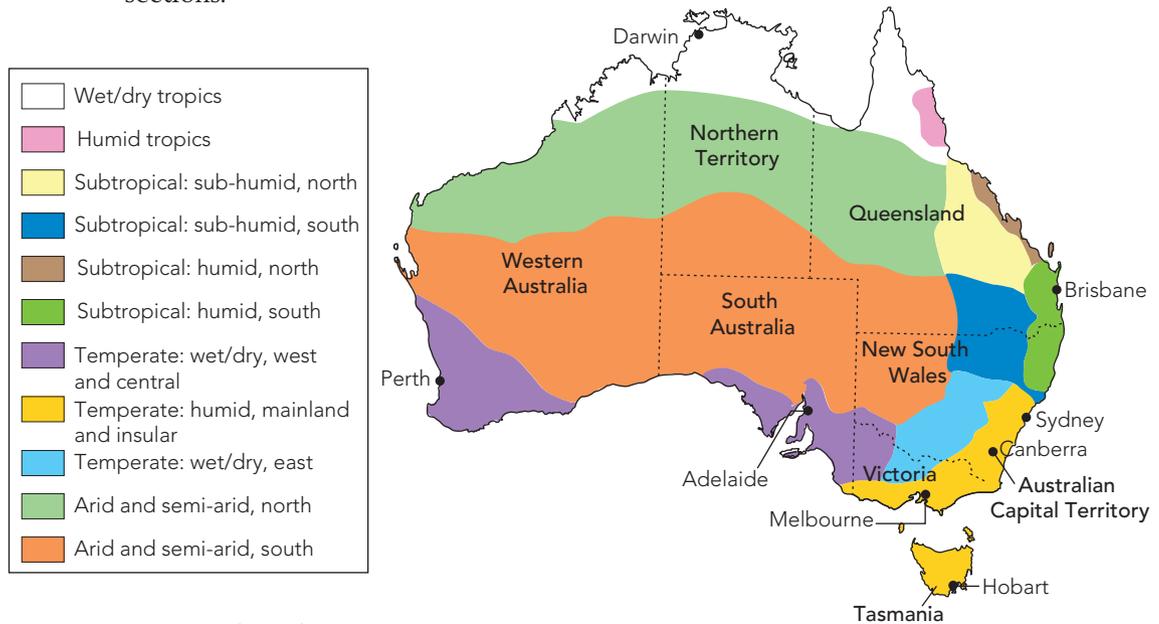


Figure 3.1 Australia's climatic regions

The temperate region

A favourable climate allows a wide range of farming activities. The temperate region (mild to warm summers and cool winters) contains some of the most productive land in Australia. The region covers four zones, shown in Figure 3.2.

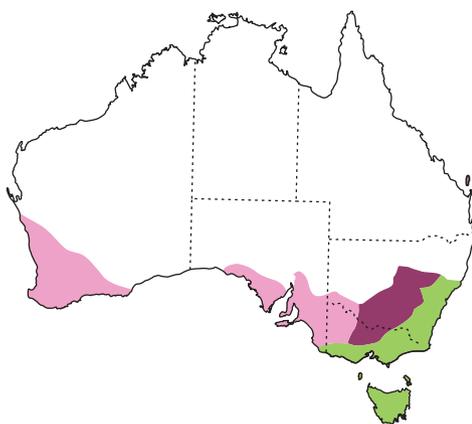
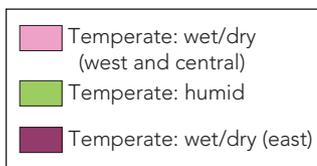


Figure 3.2 The temperate region

The wet/dry zone (west)

In this zone temperatures are relatively mild and rainfall is fairly reliable, with most showers falling in winter. This zone covers a triangular-shaped area in the south-western part of Western Australia.

The soils here range from coastal soils with a sandy texture in the top layer, to inland soils with a clayish texture. The coastal soils have been transformed from wastelands into productive farming country by sowing suitable pasture and adding major and trace elements through fertilisers. All soils in the zone are **deficient** in phosphorus. This is corrected by adding superphosphate.

In this zone, sheep provide a major source of farm income through the sale of wool, mutton, lamb and live sheep for export. Beef cattle are found in the higher rainfall areas. Dairy cattle, pigs and poultry supply the Perth market. **Crop rotation** is used, where farmers alternate cereal crops with **legume**-based pastures. The main legumes are subterranean

clover and medics. Wheat is the major export crop. Other crops include barley, canola, lupins and oats, while the many grape growers in the surrounding areas produce fruit that is turned into high-quality wines.

The wet/dry zone (central)

This zone has a climate of cool, wet winters and hot, dry summers. It covers part of South Australia and part of north-western Victoria.

Its soils include sandy earths, brown soils and red-brown earths. The brown soils are used to grow *irrigated* tree crops and vegetables along the Murray River.

The main livestock grazing industries are sheep, beef and dairying. The main *intensive* animal industries are pigs and poultry. A typical mixed farm in this zone would be about 600 hectares in size. Of this area, half would be sown to cereal crops and half to pasture. The farm produces wool, meat and cereal grain. The farmer would typically own two tractors, a disc plough, harrows, seed drill or combine, header, haymaking machinery, grain handling equipment and a truck. This zone also produces almonds, apples, cherries, grapes, pears and vegetables – onions, potatoes and tomatoes.

The wet/dry zone (east)

In this zone rain may fall in any month, but it is of little use in summer because of high temperatures and evaporation. This zone covers much of the western slopes and plains of New South Wales.

Soil types include red earths, red-brown earths, and grey and brown soils. The soils are low in organic matter (any living or dead animal and plant material), phosphorus and nitrogen. In some areas soil *erosion* has become a problem due to overgrazing and overcropping.

Wool-growing is the main **enterprise** in the drier western areas of the zone. In the higher rainfall areas, prime lambs and beef cattle breeding and fattening are the main activities. Dairying is found in irrigation areas, along rivers and often close to the larger towns such as Mudgee and Dubbo. The zone's dryland areas grow mainly pastures and legumes in rotation with cereal crops such as wheat. Many other crops can be grown, including barley, canola, field peas, lupins, oats, rice, sunflowers and triticale. Irrigated fruit and vegetable production takes place in the Murrumbidgee, Coleambally and Murray irrigation areas. The fruits grown include apples, grapes, oranges, peaches and pears, and dried fruit production is also a significant activity.

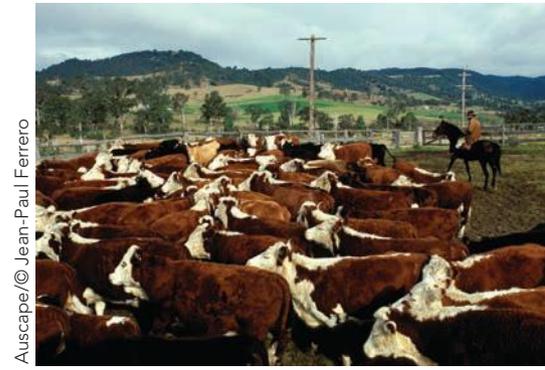
The humid zone

This zone has cool winter temperatures and warm to hot summers. Rain falls throughout the year, but there is more rainfall during winter. This zone includes the whole of Tasmania, and a belt of land on the mainland extending from the south-eastern corner of South Australia, through southern Victoria to the central coast of New South Wales.

Soils range from sands to heavy clays, but most are loams or clay loams. They are generally acidic, low in organic matter and low in nitrogen.

Sheep are of major importance in the humid zone. There are also many beef properties and dairy farms. Farm size varies between 400 and 800 hectares. Most of these properties are operated by families.

Pig and poultry raising is very specialised and tends to be located in the grain-growing areas where cheap grain is available. Large companies operate these intensive farms. Buildings are environmentally controlled. Some poultry farms have 5000–10 000 laying hens and some piggeries have 1000 or more sows.



Auscapse/© Jean-Paul Ferrero

Figure 3.3 Cattle are typically raised in the wet/dry temperate zone.

- 1 What fertiliser has to be applied to the soils in the wet/dry zone (west)?
 - 2 What is the zone's major export crop?
 - 3 Describe the climate of the wet/dry zone (central).
 - 4 List the machinery found on a typical farm in the wet/dry zone (central).
-
- 5 Why is rain of little use in the wet/dry zone (east) during summer?
 - 6 What is the main enterprise in the drier western area of the eastern zone?
-
- 7 What is the range of farm sizes in the humid zone?
 - 8 Why are pig- and poultry-raising enterprises located in grain-growing areas?

Pasture legumes are grown, including lucerne, subterranean clover and white clover. Grasses include cocksfoot, perennial ryegrass and phalaris. Only small areas are cropped. The grain crops grown include barley, lupins, oats and wheat. The main fruit crops are apples, cherries, peaches, pears and plums. (To get good-sized fruit, irrigation is usually necessary in summer.) The main vegetable crops grown in this zone are beans, brussels sprouts, cabbages, carrots, cauliflowers, lettuces, onions, parsnips, peas and potatoes.

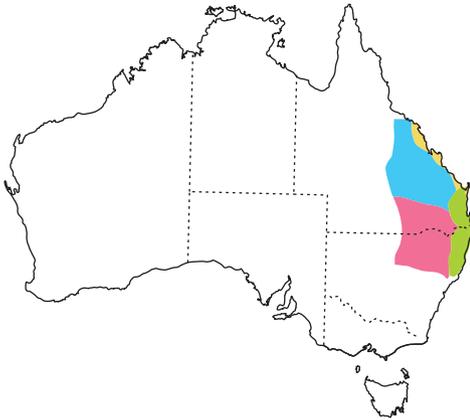
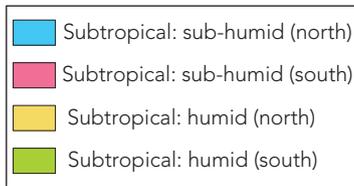


Figure 3.4 The subtropical region

The subtropical region

The two most important products of the subtropics are beef and sugar. The sugar industry has developed specialised machines for cane growing and harvesting. The beef industry has expanded, even though this region has a relatively long dry season and is subject to the cattle tick. The region contains the largest concentration of cattle in Australia. Most of the cattle in the subtropics are fattened on pasture. Land has been made productive by sowing tropical legumes and applying fertilisers.

The vegetable industry in the subtropics has been developed to supply out-of-season produce. These vegetables are transported to southern city markets. Fruit production is now established and fruit is exported to nearby Asian markets.

Australia's subtropical region covers four climatically different zones, shown in Figure 3.4.

The sub-humid zone (north)

The northern part of this zone is affected by summer monsoons, and the southern part by winter westerlies. Some useful rain falls in winter, but this is not always reliable.

This zone contains the Burdekin, Fitzroy and Burnett rivers. The brigalow scrubland has proved an obstacle to farmers – the land has to be cleared by crawler tractor and the trees burnt, or aerial spraying with herbicide combined with clearing, burning and subsequent grazing to remove any regrowth. The soils vary, but all contain clay and are lacking in nitrogen and phosphorus.

The crops grown include barley, cotton, grain sorghum, oats, safflowers, sunflowers and wheat.

The sub-humid zone (south)

This zone covers parts of northern New South Wales and some of southern Queensland. It includes the Darling Downs and the Condamine and Maranoa rivers in Queensland. In New South Wales it includes the Northern Tablelands, North-Western Slopes, North-Western Plains and the Hunter Valley.

Soils vary greatly throughout the zone.

The main pastoral areas are sown to **improved pasture** species, such as cocksfoot, lucerne, phalaris and white clover. The main animal industries are beef, dairying, pigs, poultry and sheep. Crops grown include barley, grain sorghum, oats, safflowers, soybeans, sunflowers and wheat.

The humid zone (north)

This zone covers a coastal strip on the central coast of Queensland. The area is intensively farmed. There is a relatively dry period from April to October, and December to March is the wet season.

- 9 Name the two most important products of the subtropical region.
- 10 Why has the vegetable industry developed in the subtropical region?
- 11 In what season does useful rain fall in the northerly sub-humid zone?
- 12 Explain how the zone's land is cleared.
- 13 Name the four improved pasture species sown in the southern sub-humid zone.
- 14 Name the main animal industries in this zone.

Soils include red and yellow earths and deep **alluvial soils**.

A number of legumes have been sown, including stylo, red clover and lucerne. Beef and dairy cattle are run in this zone and its most important crop is sugarcane. Coarse grains include sorghum and maize. Horticultural crops include avocados, cucumbers, mangoes, pawpaws, pineapples, pumpkins, tomatoes and zucchinis.

The humid zone (south)

This zone covers a narrow strip of northern New South Wales and the Queensland coast south of Brisbane. The area has warm to hot summers and mild winters.

The high quality alluvial soils of the four main river valleys are suitable for intensive cropping and livestock production.

Beef cattle, dairying and pig farming are the main animal industries. Sugarcane is confined to the alluvial soils in frost-free areas. Horticultural crops also include avocados, bananas, beans, macadamia nuts, passionfruit, pawpaws, pumpkins, watermelons and zucchinis.

The tropical region

Agricultural development of this region began in the early 1880s. Early settlers were attracted by the forest resources and the large areas of grazing and farming land near the coast. They faced many problems, including long distances to markets, low population densities, extremes of climatic conditions and a lack of towns to provide goods and services.

Australia's tropical region covers two separate zones with distinct climates (Fig. 3.5), but with considerable overlap of agricultural industries.

The wet/dry tropical zone

This zone has a well-defined wet and dry season. The 'wet' summer lasts 3–4 months and is followed by a 'dry' period of 8–9 months. The zone includes the Kimberley of Western Australia, the 'Top End' of the Northern Territory and the Cape York Peninsula.

The following problems occur in the zone in the 'wet' season.

- It is difficult to transport and handle cattle.
- Soil erosion in cultivated areas is increasing.

Often the soils are very **infertile**. They can be deficient in nitrogen, phosphorus and trace elements. But some of the deltas, the areas where rivers reach the sea, are deep, easy to cultivate and reasonably fertile. These are suitable for growing sugarcane.

Beef cattle properties dominate the zone and are very large. Indian breeds are crossed with British breeds such as Hereford, Angus and Shorthorn. This improves the heat tolerance, tick resistance and growth rate of the cattle. The area has poor natural pastures, which means cattle take a long time to reach slaughter weight. This problem is being overcome by introducing legumes such as Townsville stylo.

The crops grown are cassava, grain sorghum, peanuts, rice, soybeans, sugarcane, sunflowers and tobacco.

The humid tropical zone

This area occupies a small strip along Queensland's north coast. The area receives the highest rainfall in Australia. Dry periods are relatively short. Cyclones can cause damage to crops and buildings.

-
- 15 When is the northern humid zone's 'dry' season?
 - 16 Name the horticultural crops grown in the zone.
-
- 17 What is the main soil type of the southern humid zone?
 - 18 In which areas is sugarcane grown?
 - 19 What attracted settlers to the tropics?
 - 20 Name the problems faced there by early settlers.

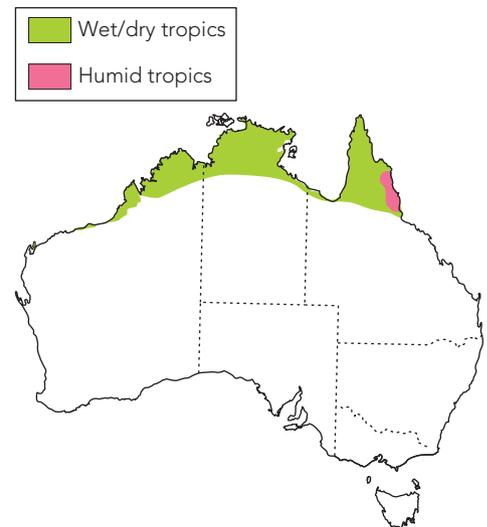


Figure 3.5 The tropical region

-
- 21 List the main problems occurring during the wet/dry tropical zone's wet season.
 - 22 List the main crops grown in the wet/dry tropical zone.
-
- 23 What are the humid tropical zone's fertile alluvial lowlands used for?
 - 24 List the beef breeds that have been recently introduced into the region.

The alluvial lowlands are used for sugarcane and beef cattle fattening. The tablelands have large areas of fertile red soils and are used for cropping. The mountain slopes (of basalt origin) are used for dairying.

The main livestock industries are beef cattle breeding and fattening. A number of new breeds have been introduced into the area. These include the Belmont Red, Brangus, Braford and Droughtmaster. Improved pastures have led to increases in stocking rates and livestock production. These pastures are based on plants that have adapted to damp conditions.

Sugarcane is the most important crop in the region. Other key crops include bananas, peanuts and potatoes.

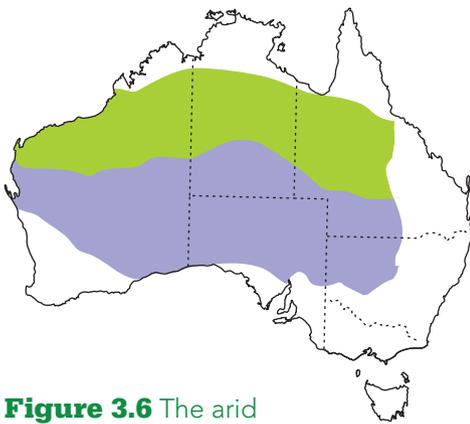
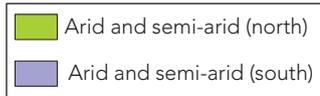


Figure 3.6 The arid and semi-arid region

The arid and semi-arid region

This region covers about 70 per cent of Australia and is a harsh environment for those living in it.

The region's individual properties (called **stations**) are large and are used for cattle and sheep. Improvement to roads in recent years has led to more rapid transport, with large **road trains** travelling long distances. Road trains are used to transport stock to market or to areas not affected by droughts (for agistment).

Australia's arid and semi-arid region covers two separate zones, shown in Figure 3.6.

- 25 What is a 'station'?
- 26 What are road trains used for?
- 27 What nutrients are the northern arid and semi-arid zone's soils deficient in?
- 28 List the main buildings found on a cattle enterprise in the zone.
- 29 What is the main breed of sheep in the southern arid and semi-arid zone?
- 30 What are the main problems facing graziers in this zone?

The arid and semi-arid zone (north)

The rainfall in this zone is low and unreliable, with the main falls occurring in summer. Heatwaves are also common. Soils are infertile and lack nitrogen, phosphorus and some trace elements.

The northern zone is dominated by the pastoral industry. This includes beef cattle in the Barkly Tablelands, beef cattle and sheep in northern Queensland, beef cattle along the Channel Country, and sheep in southern Queensland. A large cattle enterprise in this zone is really a small community. It will typically have a station homestead and houses for the manager, teacher, cook and mechanic; a school (or access to online education or School of the Air), workshop and general shop; and accommodation for the workers. It would also have an airstrip.

The arid and semi-arid zone (south)

This zone runs mainly sheep. As in the northern zone, rainfall is low and unreliable. More falls occur in winter than summer.

Soils are infertile. They are deficient in nitrogen, phosphorus and some trace elements. Native pastures contain both perennial and annual species. These pastures grow well after rain.

The main land use is the running of sheep and cattle. Cattle are run in the more favourable areas. Nearly all the sheep are Merinos (and Merino crossbreeds) and their main purpose is to produce wool. The main problems facing graziers in this zone are drought and grasshoppers (plague locusts).



Fotolia/© Steve Lovegrove

Figure 3.7 Sheep are typically run in the southern arid zone and semi-arid zone.

Chapter review

Things to do

- 1 Trace or download an outline map of Australia and mark and label the four main agricultural climate regions.
- 2 Collect pictures from old magazines or access the internet to obtain images showing farming activities carried out in each of the four Australian agricultural regions.

Things to find out

- 1 Which country or countries are live sheep exported to?
- 2 How can soil erosion be prevented in grazing areas?
- 3 Explain why crops normally grown in the high rainfall areas can be grown along the lower rainfall areas of the Murray River.
- 4 How is cattle mustering conducted on a large station in northern Australia?
- 5 What activities are daily routines on a large cattle or sheep station?

Extension activity

- 1 Sir Sidney Kidman was a pastoralist who had a number of properties in South Australia and south-eastern Queensland. How could he have used these properties when drought conditions occurred in one of these states?
- 2 Imagine you travel in a straight line across Australia from Perth to Brisbane. Using Figure 3.1 as a guide, name the climatic regions you would pass through and the kinds of agricultural enterprises you would be likely to see as you travelled. Do the same for a trip from Darwin to Melbourne. You may like to use a table with columns headed 'Climatic region' and 'Agricultural enterprises' to help you.

Test yourself

Copy out and label each statement true or false.

- 1 The temperate region contains some of the most unproductive land in Australia.
- 2 In the subtropical region the land has been made productive by sowing tropical legumes and applying fertilisers.
- 3 Early settlers in the tropical region did not face many problems such as long distances to markets, low population densities, extremes of climatic conditions and a lack of towns to provide goods and services.
- 4 The arid and semi-arid region has large individual properties called stations that are used for sheep and cattle.
- 5 Soils in most climatic regions of Australia are deficient in phosphorus, which is corrected by the application of superphosphate.
- 6 Irrigated fruit, vegetable and rice production takes place in the Murrumbidgee, Coleambally and Murray irrigation areas.

- 7 The beef industry has contracted or become much smaller in the subtropical region even though the region has a relatively long dry season and is subject to cattle tick.
- 8 The most important crop in the northern part of the humid zone is sugarcane.
- 9 The humid tropical zone receives the least rainfall of anywhere in Australia.
- 10 The arid and semi-arid region covers 70 per cent of Australia and is a harsh environment.

CHAPTER 4

AGRICULTURE IN THE AUSTRALIAN ECONOMY

Words to know

consumers people who buy and use a product to satisfy their needs or wants (e.g. people buying fruit and vegetables to eat)

domestic market for sale within Australia

manufacturing industries those that produce manufactured goods (e.g. cars, machinery, clothes)

mining industries those involved in extracting valuable ores and minerals from the ground and then selling them (e.g. gold, coal, bauxite, iron)

service industries those that provide services to people (e.g. banks lend money, stock and station agents assist with buying and selling animals)

tariff a tax imposed on imported or exported goods to affect trade

technology the practical application of knowledge such as the use of machinery, computers and/or techniques for undertaking agricultural practices (e.g. the machinery and the method used to grow a wheat crop)

value adding further processing of a product so that it can be sold for a higher price

connect

Trade in agriculture

Find out more information on Australia's trade in agriculture.

1 What was the approximate value of farm exports for 2010–11?

Introduction

The *Australian economy* refers to how the country's resources are managed – what is produced in Australia, how it is produced, and for whom it is produced. The economy can be divided into parts or sectors to make it easier to understand. Agriculture is one of those sectors and others include the **manufacturing, mining** and **service industries**. Figure 4.1 shows the value of Australian exports by sector of the economy.

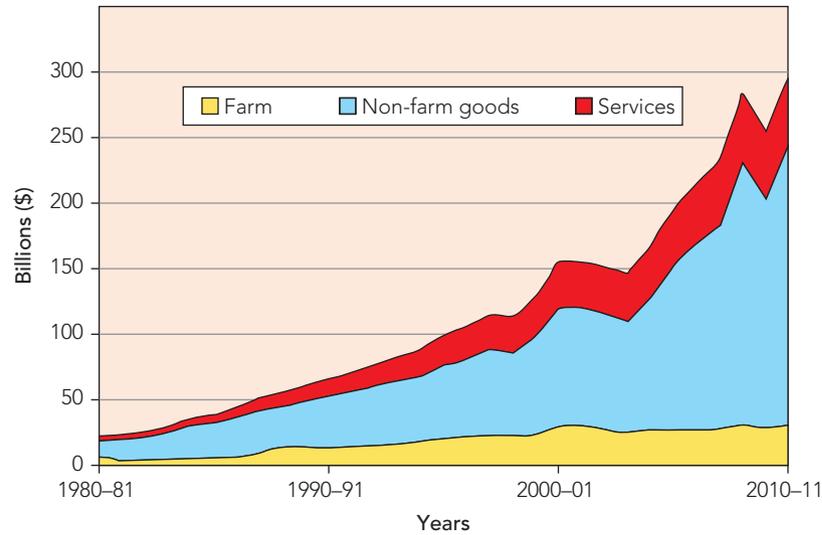


Figure 4.1 The contribution of Australia's major industries to the economy

connect

Australian Bureau of Statistics – Year Book Australia

Examine the latest year book to outline what types of production most of Australia's agriculture businesses are involved in.

- 2 Are these statements true or false?
- a The number of farms in Australia has increased since the 1950s.
 - b Most Australian farms are run by farmers and their families.
 - c Mixed crop and livestock farmers represent 22.1 per cent of all farmers in Australia. (Refer to Figure 4.2.)
 - d Grape growers represent 4.2 per cent of all farmers in Australia.

The farms of Australia

According to the Australian Bureau of Statistics, 52 per cent of the land suitable for use in Australia is used in agriculture. Of that 52 per cent, 6.5 per cent is under crops and a further 5 per cent under pasture. Livestock grazing accounts for most of the land used in Australian agriculture.

In the early 1950s there were 205 000 establishments in Australia engaged in agricultural activities with a value of more than \$5000 per farm per year. Currently there are approximately 134 000 such establishments. Farms must have become larger through amalgamation and these farms are becoming more productive due to the more efficient use of **technology** and effective use of capital. Farms range in size from just one or two hectares to many thousands of hectares. The majority of farms are reasonably small with yearly production levels of less than \$100 000 dollars.

Many farms are family farms – they are owned and operated by a farmer and the farmer's family. The farmer's spouse and children often contribute to the running of the farm.

Off-farm employment has become increasingly important to maintaining family farm incomes.

In Australia, according to figures from the Australian Bureau of Statistics, 99 per cent of agricultural businesses and 89 per cent of agricultural land is Australian owned. Figure 4.2 outlines the proportion of farming activities across Australia.

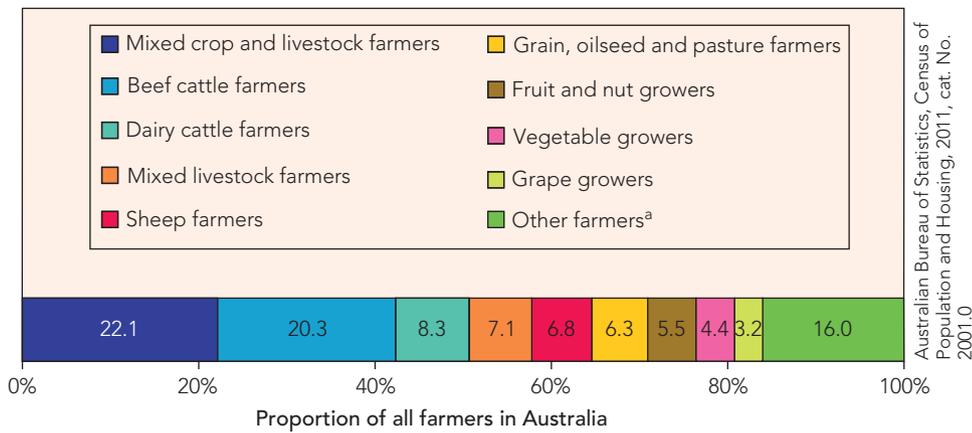


Figure 4.2 Farming activities in Australia

^a Includes sugarcane growers, poultry farmers, flower growers and apiarists etc.

What happens to Australian farm produce?

In 2012, 60 per cent by value of agricultural products produced in Australia was exported. The rest was consumed on the **domestic market**. Australian farmers produce almost 93 per cent of the daily domestic food supply.

The export market

Agriculture plays a significant role in the Australian economy – about 12 per cent of Australia’s export income comes from the sale of agricultural products. Mining and manufacturing exports make up the majority of the rest of Australia’s exports. The products exported from the agriculture sector include wool, meat, sugar, wheat, rice and other grains, and horticultural produce. Exports have become more diverse with less reliance on traditional commodities such as wool and more on processed products such as wine. Table 4.1 shows the value to the Australian economy of the main agricultural exports in 2010–11.

Australia’s major overseas markets are China (14 per cent), Japan (13 per cent), ASEAN (21 per cent), other Asian countries (16 per cent), Europe (8 per cent), Middle East (8 per cent), United States (7 per cent), with the remainder being 13 per cent. (ASEAN refers to the Association of South-East Asian Nations and includes Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.) Of the total value of farm exports, 54 per cent is gained from crops and 46 per cent from livestock industries. These figures indicate the increasingly important role Asian countries are playing in our export market. In the future Australia will need to improve the identification of consumer needs in fast-growing marketplaces, especially Asia. The Chinese market will increase its demand for agricultural products such as fruit and dairy products, and quality meat and seafood products as the number of people in the middle class in Chinese society grows.

In terms of export earnings for Australia, each of the top eight commodities in Table 4.1 make a massive contribution to the national economy – accounting for over 60 per cent of the total \$32.5 billion value of agricultural exports in 2010–11.

The value of exports is affected by the value of the Australian dollar, world commodity prices and seasonal conditions.

Table 4.1 Australia's main agricultural export-earning industries, 2010–11

Agricultural industry	Value of export earnings (\$ million)
Wheat	5526
Beef and veal	4328
Wool	2376
Wine	1957
Dairy (excluding cheese)	1614
Sugar	1492
Barley	1295
Lamb	1026

'Agricultural Commodity Statistics, 2011', Department of Agriculture, Fisheries and Forestry, ABARES, Commonwealth of Australia

-
- 3** List the agricultural products that Australia exports.
- 4** Where are the main markets for Australia's agricultural exports?

The domestic market

Australian agriculture supplies the products to meet the national need for food, clothing and shelter. Very little food is imported. Australian farms produce 93 per cent of the total volume of food consumed in Australia; after meeting this need, remaining agricultural produce is exported.

Table 4.2 shows the proportion of the total farm production of food that is consumed in Australia.

Table 4.2 Proportion of total farm production of food consumed in Australia

Produce	Proportion consumed in Australia (%)
White meat (chicken and pork)	100
Dairy produce	70
Sheep meat	67
Beef	60
Sugar	35
Grain	10

Australian Bureau of Statistics, *Apparent Consumption of Foodstuffs, Australia, 1997–98 and 1998–99*, cat. no. 4306.0

-
- 5** Construct a histogram to represent the information in Table 4.2 graphically.

Value adding

Most agricultural products are processed in a variety of ways *after* they leave the farm and *before* they are purchased by the domestic consumer. But many of Australia's agricultural products (e.g. wool) are exported with very little processing. Doing all or some of the necessary processing before export (such as scouring and combing wool so that it is ready for spinning) means a higher price can be obtained for the product. That is, processing the wool is **value adding**.

Agriculture as an employer

In the 1950s and 1960s agriculture directly employed about 20 per cent of the Australian workforce. Now it employs 17.2 per cent. There has been a steady increase in the number of people employed in the industries servicing agriculture or supplying materials to be used on farms and in those industries handling and processing farm products. Farmers have come to rely more and more on improved technology and services to increase their efficiency of production. People are employed in services such as those that supply chemicals, fertilisers, fuel, machinery, marketing, insurance, banking and finance to farmers. They are also found in government agencies such as the CSIRO and state departments of agriculture, each of which carries out research and provides advisory services for the rural industries.

Two-thirds of the people working on farms are self-employed; that is, they own and operate their own farms. The remaining one-third is composed of salaried or wage employees. Of all people employed on farms 68 per cent are male. Lower returns for farm products and increasing costs of inputs – everything that must be purchased to keep the farm business going – has meant that hired labour is often no longer affordable; farmers look more and more to their spouses and families for assistance in running their farms. Farmers may still employ casual labour during important activities in the farm year, to assist where additional help is required (such as for picking fruit, baling hay, harvesting wheat and shearing sheep).

There is a steady drift of people from the rural areas to the large cities. There has also been an increase in the number of farms that are not their owners' only source of income; for example, where the owners have another job off the farm. Hobby farms are run as a means of recreation, and some are very successful. Many hobby farmers try to be self-sufficient and possibly sell some excess produce locally.

-
- 6 What percentage of the Australian workforce is employed in agriculture?
 - 7 Why do farmers look more and more to their families for help in running their farms?

Agriculture as a consumer

Agriculture is itself a consumer of resources, goods and services. These include land, labour, fertiliser, water, money, electricity, chemicals, fuel and machinery. The people who live and work on farms are also **consumers** of the products produced by other sectors of the economy – everything from cars and electrical goods to clothes, holidays and entertainment.

-
- 8 Explain how the agricultural sector of the economy is a consumer.

The future

Agriculture will continue to make a significant contribution to the Australian economy and to Australia's wellbeing. It will continue to play an important role as an export earner, as an employer, and as a consumer of what is produced in other sectors of the economy. The future of our agricultural industries depends largely on the conditions faced in overseas markets. Globally, the balance of agricultural trade is distorted by the use of trade barriers (such as the **tariffs** imposed by some countries) and subsidies (direct payments of money to support agricultural industries by governments in various countries). For example, the United States and Japan restrict the amount of meat they import from Australia.

Agricultural productivity growth is slowing and reflects the need for research and development so agricultural industries can meet future needs.

There is an increased awareness in the agriculture industry that what is done should be done sustainably. Farming not only involves the production of plants and animals but the management of plant and animal populations, interacting with each other and with their physical, biological and chemical surroundings. The farmer seeks to manage the farm environment so that there is a balance between the degree of land clearing and the needs of local wildlife; and to use natural pest regulation and computer-based technology to effectively target and therefore limit the amount of chemicals used in the natural system. **Sustainability** means that people involved in agriculture can make a living from the land while maintaining and improving the environment, so that production can continue into the future. It also means that communities, especially those in rural areas, should continue to provide the support and services needed by the people living in them.

Farming is now a series of complex decisions based on scientific, economic and social factors. Challenges include the effect of genetic engineering on farm management practices and marketing strategies; the effect of social and ethical issues introduced through animal welfare legislation and occupational health and safety legislation; and the degree of acceptance of genetically modified farm products by consumers.

9 List two things that distort global agricultural trade.

10 Construct a table with three columns and use this to list scientific, economic and social factors that affect farming.

Chapter review

Things to do

- 1 Use the weblinks to obtain the latest figures on the production and export of agricultural commodities for both your state and Australia.
- 2 List the agricultural industries in your district. What happens to the produce? Is it sold for local consumption, or for export?
- 3 Conduct a survey to find out the reasons for any population changes in your area in the last 10 years, using the survey below. Each member of the class should give the questionnaire to 10 people who are either working as an employee or self-employed. The results for the whole class can then be collated and conclusions drawn.

Population and employment survey

Please tick the box next to the answer that is the best answer for you for that question.

1	What is your age?	<input type="checkbox"/> Under 21 <input type="checkbox"/> 41–50	<input type="checkbox"/> 21–30 <input type="checkbox"/> 51–60	<input type="checkbox"/> 31–40 <input type="checkbox"/> 61 and over
2	What is your sex?	<input type="checkbox"/> Male		<input type="checkbox"/> Female
3	Are you ...	<input type="checkbox"/> Employed		<input type="checkbox"/> Self-employed
4	In which industry do you work? (You may tick more than one answer.)	<input type="checkbox"/> Farmer <input type="checkbox"/> Farm worker <input type="checkbox"/> Contract work <input type="checkbox"/> Retailing <input type="checkbox"/> Food <input type="checkbox"/> Clothing	<input type="checkbox"/> Insurance <input type="checkbox"/> Service <input type="checkbox"/> Education <input type="checkbox"/> Financial <input type="checkbox"/> Professional <input type="checkbox"/> Manufacturing	
5	How long have you lived in this area?	<input type="checkbox"/> <2 years <input type="checkbox"/> 2–5 years <input type="checkbox"/> 6–10 years <input type="checkbox"/> 11–15 years	<input type="checkbox"/> 16–20 years <input type="checkbox"/> 21–25 years <input type="checkbox"/> >25 years	
6	In your opinion, has the population in your local area changed in the last 10 years?	<input type="checkbox"/> Increased <input type="checkbox"/> Decreased		<input type="checkbox"/> Not changed
7	In my opinion, the reasons for the change are: (You may tick more than one.)	<input type="checkbox"/> Fewer jobs available <input type="checkbox"/> Farm incomes have decreased <input type="checkbox"/> New industry has developed in the area <input type="checkbox"/> More jobs available <input type="checkbox"/> Many retirees have moved into the area		<input type="checkbox"/> Drought <input type="checkbox"/> Loss of services such as banks and doctors <input type="checkbox"/> Major industry has closed down <input type="checkbox"/> Impact of the mining industry on the workforce <input type="checkbox"/> Other reasons – please specify below <hr/> <hr/> <hr/> <hr/>

connect

Department of Foreign Affairs and Trade

connect

Department of Agriculture

connect

Australian Bureau of Agricultural and Resource Economics and Sciences

connect

National Farmers' Federation

🔍 Things to find out

- 1 Visit the [National Farmers' Federation](#) website and go to Farm Facts. Explain how agriculture contributes to the social, economic and environmental sustainability of Australia.
- 2 Assess changes that have occurred to the agricultural sector in the last 10 years. Use the library or search the internet.
- 3 What has happened to the population in your district in the last 10 years? Discuss reasons for any changes that have occurred.

connect

Yellow pages

+ Extension activity

- 1 Contact a business in your area that supplies goods and services to farms. Make a list of these goods and services. If you live in the city you could use the online telephone directory to find a business in a country town to contact.

connect

White pages

✓ Test yourself

- 1 List four sectors of the Australian economy.
- 2 List four of Australia's main agricultural export industries.
- 3 Define 'sustainability'.
- 4 Describe what has happened to the number of farms and the size of farms since the 1950s.
- 5 Discuss your concept of a family farm.
- 6 Identify two major markets for Australian farm produce.
- 7 As well as being a producer in the Australian economy agriculture has two other roles. Describe these two roles.
- 8 List three challenges farmers now face when making decisions about their business. Explain the likely effect of each factor.

CHAPTER 5

MARKETING AUSTRALIAN AGRICULTURAL PRODUCTS



Words to know

agribusiness those activities involved in the production, processing, distribution and marketing of food and fibre products

auction a public sale in which goods are sold to the highest bidder

carbonising removal of vegetable matter, such as seeds and cotton, from wool using acids and other chemicals

commodity goods of trade

firm a company conducting a business

grading dividing goods into similar quality lines or classes based on weight, colour, shape or other criteria

organic farming farming based on the use of organic (natural) materials

producer a person who produces goods or services

sustainable agriculture a system of agriculture that maintains production levels over a long time

transaction a commercial business carried out or performed where a conclusion or settlement is reached

Introduction

The **agribusiness** sector refers to the many industries that either directly or indirectly support the production, processing, distribution and retailing of agricultural products. Raising crops and animals on the farm is only one part of this process, along with the products, services and technologies developed to support particular production systems and markets. Farmers must develop the skills and knowledge needed to support the production and marketing of products. A knowledge of the products, services and techniques developed to support particular production systems and markets is also necessary.

Agricultural markets

Farmers are usually concerned with the marketing of products they produce. They can often increase returns by carefully timing the sale of produce. But the process of marketing is not only buying and selling, it is also the associated activities of transport, quality assessment, packaging, storage and promotion. In addition there is research and development associated with both the production of raw materials and their consequent processing, and the development of new markets and marketing strategies. The combined effect of these processes associated with buying and selling is to add value to the raw farm product or, in the case of fresh produce, to extend the shelf life of these products.

Many marketing operations have now been deregulated (they are no longer controlled by government) and farmers deal directly with processors. In some instances farmers have formed groups called cooperatives to market their products. In other cases, governments have set up marketing boards. These aspects of marketing are described in more detail later in this chapter.

A highly developed marketing system is required to distribute farm products to the place, at the time, and in the form required by consumers.

Marketing

Marketing may be simply defined as the performance of all the operations involved in moving products from the original **producer** to the consumer. The necessary functions of marketing are carried out by different marketing agencies. Some **firms** carry out several functions – buying, transportation, storage, **grading**, packaging, financing, selling and promotion – while others are more specialised. Some of the processes involved can be seen in this example of the marketing of milk.

- 1 Milk is collected from the cow and pumped to the farm's bulk storage vat.
- 2 It is collected from the farm vat by a milk tanker and taken to a receival depot in the region.
- 3 The milk is tested before being taken to the city dairy plant.
- 4 At the plant the milk is tested again and receives special treatment such as pasteurisation and homogenisation.
- 5 By setting different prices and creating different products, such as low fat or extra calcium milk, milk companies attempt to make milk attractive to as many different consumers as possible.
- 6 The milk is packaged into plastic containers or cartons.
- 7 Milk is distributed to retail outlets; for example, supermarkets.
- 8 Advertising, on television and in magazines, and promotion, such as sponsorship of sporting events, by dairy companies and retailers keeps milk in the minds of potential consumers as something they need to buy.

-
- 1 Define 'marketing'.
 - 2 List the stages involved in the marketing of milk.
 - 3 How is the importance of marketing measured?

Marketing operations have both physical and economic aspects. Transport and storage are considered to be *physical* operations. Capital and labour are considered to be *economic* operations.

Transactions occur, and a market is established when the price at which producers are willing to supply a given quantity of a **commodity** is equal to the price that consumers are prepared to pay for the same quantity of that commodity.

The importance of marketing can be measured by looking at the volume of products that pass through the marketing firms; for instance, the number of livestock slaughtered each year, the tonnes of wheat handled by various trading companies, and the number of wool bales handled by wool brokers.

The difference between the price received for a product by the farmer – often called the farm-gate price – and the retail price paid for an equivalent quantity of the product at the final point of sale is called the market margin. Much of the price paid by the consumer goes to the people in the middle – these include the wholesalers, retailers, processors and commission agents.



Figure 5.1 Much of the price paid goes to those in the middle.

Methods of marketing

There are several types of marketing associated with agricultural products.

Direct selling or contracts

With direct selling the grower negotiates directly with buyers or sellers via an agent at a set market location; for example, vegetable or flower growers at large produce markets. Market forces of supply and demand determine the price at which goods are exchanged. Farmers may also enter contract arrangements where they agree to supply a product of specific quality and quantity to the retailer at a set date and time. In this situation the grower is guaranteed a market for their product.

Objectively assessed product marketing

Here farm produce is sold on a preferential basis according to factors such as purity, protein content, fat content or frame scores. This principle applies to the marketing of products such as wheat, canola or fat lambs, where payment to the farmer depends on both quality and quantity of product marketed.

Marketing bodies

This type of marketing arrangement is under the democratic control of members (farm businesses) and is operated on a not-for-profit basis; for example, agricultural cooperatives or compulsory marketing boards supervised by federal and state governments.

Cooperatives

4 List the three types of cooperatives.

There are three types of cooperative.

- Market-focused cooperatives are owned by primary producers and provide assistance to farmers in meeting market quality and quantity needs. Consequently, processes that add value to the raw farm product are important. These cooperatives assist farmers with transport availability and standards, grading, packing, storage, promotion, wholesale, processing, distribution and export information and facilities. These services are usually funded through a levy imposed on the producers.
- Supply cooperatives are also owned by their members and use economies of scale to purchase feed, fuel, fertiliser, chemicals, seed and hardware for sale to farmers at lower prices.
- Agriculture service cooperatives and jointly owned operations provide specific and economic services for farmers such as herd improvement, supply of plant or equipment to process what a farm produces, and a range of marketing services.

Statutory marketing boards

These were set up in different states when voluntary cooperatives were found to have problems relating to the effective marketing of products because of their relatively small size. With statutory marketing boards, producers can seek the assistance of government so that legal powers can be used to force producers to market their produce through the board. The board is usually made up of producers and a small number of government officials. For example, the Rice Marketing Board, under a formal agreement with the Rice Growers' Cooperative, coordinates the purchase and marketing of rice in New South Wales. Statutory marketing boards are of decreasing importance as agricultural industries become more deregulated, as has occurred in the dairy industry, where milk is now sold by farmers directly to various milk processors.

Export control boards

In addition to the statutory marketing boards in the various states, there is a series of marketing boards set up under Commonwealth legislation. Originally, boards such as the Australian Meat Board (now Meat and Livestock Australia or MLA) were set up to check that the products being exported from Australia met minimum standards of quality and to regulate shipments to overseas markets at a steady rate. Firms had to have a licence from the boards before they could be involved in export trade.

A number of these boards have now been given actual trading powers instead of being restricted to the supervision of export transactions. More recently the efficiency of marketing has been determined by the amount of competition between all sectors of the marketing process. This has led to the deregulation of markets for many farm products such as wool and wheat.

Marketing developments

Two styles of management that affect the financial returns of Australian farmers are vertical and horizontal integration.

Vertical integration refers to the coordination between a number of stages in the production and marketing processes. One way of achieving control over another stage of production or marketing is to use contracts. This occurs, for instance, in the broiler industry. Here a processor may have a contract with a farmer to supply a certain number of birds at a certain age and an agreed price. The processor pays for the day-old chickens, the feed and the veterinary bills. Such a contract gives

the farmer greater security. Along similar lines, a large firm operating in the meat industry in the Northern Territory has its own cattle station, coastal killing centres and meatworks, refrigerated shipping lines, wholesale distribution facilities, and retail butcher shops.

Horizontal integration involves the linking together of firms at the same level of marketing. In a department store supermarket, for instance, groceries, meat and fruit are sold together. This also makes advertising more effective, and there can be a larger turnover of products at relatively low mark-ups.

Marketing of selected products

Wheat

The grains industry covers producers, handlers, marketing people, processors, manufacturers, researchers and consumers. Of all Australian grain produced, 80 per cent is exported, with wheat accounting for 70 per cent of the value of grain exports. The largest export markets are South-East Asia, other Asian countries, Japan and the Middle East. In an effort to value add, wheat is sold as flat bread in Egypt, pasta in Italy and noodles in Japan, resulting in an expanded market share.

A variety of marketing systems have existed since 1948, designed to provide farmers with a guaranteed minimum delivery price and to protect them from the severe market price fluctuations that can occur if too much or too little wheat is produced due to events such as floods, drought or disease outbreaks.

The Wheat Export Authority (WEA) was the overall wheat export industry watchdog. It arose from the privatisation of the Australian Wheat Board (AWB) in 1999 and ceased operations in 2012. The single-desk model – where only one company was responsible for the export marketing of wheat – ceased in 2006. The export market is now made up of a number of international companies while other companies have been consolidated. There has been an increase in the number of smaller trading companies in the market, helping farmers find the best marketing opportunities. The market will continue to develop as it changes from its regulated position under the single-desk model to the current deregulated market structure.

There are a variety of marketing options available to wheat growers. Farmers can sell their crop before harvest using a forward-selling approach or base prices on international markets. Both these methods expose the farmer to some market risk. Futures contracts may be used through the Australian Stock Exchange allowing better risk management. Producers who do not wish to be exposed to market risk can engage external providers or market their grain using *pools*. In a pool system, farmers market their grain along with other producers and the farmers receive a payment that is based on the returns gained from the pool of grain sold.

Wool

The major markets for wool are China, India and Italy. The demand for wool has declined in recent years but should improve with improving economic and seasonal conditions.

The main method used by woolgrowers to sell their wool is public **auction**. Individual woolgrowers send their clips to a wool-selling broker who arranges for them to be stored; samples are taken for laboratory tests, and arrangements made for the wool to be valued and offered at a later sale. Farmers can also use forward-selling contracts, based on quality and the futures market. The value of the raw wool product can be increased by scouring and **carbonising** wool.

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- 5 What does 'vertical integration' mean?
 - 6 What does 'horizontal integration' mean?

connect

AWB

For more information on wheat production and marketing in Australia, go to the Australian Wheat Board website.

connect

GRDC

For more information on wheat production and marketing in Australia, go to the Grains Research and Development Corporation website.

-
- 7 List the countries to which wheat is exported.
 - 8 Where can wheat growers sell the wheat that they produce?

connect

NFF

For more information on wool production and marketing in Australia, go to the National Farmers' Federation website.

The promotion of wool in Australia and around the world is conducted by other government agencies. In 2001 Australian Wool Services Ltd replaced the Australian Wool Research and Promotion organisation and in 2002, Australian Wool Innovation Pty Ltd demerged and this company is responsible for managing the wool levy funds directed towards industry and marketing research and development. The wool levy is currently set at 2 per cent and applies to the gross value of shorn wool.

The Woolmark company works to provide quality assurance, innovation and information to growers and purchasers via promotion of the woolmark symbol. This company is self-funded from the licensing of its wool logo and its promotion of wool products.

- 9 What is the main method of selling wool?

Meat and livestock

For more information on marketing livestock in Australia, see the [Meat and Livestock Australia \(MLA\)](#) and [Aus-meat](#) websites.

In Australia 2.1 million tonnes of beef and veal are produced each year. In terms of volume, beef is the second-most popular fresh meat consumed after poultry. Major export markets for beef and veal are Japan, the United States and Korea.

The Australian beef industry contributes 17 per cent toward total Australian farm exports.

There are a number of ways of marketing livestock and meat to consumers in Australia and to export markets.

Australian sheep meat consists of lamb and mutton. There are over 10 700 specialised sheep farms and properties in Australia. Australian sheep meat production accounts for 8 per cent of world production. The main market for lamb export is the United States; mutton exports mainly go to China and Saudi Arabia.

The main methods of selling are by auction at saleyards (Fig. 5.2), in the paddock, and by 'over-the-hook' agreement at meat works. All animals have to be slaughtered at a licensed abattoir. At the retail level, meat is sold mainly in the form of chilled cuts in supermarkets or by specialist butcher shops.

Statutory control over meat marketing in Australia is shared between a number of state authorities and one Commonwealth authority – the MLA. The MLA has several main functions:

- to improve the production of meat and livestock in Australia
- to encourage and promote the sale and consumption of Australian meat, and the sale of Australian livestock, both in Australia and overseas. Meat Standards Australia provides a quality endorsement for graded cuts of red meat based on standards for tenderness, juiciness and flavour.
- to encourage, assist, promote and control the export of meat and livestock from Australia.

Eggs

The Australian Egg Corporation Limited (AECL) provides research, marketing services and promotional activities for the industry to promote increased demand for eggs across Australia irrespective of brand names. Marketing activities include various types of advertising on radio, in magazines and online. An educational program regarding nutrition and eggs is also available. Visit the weblinks to see examples of marketing and educational activities. For every chicken purchased by an egg-producing farm the AECL receives 46 cents as a levy in total for promotion. Eggs are sold under a variety of labels, including organic, free range, barn and cage.

connect

MLA

connect

Aus-meat

- 10 Identify the main methods of selling livestock.

- 11 Describe the main functions of the MLA.

connect

AECL

Information on the egg industry in Australia

connect

Australian eggs

connect

Egg Nutrition Council



Shutterstock/Lakeview Images

Figure 5.2 A cattle auction

Dairy

Australian dairy farmers produce 9102 million litres of whole milk per year with a farm-gate value of \$4 billion. Milk products are sold as cheese 34 per cent, whole milk 25 per cent, skim milk or powdered milk 24 per cent, whole milk powder 11 per cent, casein or butter 3 per cent and remainder 3 per cent. Australia accounts for 10 per cent of world trade in dairy products.

The average size of the Australian herd is 220 cows; on average one cow produces 5445 litres of milk per year. Australia exports 45 per cent of its annual milk production mainly to Japan, China, Singapore and Indonesia.

Victoria produces 65 per cent of Australia's total milk production, compared to 12 per cent in New South Wales.

Milk can be used either in the liquid milk market or to manufacture dairy products such as cheese, milk powder, cream, buttermilk, condensed cream, yoghurt and ice-cream. Milk used to make dairy products returns a lower price to the farmer than milk used in the liquid milk market. Individual milk factories control the pricing and distribution of milk for the liquid milk market. The price paid to farmers depends on the quality of milk as determined by factors such as high fat and protein levels and low levels of micro-organism activity. To ensure year-round production and to avoid penalties for not meeting entitlement levels, farmers make sure calving patterns are coordinated to maintain a constant supply of milk during the year.

Before July 2000, milk production on farms was regulated by a quota system supervised by a marketing authority. This process has been replaced by a contract system administered by individual processing companies in a deregulated environment. The dairy industry has also been restructured. It once consisted of three groups: the Australian Dairy Corporation looked after marketing; the Dairy Research and Development Corporation oversaw research, development and the commercial application of research outcomes; and the Australian Dairy Industry Council dealt with the process of milk manufacture and associated industry interactions. There is now one unified body, Dairy Australia, to cover all of these

-
- 12** What is the levy paid by farmers on purchase of chickens used for?
 - 13** List the variety of labels used to produce and market eggs.

-
- 14** List three factors that are used to assess the quality of milk and therefore its price to the farmer.
 - 15** What process has replaced the quota system for milk production?

connect

Dairy Australia

functions and promote milk quality. Funding for this change has come from a mix of farm levies and government research and development funding.

Visit the dairy websites for more information on the dairy industry in Australia.

connect

Dairy New South Wales

Organic farming

The retail value of organic markets in Australia is estimated at more than \$1 billion with an estimated future growth of 10–25 per cent per year. This is a diverse industry involved in both food supply and product manufacture such as cosmetics. The Australian organic food and farming industry has been in existence for more than 20 years although organic produce represents only 1 per cent of retail turnover, meaning this is a niche or small, specialist industry.

Organic farming is one type of **sustainable agriculture** that tries to ensure the long-term maintenance of productivity. Organic farmers have adopted low maintenance systems that are designed to meet the needs of the farmer, local resources and the consumer. Organic farming systems are environmentally functional in that they reflect a balance in inputs and economic returns.

In the organic farm production system, the farmer does not use inorganic fertiliser, manufactured chemical sprays or growth hormones to raise crops, manage pastures or produce animal products. On organic farms, the farmer's chief consideration is the natural cycling of material and the effect of management decisions on the total farm ecosystem and neighbouring living systems. The soil is seen as a reservoir for plant water and minerals as well as home for many types of micro-organisms and invertebrates, which aerate the soil, improve its structure and recycle minerals (this view is not unique to organic farming).

Organic farming is more closely tied to the effects of seasonality than conventional farming systems. Consumers may have to accept produce that is in season, rather than seeking a year-round supply of fruit and vegetables. Markets are more prone to situations of scarcity or glut. Organic farms are in general labour intensive but remain self-sufficient for all major inputs into production. Major marketing outlets include farmers' markets, agricultural cooperatives, supermarket and major retail contracts and export markets.

Production costs for organic farms are higher due to labour, transport and packaging costs. The general appearance of organic products can be less appealing to the consumer than that of conventional products. Fruit grown by conventional methods is often presented waxed and treated to avoid spoilage by fungi or bacteria. Organic products do not receive this treatment. Consumer awareness of health and environmental issues has proved to be the basis on which to develop a marketing strategy. Many large retail outlets now advertise a range of organic products, as more consumers are starting to prefer organic products because they are free of additives, including added hormones and antibiotics, and produced by environmentally friendly farming techniques.

Accreditation by one or more major producer groups of organic products is the only way to certify that the product being marketed was grown organically. An advisory committee called the Organic Producers Advisory Committee (OPAC) developed a national set of standards for produce, to assist states in developing legislation.

A certification scheme now operates as a guarantee to the consumer that the product is from an organic farming enterprise. The scheme is based on the use of printed logos representing a standard of production, on-site inspections of farming practices and an in-depth application review by a certifying agency. While each Certification body has differing standards they all meet the guidelines as developed by OPAC and the Organic Industries Standards and Certification Council.

connect

New South Wales Farmers

-
- 16 What is organic farming?
 - 17 List two advantages of organic farming.
 - 18 List two disadvantages of organic farming.

Major certification agencies include the National Association of Sustainable Agriculture, Australia (NASAA), Australian Certified Organic and the Bio-Dynamic Research Institute and several other organisations. Initially the standard is the responsibility of the farmer. The certification body oversees the production standards of the farmer, wholesaler and retail outlets. All certifying agencies are monitored by the Organic Federation of Australia. The Australian Quarantine Inspection Service officially oversees the entire Australian organic industry while the global organic market is overseen by the international Federation of Organic Agriculture Movements so overseas organic marketing standards can be achieved in our export market.

19 How are organic products certified for market as genuinely organically grown?

Chapter review

Things to do

connect

MLA

1 Look up the market report section in a weekly rural newspaper or at the [MLA](#) website (look at the physical market reports). Select one selling centre and write the price of one type of sheep and one type of cattle.

2 Go to your local supermarket and look at the different egg cartons. On what basis have the eggs been graded?

3 Go to the [Auctionsplus](#) website. How are computers used in the Auctionsplus system of marketing livestock?

4 Go to the [MLA](#) website and click the 'Cattle, sheep & goat industries' tab and experience a virtual farm visit. Write an account of your visit.

5 Go to your local saleyards and watch cattle, sheep or pigs being auctioned. Report on how buyers decide which animals they are going to purchase.

connect

Auctionsplus

Things to find out

1 List as many different advertisements for poultry products (chicken, eggs, fast foods) as you can find in the media (television, newspapers, magazines, junk mail) over one week.

2 Go to the [Dairy Australia](#) website.

a What is the function of this organisation?

b Why do they use a logo to promote milk products?

3 There has been a steady increase in the percentage of pigs sold direct to processors, usually on consignment. On what basis is payment made?

4 Evaluate the methods used to promote egg marketing in your state.

5 a How does MLA promote the increased use of red meats?

b Critically evaluate if the promotion of red meat has been successful.

6 'Agriculture traditionally is a system that exploits the environment with little consideration to long-term consequences.' Critically evaluate this statement.

7 a Visit the [AWB](#) website. What is the function of this organisation?

b Under the menu item 'About AWB' read the overview of the industry and summarise it so that you can present an oral or written report to your class.

connect

Dairy Australia

connect

AWB

+ Extension activities

1 Describe what effect deregulation has had on the price received by farmers and the price paid by consumers for milk.

2 Why are biosecurity measures important on poultry farms?

3 Choose a farm product and design and produce a 20-second radio commercial, video clip or PowerPoint presentation for it. Use sound effects and music to make your commercial attention-grabbing.

4 Define 'permaculture', then draw a diagram to show some of the design principles of this type of farming. Reflect on why these principles are used.

✓ Test yourself

- 1 Copy out these statements and fill in the missing words.
 - a Marketing of agricultural products may be defined as the performance of the operations involved in moving _____ from the original _____ to the _____.
 - b Much of the price paid by the consumer for agricultural products goes to the people in the middle. These include _____, _____ and _____.
 - c In _____ markets the grower negotiates directly with buyers or sellers via an agent at a set market location. For example, vegetable or flower growers at large produce markets.
 - d The _____ focused _____ assist farmers with transport availability and standards, grading, packing, storage, promotion, wholesale, processing, distribution and export information and facilities.
- 2 Copy out these statements and cross out the incorrect words.
 - a Statutory marketing boards are of *decreasing/increasing* importance as agricultural industries become more *regulated/deregulated*, as has occurred in the dairy industry, where milk is now sold by farmers directly to various milk processors.
 - b An example of *vertical/horizontal* integration is where one company owns the farm that produces the product, the factory that processes the product and the retail outlets that sell the product to the consumer.
- 3 Choose one agricultural farm product and describe in a paragraph one way a farmer could sell the product.
- 4 Discuss the principles on which organic farming methods are based.
- 5 Evaluate the process of certifying an organic product.

UNIT 3

FARM RESOURCES AND PRODUCTION SYSTEMS

CHAPTER 6

FARM ENTERPRISES

Words to know

boundary something that divides a system from its environment; it can be physical (e.g. a shed wall or fence), economic or psychological

environment the immediate surroundings

process an action that changes inputs into outputs

rate a measure of production in a specified time interval

system a group of objects that interact to achieve some purpose

Introduction

Within our agricultural industries, the main unit of production is the farm. A farm has one or more enterprises that can be readily identified; for example, dairy cattle, sheep for wool, or wheat production. Farm enterprises produce a product or products for sale. The farmer decides how to produce material by selecting the type of plants and animals needed for production. Agricultural production on a farm is very complex.

- 1 List the different enterprises making up a farm you have visited, or the school farm.
- 2 Define 'system' and 'enterprise'.

A farm is a **system** consisting of interconnecting parts, like pieces of a jigsaw puzzle – parts such as plants, animals, soil, climate, management, micro-organisms, and insects and other invertebrates. Through good planning (and decision-making), a farmer organises these parts into enterprises to obtain products. These parts must all function together for the farm as a whole to produce materials that the farmer can sell.

Farm enterprises and processes

Within each enterprise of a farm or subsystem, certain basic **processes** occur to turn raw materials (inputs) into products (outputs). In a dairy enterprise or subsystem, for example, these basic processes include growth, milk production, digestion and many other functions that allow the dairy cows to live and produce milk. A similar situation exists for plant enterprises such as growing wheat. Fundamental processes, such as the absorption of water and nutrients from the soil and the conversion of raw materials into sugars (food manufacture/photosynthesis), are necessary for life and the production of the wheat grain. Look at the farm system shown in Figure 6.1 and study the various inputs, outputs and subsystems or enterprises that are shown.

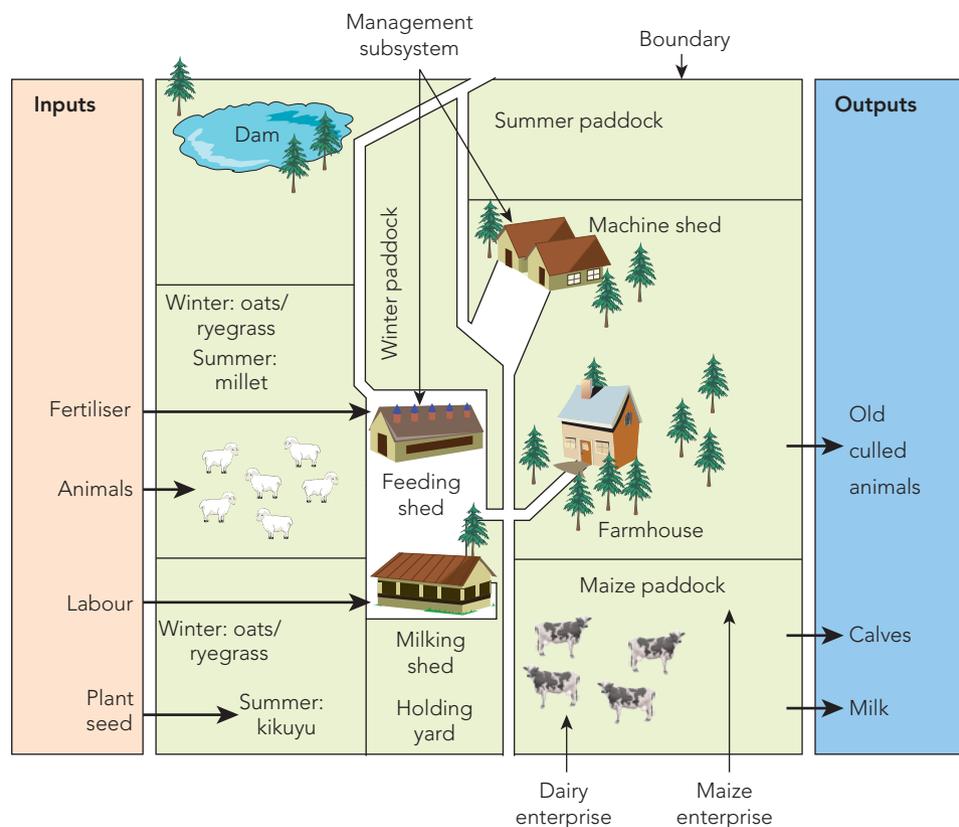


Figure 6.1 A farm production system

Farm inputs

Each process on a farm requires a source of certain materials (or inputs). It is the farmer who makes decisions about the type and level of production on a farm – decisions involving the achievement of definite goals in production management. To successfully harvest products, the farmer must add inputs or materials to the farm and use them. These inputs include the type of animal or plant chosen for production, the amount of money invested, the management system used, the fertilisers required, the irrigation levels and many other factors. The type and level of inputs decided upon by the farmer will affect how well each enterprise of the farm operates, the level of total farm production and ultimately the profit the farmer makes.

Farm outputs

Material produced on the farm is termed an output. Output from a farm is usually expressed in terms of how much is produced over a given time or area of land. This form of measurement is termed a **rate**. Examples include litres of milk produced per cow per year; number of piglets born per sow per year; or kilograms of wool produced per sheep per year. By the use of these measurements a farmer may determine how efficient the enterprises are; that is, how effectively inputs can be converted into outputs. This is a measure of the farm's biological efficiency and allows a direct comparison of productivity between similar enterprises on different farms; for example, the wheat yields across farms in a particular district. By keeping records of farm production levels, the farmer is able to check or monitor how well the farm is performing. Economic efficiency refers to how much money is returned by a particular enterprise or subsystem on a farm. This type of efficiency is determined by keeping records of the cost of establishing, running and maintaining the enterprise relative to what is gained when the product is sold at market.

- 3 Define 'rate', 'monitor', 'biological efficiency' and 'economic efficiency'.
- 4 Identify some examples of rates.
- 5 What factors affect how well an enterprise on a farm can operate?

Limiting factors

There are many factors that can reduce or hinder production on a farm. These include the occurrence of competitors (pests, weeds and disease); those related to the local **environment** (the adverse effects of climate or soil on production); and bad management practices such as poor feeding of animals, overcropping or overgrazing. A skilful farmer will attempt to overcome these limiting factors by correct selection and use of inputs. This allows the basic processes on a farm to operate efficiently. Figure 6.2 indicates some of the factors that may limit production on a farm.

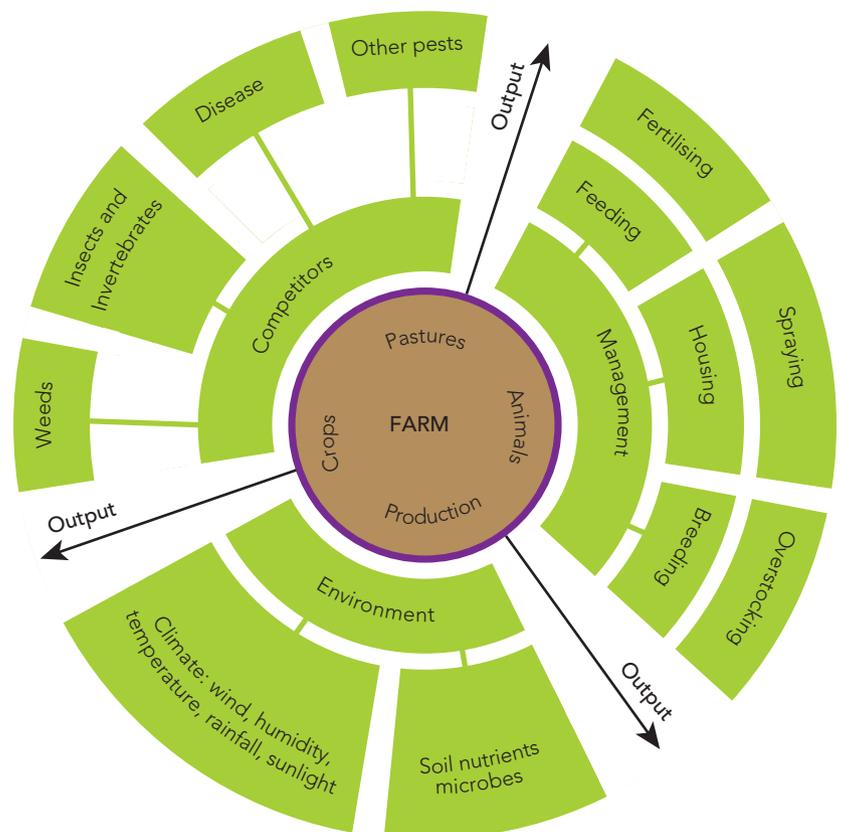


Figure 6.2 Factors influencing production on a farm

- 6 Define 'limiting factor'.
- 7 Refer to Figure 6.2 and identify three factors that could limit crop production on a farm.
- 8 Refer to Figure 6.2 and identify three factors that could limit animal production on a farm.

- 9 Define 'farm boundary'.
- 10 Give some examples of the types of records a farmer may keep to accurately monitor farm production.

Farm management

Agricultural production occurs within a definite area – namely, the farm. To assist with the management of a farm it is convenient to consider it operating within a **boundary**. One boundary for many farm production systems is the fence line around the outside of the farm (i.e. the boundary fence).

Other boundaries include:

- how much land is available
- what the farmer can afford to buy
- the farmer’s ability to manage a certain area of land
- the farmer’s ability to carry out a number of farming activities
- the farmer’s skill level.

The management of a farm does not only involve activities with plants or animals; all parts of the farm must be managed.

The farmer monitors the level of farm production in terms of the amount produced from the farm (quantity) and the quality of this product. These records can be kept in books or on a computer. Figure 6.3 illustrates a model of a plant enterprise. If satisfactory production levels are obtained, the farmer may not alter the type or quality of inputs into the various farm enterprises. When production is not satisfactory, the farmer may need to make changes to aspects of the farm enterprises (such as the type and level of input), or to the processing part of the enterprises. The farm manager must also take into consideration what effect production decisions will have on the environment, both on the farm and in the surrounding areas.



Figure 6.3 A model of a plant enterprise

Chapter review

Things to do

- 1 Copy Figure 6.4 into your notebook. List the main inputs required by the cow to produce milk. List other products that may be made by processing the milk.

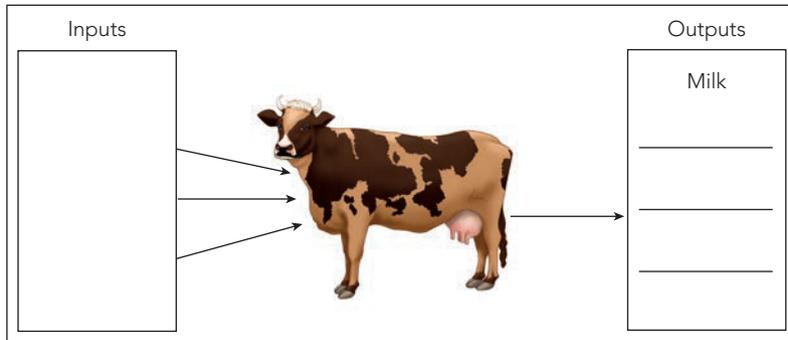


Figure 6.4 A production model

- 2 Make an accurate map of a farm or the school agriculture plot. On this map show (by means of arrows) major inputs into the system. List major outputs. Describe, or show on the map, the main enterprises on the farm.
- 3 Choose an animal or plant production enterprise and list three different types of records that would be kept by the farmer to monitor production.

Things to find out

- 1 What effect do the local environment, the needs of the townspeople and the influence of government have on the way the farmer manages the farm?
- 2 Interview a farmer and find the answers to the following questions.
 - a What are the boundaries to the farm system?
 - b What are the major enterprises of the farm and the products produced by each enterprise (i.e. outputs)?
 - c What are the major inputs or materials used for each enterprise?
 - d What factors limit the production potential of the farm?
 - e List the ways the farmer records information needed to monitor farm production.
 - f Does the farmer use a computer to record information? If so, what records are kept?
- 3 Discuss why farmers are concerned about the efficiency of their operations.
- 4 Is this efficiency expressed in terms of money only, in terms of energy use (e.g. fuel), or in other ways?

- 5 From your interview in question 2, do you think it is possible to isolate management of the soil from the plant or animal enterprises on the farm when managing production? Give reasons for your answer.
- 6 From your observations of the farmer and the farm production enterprises, can the activities and production levels of the farm be improved?

+ Extension activities

- 1 Make an illustrated A3-sized poster that shows the way an enterprise on a farm can be viewed as a system. Include inputs, processes and outputs. Use pictures cut from magazines or photographs of an enterprise on the school farm taken with a digital camera.
- 2 Identify and discuss interactions within and between agricultural enterprises on the school farm.
- 3 Go to the [Virtual farm](#) website and list the interactions that are occurring within and between the various farm enterprises shown. You may wish to develop a website for your own farm using similar models.

connect

Virtual farm

✓ Test yourself

- 1 Write a paragraph that shows you understand the difference between these terms.
 - a Inputs and outputs for a farm
 - b An enterprise and a process
- 2 What is a limiting factor for an enterprise? Use a specific example in your answer.
- 3 A dairy farmer keeps careful records of the amount of milk produced each day. Describe two ways these records could be used by the farmer to help manage the farm.
- 4 The rate of production of wheat from a farm is 4 tonnes per hectare per year. From another farm it is 2 tonnes per hectare per year. Describe and discuss two factors that could have caused the rate of production of wheat to be different on these two farms.

CHAPTER 7

THE FARM ENVIRONMENT

Words to know

autotroph an organism that produces its own food

biodiversity the range and variety of organisms and their relationships in a system

biotic relating to living organisms

carbon credit a certificate or permit to allow the production of 1 metric tonne of carbon dioxide or another greenhouse gas

carbon sequestration natural or artificial process that removes and traps carbon dioxide from the atmosphere

carbon trading an emissions trading approach that relies on the buying and selling of carbon credits

direct drilling direct placement of seed into the soil with little or no soil preparation

ecosystem the relationship between an interacting community of organisms and their physical environment

greenhouse effect the overall increase in temperature caused when solar radiation is unable to escape from Earth's atmosphere because of the build-up of atmospheric gases, particularly carbon dioxide

heterotroph an organism that needs a supply of food from its surroundings

mycorrhiza an association between a fungus and the roots of a plant

output items or material produced in a system and removed from it

soil acidification the processes by which soils become more acidic

soil degradation the breakdown of soil structure and loss of fertility

soil salinisation the processes by which salt accumulates in the surface layers of the soil

stubble retention the residue left after a crop is harvested is not removed by burning or any other means but is retained so that it decomposes and is incorporated in the soil

subsystem a system that itself forms part of a larger system. This may be a farm enterprise, such as growing wheat, or a discrete unit of the farm, such as the soil

sustainability the ability of a farm to maintain and improve its environmental resources, such as soil and biodiversity, and to continue to be profitable

withholding period the period of time after the application of a chemical during which the plants or animals treated cannot be used for human consumption or processing

Introduction

Buying a farm represents an enormous investment of both time and money. A farmer will choose the district in which to buy a farm based on personal preference for a location, experience with a particular type of farming activity (it should suit the type of farming activity that the farmer will undertake), and environmental and economic considerations. Climatic and soil effects are also very important factors. Due to climatic effects certain districts give farmers some seasonal advantages in production. Other environmental factors to be considered include water sources (apart from rainfall), the presence of trees, the presence of helpful organisms (e.g. dung beetles) and the presence of weeds or pests (e.g. rabbits and foxes) and their effect on total production levels.

Soils are important. How easily a soil can be cultivated, levels of nutrients in the soil, drainage and availability of irrigation are factors that farmers consider when purchasing a property. The presence of soil-borne pests or disease such as crown gall, nematodes, tetanus or take-all can have significant effects on the success of any farming venture.

In addition to these physical factors there are personal and economic considerations for any farmer. The likely future potential for any industry is very important. This relates to how strong the market is and whether products from the farm can be processed locally so transport costs are minimised. The farmer's personal skills and management ability are also important in developing farm enterprises, as is knowledge of local and state government regulations relating to farm activities and the marketing of farm products.

A farmer is the manager of an agricultural system. When a change is made to farm operations, such as an increase in stocking rates, adding fertiliser to a soil or selecting a method of pest control, this decision to alter the farm environment often affects many other aspects of the farm. For example, if a farmer changes the amount of fertiliser placed on a pasture there is a direct effect on soil fertility. The type and amount of fertiliser used may also affect the level of acid in the soil (the soil pH), which may in turn influence the type and number of soil micro-organisms. Plant growth is stimulated due to the application of the fertiliser, and more organic matter is then created as the extra green material eventually dies and decays. The increase in soil organic matter influences soil structure and water-holding capacity. With an increase in plant growth due to a variation in fertiliser use, more livestock could be carried on the pastures in the paddocks. The presence of more animals may lead to changes in management – changes to yard or shed design, labour demands, equipment capacity or methods of recording production levels. So a change to one aspect of farm operation can influence many other associated farm activities.

A farm is made up of a number of interlocking pieces that operate together to create a common environment. These interlocking pieces, or **subsystems**, result in particular materials or products being produced on the farm through a range of farm enterprises which are selected and managed by a farmer because of their suitability to the environment, the farmer's personal skills and economic forces.

Materials are added to the farm system for the various farm enterprises to work. These materials are termed inputs and include items such as seed, fertiliser, replacement animals, various animal feeds and water. The items or material produced in a farming system and removed from the farm are called **outputs**. A model of this concept is shown in Figure 7.1. To reflect the more realistic and dynamic nature of a farm, a detailed model is needed that shows the main *farm enterprises* and how they interact with the farm environment and the management style of the farm. Figure 7.2 illustrates the impact of these forces on farm output.

-
- 1 Outline the factors that should be considered when deciding on an area in which to buy a farm.

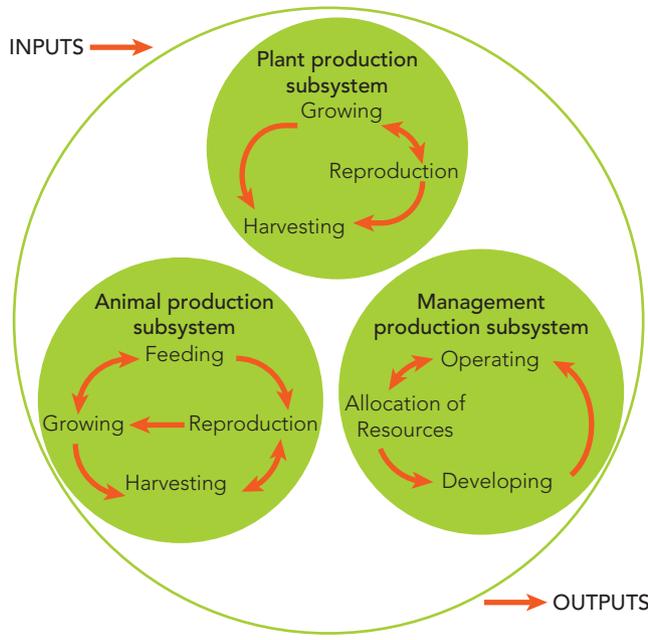


Figure 7.1 A static model of a farm

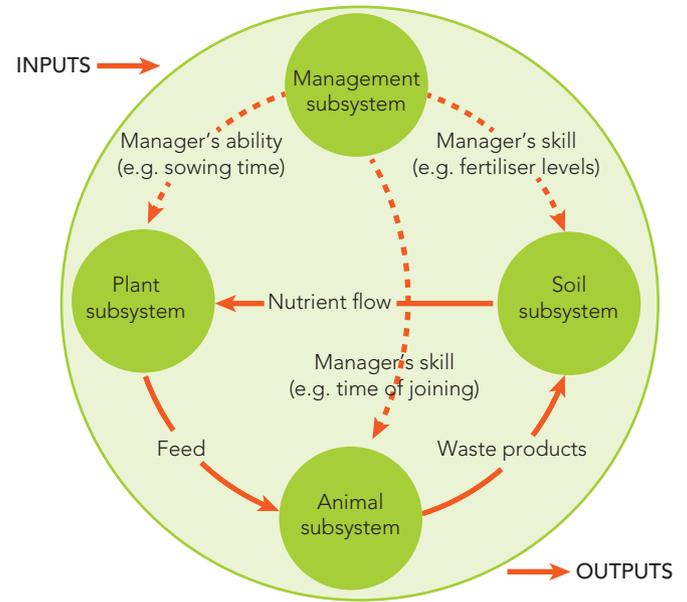


Figure 7.2 Farming system

Natural environments

An organism's surroundings or environment have two basic components:

- 1 a non-living part concerned with such resources as soil and climate
- 2 a living or **biotic** part concerned with living organisms such as micro-organisms, plants and animals.

A group of living organisms, their relationships with each other and their environment is termed an **ecosystem**. To survive and multiply, organisms require certain environmental conditions. These include suitable climatic conditions – rainfall, temperature, light, humidity – and a source of food and shelter. There is also a dynamic interaction between organisms. The competition for available resources affects growth and production over time. This relationship between organisms and their environment is ever changing, both on the farm and in natural systems. It allows many species of organism, both plant and animal, to live in the same area of land, some existing independently and some depending on others for survival.

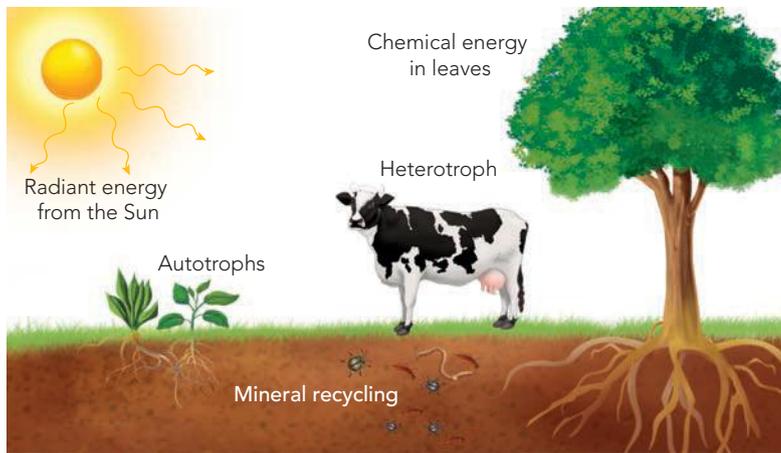
Within a naturally functioning ecosystem two things happen. First, there are means of supplying all organisms with energy. Second, minerals are recycled from dead remains of plants and animals back to living communities.

- 2 Define 'biotic', 'environment' and 'ecosystem'.

Energy flow

Figure 7.3 shows an ecosystem in which there is a flow of energy from the Sun to plants, which convert this radiant energy to chemical energy in the form of sugars. The animals that eat plants then get their energy from these plants. Those animals that live off other animals obtain their energy indirectly from plants. The energy flow in this natural system forms an open system – the energy from the Sun, which is stored in the plants, is either eaten by animals or the plants die and energy is lost.

Organisms (plants and certain bacteria) that can manufacture their own food are called self-feeders or **autotrophs**. Organisms that feed off others are called **heterotrophs**. *Decomposer organisms* live in the soil and recycle minerals, such as carbon, nitrogen and calcium, in a functioning ecosystem.



There are significant areas of energy loss on a farm and only a small amount of energy from the Sun is eventually contained in animal products (Fig. 7.4).

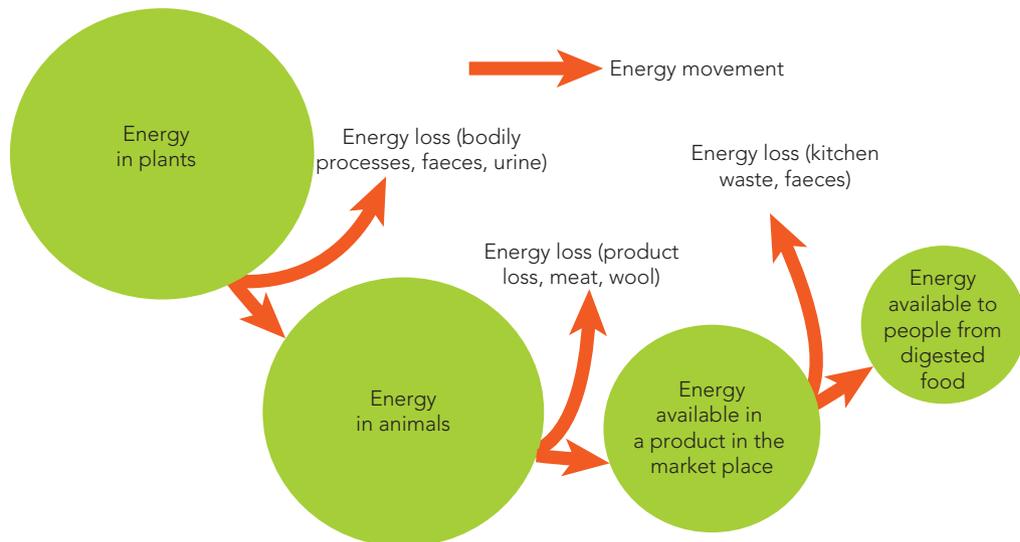
Mineral cycles

Nutrients in the form of minerals are also cycled between the living and non-living parts of the environment, by means of micro-organisms. Microscopic bacteria and fungi, as well as many invertebrates (animals such as worms and insects that do not have an internal backbone),

Figure 7.3 A functioning ecosystem

decompose the remains and wastes of plants and animals that are found in the soil, releasing the chemical elements found in them. These elements can then be absorbed by roots and used by plants again. Figure 7.5 illustrates how decomposer-type organisms assist in the release of minerals and how these minerals move through a living system. The cycling of minerals is an example of a *closed system* in

- 3 Identify the autotrophs shown in Figure 7.3.
- 4 Copy Figure 7.4 into your notebook. On it, trace how energy moves through the system.



- 5 Name some decomposer organisms.
- 6 List three elements that are cycled in nature by micro-organisms.
- 7 Define 'leaching'.
- 8 Why could leaching become a problem?
- 9 Refer to Figure 7.5. Describe how plants take up minerals from the soil.
- 10 What do you think would happen if all the decomposer organisms were eliminated from the world?
- 11 Examine Figure 7.5 carefully. If a mineral such as copper did not exist in the soil on a farm, why could animals on the farm suffer from a copper deficiency?

Figure 7.4 The fate of energy on a farm

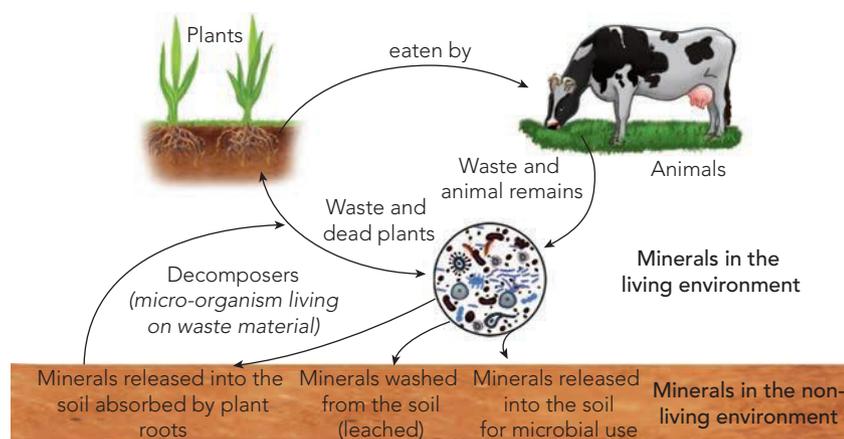


Figure 7.5 A nutrient cycle

that minerals are cycled between the living and non-living parts of the environment. *Leaching* occurs when mineral nutrients are washed down through the soil. If they are leached down past the roots they are lost to the system.

All elements in nature, especially nitrogen, carbon and oxygen, can be recycled in this way.

In general, scientists and farmers are developing a greater understanding of how to manage agricultural systems to provide long-term productivity. In areas where the climate limits what farming activity can take place, farmers must take other factors into account:

- the amount of vegetation cover and its rate of regrowth
- the level of soil fertility and structural stability
- proper farm planning, including placement of fences, roads and watering points, to prevent damage to the soil
- how the land has been classified if there is a state classification scheme.

Carbon is cycled continuously in nature, mainly in the form of carbon dioxide (CO_2) and carbohydrates, as shown in Figure 7.6. Carbon dioxide enters the atmosphere in many ways. All animals breathe out carbon dioxide, formed from food (which contains a lot of carbon-containing carbohydrates) being used in their bodies. When dead plants and animals decompose, carbon dioxide is also given off. Vast quantities of carbon dioxide are released by the burning of fossil fuels, such as oil, petrol, coal and natural gas, which are all partly made up of carbon. Much of this carbon dioxide in the atmosphere is consumed by trees and other plants to help make sugars (or carbohydrates). Because plants absorb carbon from the atmosphere, forests and other areas of large plants are called carbon 'sinks'. As the use of fossil fuels has increased, the level of carbon dioxide in the atmosphere has gradually built up. This reduces the

connect

Dairy Australia

Further information on the greenhouse effect and climatic change.

12 Refer to Figure 7.6 to describe the carbon cycle.

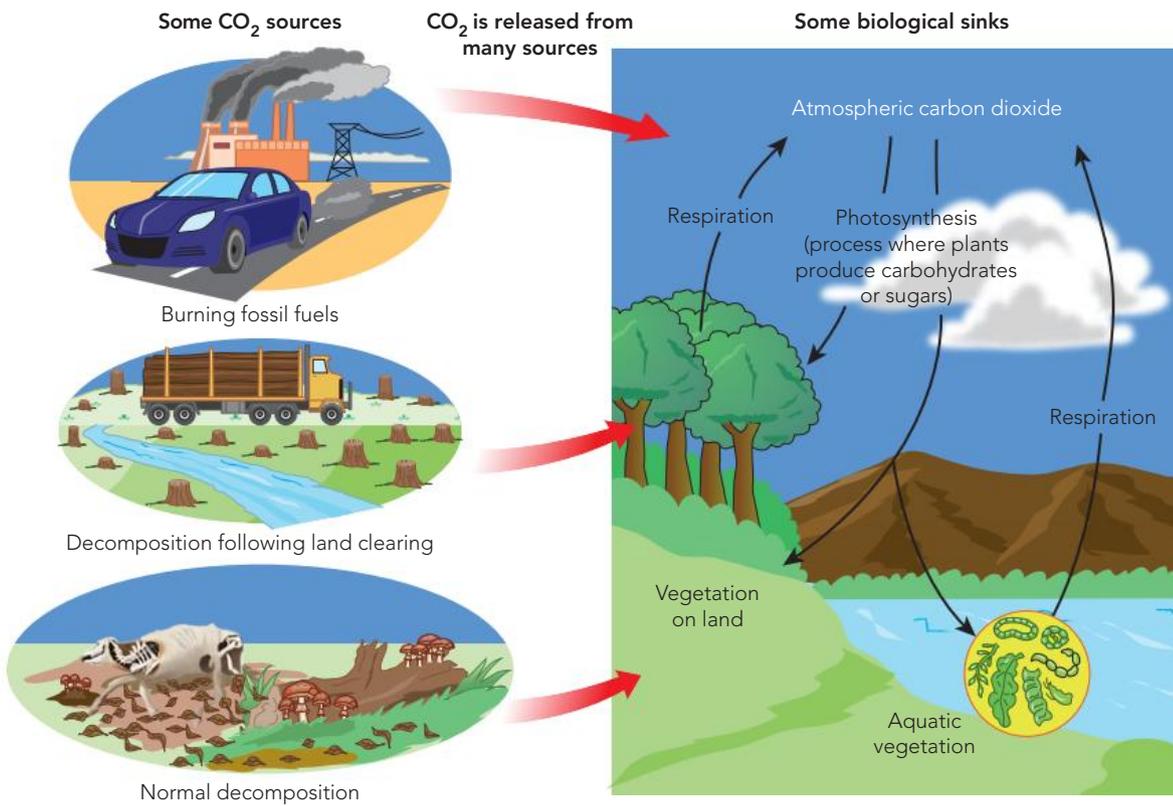


Figure 7.6 The carbon cycle

amount of heat radiated back into space from Earth and results in an increase in the surface temperatures of the planet. This process is called the **greenhouse effect**.

Nitrogen forms an important part of many compounds found in living organisms; for example, chlorophyll (in plants), protein and enzymes. Animals can only obtain the nitrogen compounds needed to make essential body tissues (such as muscle) from the plants they eat, urea supplement blocks (which contain nitrogen compounds), or from eating other animal tissue. The animal food chain when traced back eventually leads to a herbivore or plant-eater and then to plant matter. Grasses obtain the necessary minerals to make proteins from the soil, and legumes obtain them through the process of nitrogen fixation through a symbiotic relationship with *Rhizobia* bacteria that grow in the roots of legumes. In addition, when a legume dies and decomposes, the nitrogen compounds it contains are released over a period of time for uptake by other non-legume plants and micro-organisms. Over time, the soil's nitrogen reserves will increase. Figure 7.7 indicates how both a grass (or non-legume plant) and a legume plant such as clover obtain their nitrogen needs.

13 Examine Figure 7.7 and describe how grasses and legumes obtain nitrogen materials from the soil.

Several processes occur between the initial organic matter breakdown and the final intake of nitrogen by the plant. Under certain conditions nitrogen may be released back into the atmosphere, representing a net loss of nitrogen to the farming system. If soluble minerals that contain nitrogen, such as nitrates, accumulate too

rapidly in the soil, which can occur after burning stubble, the minerals are easily leached and lost to the farm system. Loss of nitrates in this fashion also results in the soil becoming more acidic. Figure 7.8 illustrates the steps involved in the nitrogen cycle.

Some soils thought to be unproductive can be made highly productive by the introduction of *trace elements*. The quantity of mineral required is very small, unlike the quantity of superphosphate needed for the same result. In other instances, where a soil is known to be deficient in certain chemicals, thus limiting animal growth and development, mineral supplements can be supplied to the animal directly in the form of salt blocks or mineral pellets. In animals such as cattle, sheep and goats, the pellet lodges in the animal's reticulum (second stomach) and slowly dissolves, releasing the chemical. The necessary supplements for some chemical deficiencies are shown in Table 7.1.

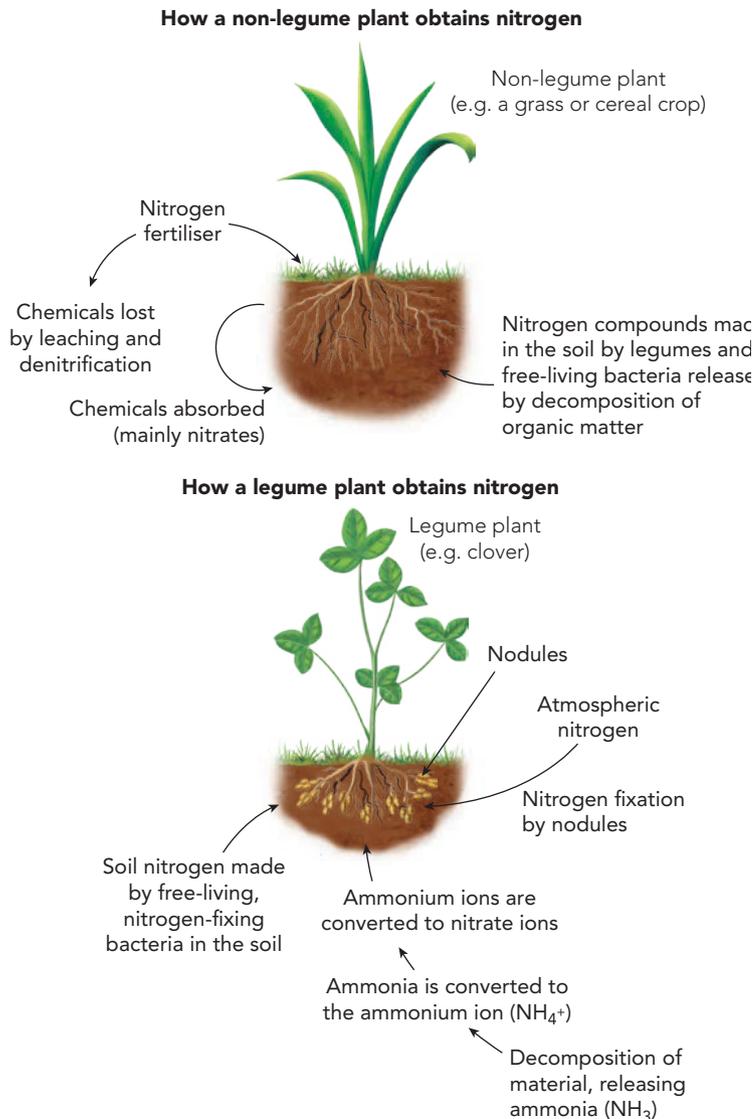
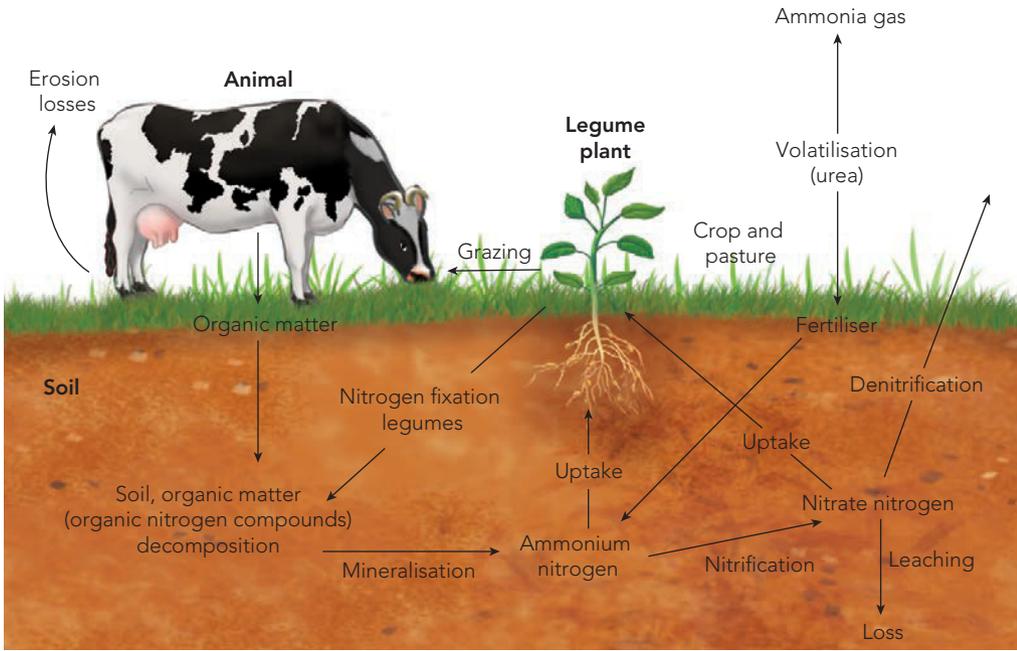


Figure 7.7 How plants obtain nitrogen



14 Refer to Figure 7.8 to describe the nitrogen cycle.

Figure 7.8 The nitrogen cycle

Table 7.1 Some chemical deficiencies

Deficient chemical	Effect of deficiency	Cure
Cobalt	Coast disease in sheep	Cobalt pellets
Selenium	White muscle disease	Selenium pellets
Iodine	Disturbed metabolism of sheep	Iodine in salt block
Molybdenum	Poor nodulation in legumes	Molybdenum – superphosphate mixture or the equivalent

- 15** Why should farmers take care with the management of soil?
- 16** Give three examples of minerals that can be added to a farm system to improve productivity.

Biodiversity

Biodiversity refers in broad terms to maintaining the many and varied living systems in an environment or, in agricultural science, on a farm. This includes soil, plant and animal subsystems, and the interactions between these subsystems. Part of maintaining biodiversity on a farm is the preservation of endangered species. Biodiversity assists in the recycling of chemicals in the soil, provides for a biological means for pest control and allows for a more balanced approach to the manipulation of farm inputs. By considering the whole environment of the farm and the effect of farming techniques on this environment, a more sustainable farming system can be developed, which is important for long-term profitability.

connect

Biodiversity

The Commonwealth Department of Environment provides more information on biodiversity.

17 Explain 'biodiversity'.

Agricultural systems

Agricultural ecosystems differ from natural ecosystems in several ways:

- the need to resupply certain inputs to the system
- the number of different plants and animals often not found naturally in the local area
- specific operations needed to manage the climate and soil on the farm.

To operate a farm effectively, farmers need to consider why they manage operations in particular ways and to assess the effect of these operations on the environment. Sustainable farming goals cover the following broad objectives:

- 1 enhancing farm productivity over time
- 2 reducing negative environmental effects such as **soil acidification**, erosion, catchment area contamination
- 3 reducing the build-up of chemicals – both helpful and toxic – in the environment
- 4 maintaining biodiversity.

Some more recent management trends, especially on small- to medium-sized farms, include allowing for habitat development and wildlife corridors on farmlands, and fencing off wetlands. Controlled irrigation and water management schemes to maintain creek levels and natural flow patterns are used to reduce creek-bank degradation and tree loss in several rural communities.

There are many economic and marketing factors that determine the management style needed to successfully operate broadacre (large) farms and intensive livestock operations, such as feedlot beef farms. The challenge on these farms is to adopt the best practice that maximises both **sustainability** and economic profitability.

The farm ecosystem and sustainability

Because of the drain of plant and animal material from the farm through the normal processes of creating and marketing products, soil nutrients are not effectively recycled and available energy reserves may become small. This is illustrated in Figure 7.9.

The farmer may need to add minerals to the farm production system by using fertilisers. The farmer has to decide which inputs are needed to obtain a satisfactory level of production. The fine balance that exists in nature between organisms and their environment also needs to be maintained.

If this balance is not kept, farm production eventually falls and farm sustainability is threatened. Extensive damage may be done, not only to the farm's production system, but also to a resource such as the soil, which is required by surrounding natural and urban systems as well.

Because of this drain of material away from the farm, it is not a closed system, as found in nature, but an open system. Farmers recognise that the natural cycling of chemicals may become disrupted and that constant adjustments are needed: farmers consider the farm as a managed extension of the natural environment.

In the process of improving rates of production and efficiency levels on farms, farmers have sought to reduce factors that limit production, such as pests and diseases, poor nutrition and lack of resources like land and water. But a lack of understanding of the natural environment in the past, coupled with the need for short-term gains at the expense of long-term sustainability, has led to problems of land degradation.

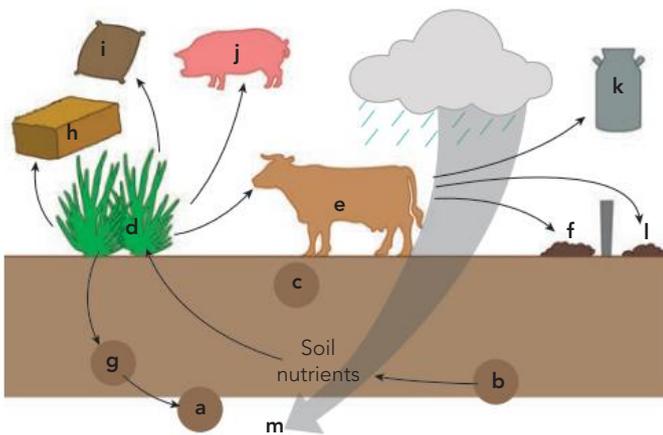


Figure 7.9 The fate of soil nutrients on a mixed farm: **a** released from decaying organic matter; **b** released from weathering soil minerals; **c** added as fertiliser; **d** taken up by plants; **e** passed into animal bodies; **f** returned to soil in manure; **g** returned to soil in green manure or leys; **h** leave farm as hay; **i** leave farm as bagged grain; **j** leave farm as meat; **k** lost to farm as dairy products; **l** lost by transfer to another paddock in manure; **m** leached from soil by rainfall

Carbon trading

Agricultural industries can be considered in general to contribute to the production of greenhouse gases. Examples of farming practices that lead to this situation include land clearing, stubble burning, grain harvesting and intensive livestock enterprises. The major greenhouse gases involved are carbon dioxide (CO₂), methane (CH₄) and dinitrogen oxide (N₂O).

In 2012, the Labor Commonwealth government introduced a carbon pricing scheme that allows **carbon trading**, requiring businesses emitting more than 25 000 tonnes of CO₂ annually to purchase emissions credits. This applies to some 300 industries in Australia. The carbon pricing system is based on **carbon credits**. The initial price for a permit for 1 tonne of carbon was fixed and this price was to rise by 2.5 per cent per year in a transition to an emissions trading scheme. The Liberal government that was elected in 2013 has promised to abolish the carbon trading scheme but will need the cooperation of other political parties to do this.

The pricing was part of an incentive scheme called the Clean Energy Plan that aimed to reduce greenhouse gas emissions in Australia by 5 per cent below the year 2000 levels by 2020. This level would be increased in later years.

Carbon emissions trading or a policy of 'cap and trade' is a market-based approach to control emissions. This means, instead of greenhouse emissions being fully regulated by law, people and companies are able to buy and sell the amount of emissions they produce: in other words, a market for the emissions is created. The government sets a limit or cap on the amount of pollutants emitted. This limit is allocated to companies in the form of emission permits or carbon credits. Companies must purchase and hold enough permits to cover their carbon-based emissions. Should more permits be required companies must trade with other more efficient companies to buy permits. Industries that produce large amounts of carbon dioxide must buy additional permits. High costs associated with high levels of pollution should force industries to lower pollution levels.

Australia generates 1.5 per cent of global emissions but on a per capita basis is a very high emitter. Australian primary industries (agriculture, fishing, forestry and mining) have reduced greenhouse gas emissions by up to 40 per cent since 2003.

Carbon sequestration refers to processes and practices that remove carbon dioxide from the atmosphere and trap it. Carbon sequestration is widely reflected in many farming practices today and 94 per cent of Australian farms actively undertake some form of natural resource management:

- they increase the biodiversity on farms by planting native plant species to act as carbon sinks
- they increase total vegetative cover on a farm
- they increase agroforestry activity on farms
- they protect creek banks through revegetation practices.

These changes also provide shelter for livestock, protect waterways and represent a source of financial return based on a carbon trading scheme. Under a carbon trading scheme, farmers gain carbon offsets that provide a financial return for land set aside for plantings to capture carbon dioxide.

There has also been an increase of 70 per cent in the number of farmers using different tillage practices in the last 30 years. Many farms are also adopting zero tillage practices. These changes in whole-farm management and environmental management have assisted in the reduction of greenhouse gas emissions from agricultural industries.

Research is being undertaken on how large areas of forests in different regions of Australia – agroforestry sinks composed of fast-growing commercial trees such as eucalyptus and plantation pines – can reduce carbon dioxide levels in the atmosphere.

18 Use Figure 7.9 to draw up a table that lists the ways soil nutrients are cycled in, lost from and returned to a mixed farm, with the column headings: 'How soil nutrients are cycled', 'How soil nutrients are lost' and 'How soil nutrients are returned'.

19 Give one reason why animals may not make full use of all the energy available to them in the plants they eat. Refer to Figure 7.4.

20 Why would companies that produce greenhouse gases buy land and plant it with fast-growing trees?

Companies that produce high levels of carbon dioxide can finance the development of these agroforestry areas, thereby trading their carbon production for carbon credits and assisting Australia to meet lower atmospheric levels of carbon dioxide required under international agreements. This is illustrated in Figure 7.10. There are other agricultural activities that can be regarded as providing carbon sinks in nature. These include Landcare revegetation projects and pasture improvement, especially using perennial pastures such as lucerne and saltbush as well as soil structure improvement.

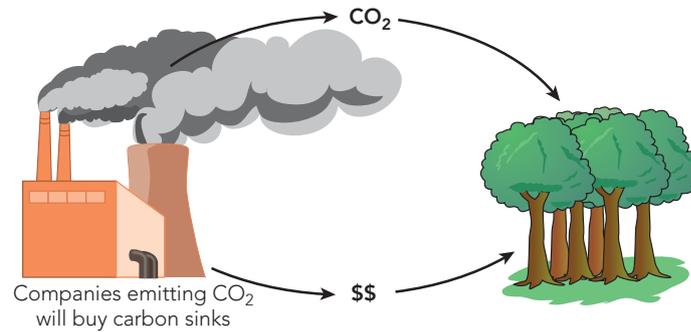


Figure 7.10 Carbon credit scheme

Use of chemicals on farms

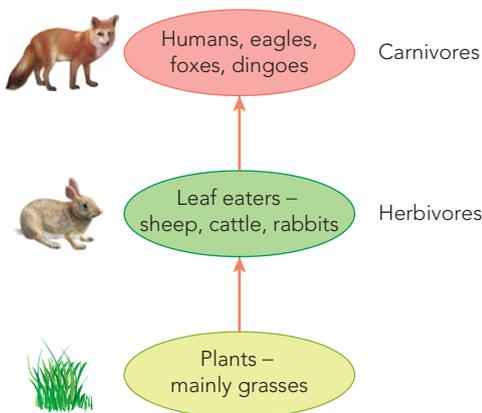


Figure 7.11 Farm food chain

Insecticide sprays applied lightly to pasture and commercial crops are a particular problem. Small insects and herbivores eat reasonable quantities of the sprayed plant material; birds, reptiles and amphibians that live in the surrounding areas eat these insects. These small birds and other animals are in turn food for larger predators. This system is termed a *food chain* and on a farm there are many food chains. Figure 7.11 illustrates a typical food chain.

Over time the higher-order members of a food chain accumulate very large quantities of poisonous spray material within their bodies through eating large numbers of slightly poisoned organisms.

The process accelerates when spray programs become too frequent or where farmers use levels of insecticide above those recommended by the manufacturer. Death is not the only

outcome – infertility, immobility, blindness and susceptibility to common diseases become more common. In the long run the numbers of predators decline and this decline affects the food chain. These chemicals may accumulate over time in the fat tissues of many grazing animals, producing toxic levels of contamination or resulting in the animal product being rejected at the market. This contamination also occurs when animals are allowed to graze sprayed pastures before the **withholding period** of a chemical spray has lapsed.

The constant use of chemical sprays, drenches or pour-on treatments can result also in pests becoming resistant to the active chemical in these preparations.

Biological insecticides are available to many home gardeners, for example Dipel®. The long-term use of one organism to control another avoids the hazards associated with overuse or long-term use of chemicals. This form of management resembles what occurs in nature. For example, sprays using the bacterium *Bacillus thuringiensis* are used to combat caterpillars on plants. No withholding period is necessary for crops sprayed with a biological agent. Some predators of common pests are being

connect

Controlling pests without toxic chemicals

Watch the video and answer the questions.

- 21** Describe two problems that may arise from the constant use of poisonous chemicals.

bred specifically for those pests. These include predatory mites and numerous wasps to control caterpillars, leaf miners and aphids.

The advantages of managing a farm on natural principles, as illustrated in Figure 7.12, may seem obvious, but economic factors may require a compromise of management styles. In the long run, it seems that the integration of several methods of pest and disease control, as shown in Figure 7.13, is desirable.

4 Highly territorial bird population frightens grape-eating nomadic birds.

1 If no pesticide or herbicide is used, small ecological systems form.

3 Other foliage grows under vines and this environment sustains birds and insects. Birds eat pests.

2 If grubs become a problem, the farmer must introduce shield beetles.

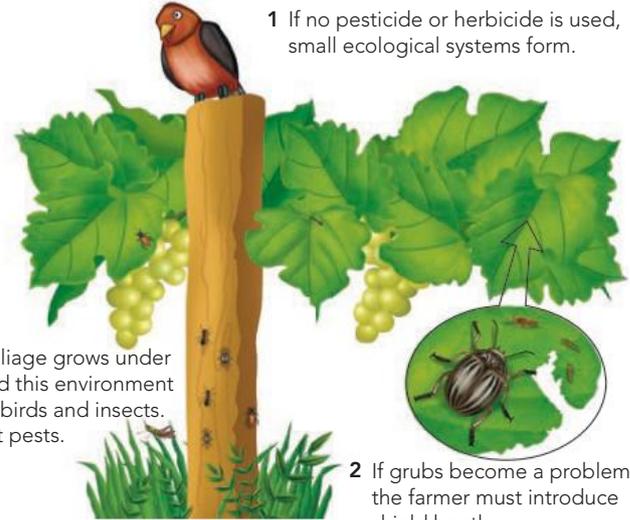


Figure 7.12 Coping without poisonous chemicals in a vineyard

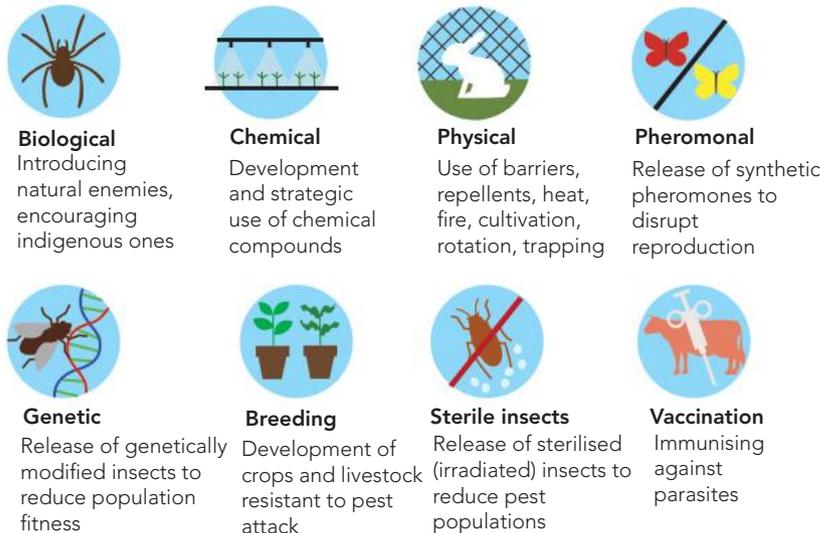


Figure 7.13 The integration of several methods of controlling pests

Water quality

Excessive irrigation means that the watertable rises and this underground water is often rich in salt. When the salts enter the plant root zone, the roots are burnt. Eventually the salt may seep onto the soil surface, producing a white surface crust or scald (irrigation salinity). This salty deposit draws water out of living organisms, causing dehydration and death. Efficient water management is required on farms to avoid this situation. One way to achieve this is to avoid excessive clearing of trees – trees effectively lower the watertable because of their high transpiration rates – they give off large amounts of water vapour through small pores on their surfaces. Salt build-up due to rising watertables as a result of land clearance programs is called *dryland salinity*.

Poor farming practice also results in the movement of large volumes of salt, previously stored in the subsoil, into local streams and rivers, causing them to become salty.

22 List three methods used to control salinity on farms and in waterways.

Excess use of fertiliser may also cause fertiliser to leach into groundwater reserves or local creeks. High levels of fertiliser in creeks and rivers promote the growth of algae, and a condition called eutrophication (an algal bloom) develops, resulting in the waterways turning green due to the algae. Eventually the plants may take all the oxygen out of the water and prevent sunlight penetrating. In time, all living things in the water, both plant and animal, may be killed. Livestock may also be poisoned from drinking water that contains an algal bloom.

Acid sulfate soils

Sulfates are naturally occurring acidic sediments that are often found in coastal locations. When disturbed, they can release quantities of acid, causing groundwater to become quite toxic at pH3. This problem is being managed by farmers at a local level with support from state and Commonwealth governments. For example, in New South Wales, remedial works to manage water run-off and to reduce the intensity and duration of acid run-off are carried out in the Shoalhaven area, Hastings, Macleay, and the Clarence and Tweed areas.

Land use

The continual removal of trees from farm properties to increase the area available for agriculture, coupled with the impact of a disease called dieback, has resulted in the loss of many eucalypts and other trees. The unprotected land is, in many instances, subject to erosion and salt problems; the lack of shelter for animals can also become a problem.

Some farmers have moved beyond the normally accepted areas for farming to operate in climate zones not suited to farming. In good seasons they have success but in poor seasons they are among the first to face what could be disaster or financial ruin. These areas are known as 'marginal' farming areas.

Soil fertility

The continuous removal of products from the farm reduces the cycling of minerals and represents a loss of energy to the farm. It also leads to a loss in the level of soil organic matter. This loss influences not only the soil mineral levels but also soil structure and water-holding capacity. Organic matter provides an effective buffer against agents of soil erosion, such as water and wind.

Rapid loss of organic matter occurs in farming systems where cultivation is an important operation because it increases susceptibility to erosion. Examples are cropping systems, especially where the soil is left ploughed up for a time; and market gardens, where the soil is continually cultivated and the soil aggregate or particle size is reduced. Cultivation also speeds up the action of microbes and increases the rate of oxidation of organic matter. The net result is a loss of minerals from the soil through leaching, as the plants use the minerals at a slower rate than they are produced. To offset this problem farmers need to consider the following solutions:

- incorporating pastures in crop rotation or green manure crops, particularly legumes
- minimising cultivation and using **stubble retention** techniques
- encouraging the recycling of plant and animal materials and improving soil structure.

Long-term use of phosphate and nitrogen-based fertilisers without analysing plant uptake rates and soil reserves results in the development of acidic soils that can limit agricultural productivity.

Soil degradation

Australian soils are very fragile compared to soils in other parts of the world. Because of their fragility, there are several factors that lead to a breakdown of soil structure (**soil degradation**) and a loss of fertility. The main factors adversely affecting soil productivity in Australia at present are soil acidification, **soil salinisation**, erosion and loss of organic matter, and pollution.

Soil acidification

Problems of high acidity (low pH) are becoming more common on farms with improved pastures in high rainfall areas (Fig. 7.14). The cause appears to be a combination of the long-term use of subterranean, clover-based pastures coupled with the use of superphosphate fertiliser (Fig. 7.15).

As the soil acidity increases, forms of aluminium and manganese, known as ions, are released into the soil.

These ions are very toxic to plants (Figs 7.16–7.18) and can cause large areas of pasture to die. At the same time, soil structure also breaks down, because aluminium forms part of the

structure of clay particles. In addition, legumes find it difficult to form nodules as the availability of the mineral molybdenum is limited under acid conditions.

An increase in acid soils also appears to be linked to salinity problems. As the soils become more acidic, plant growth declines and watertables rise, bringing salt into the root zone of plants. This is a very slow process but, as soils approach a pH of 5, many commercial plant species such as lucerne, canola and many of the

23 List three ways to reduce soil fertility decline.

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Soil degradation

Read the article on soil degradation.

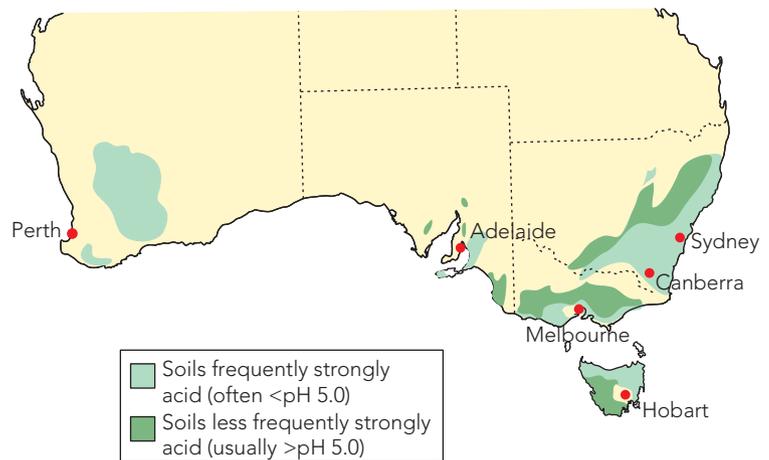


Figure 7.14 Soil acidity in southern Australia

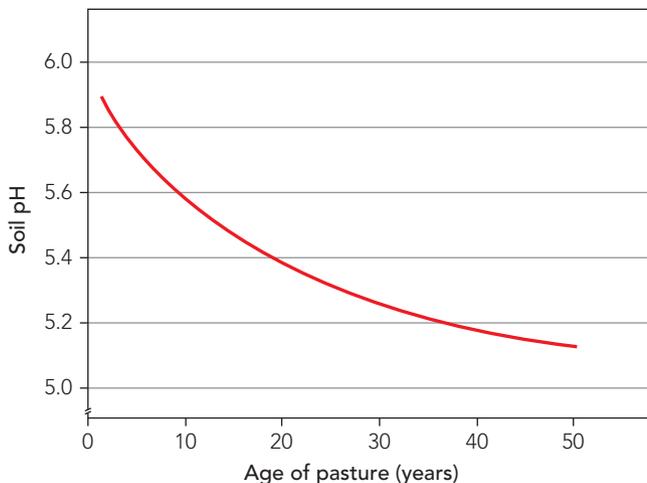


Figure 7.15 The acidification of pastures

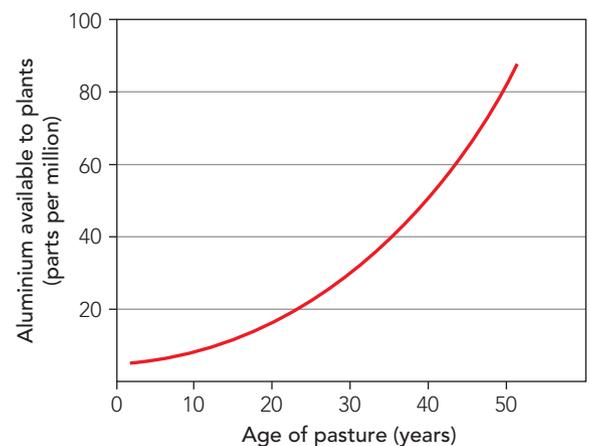


Figure 7.16 Aluminium toxicity over time

CSIRO Plant Industry



Figure 7.17 Aluminium toxicity in wheat as shown by root development of the plant on the right



NSW Department of Primary Industries

Figure 7.18 Manganese toxicity in canola. The plant on the left is healthy; the plants in the centre and to the right show manganese toxicity.

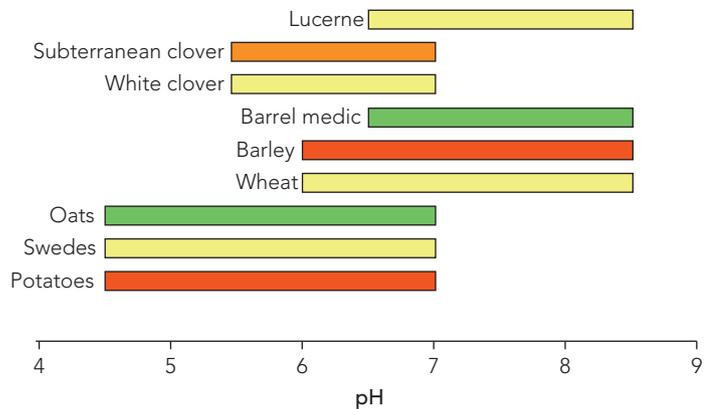


Figure 7.19 Preferred soil acidity levels of some common plants

wheats struggle to survive – lucerne is one of the pasture plants most sensitive to acid soils. Figure 7.19 shows the preferred pH ranges for growth of particular plants.

Research by the CSIRO has suggested that there are three ways to combat increasing levels of soil acidity.

- 1 Use more acid-tolerant crops and pasture plants, such as cocksfoot or cereal rye.
- 2 Apply lime to correct soil acidity levels. This may require up to 3 tonnes of lime per hectare to raise pH by one unit per year.
- 3 Use management techniques that do not allow easy leaching of excess nitrates (from fertilisers) that have built up in the soil. Such techniques may include using perennial grass–clover combinations; incorporating stubble into the soil before pasture planting to allow for a slow release of nitrogen-containing minerals; and avoiding excessive removal of legumes from the farm, so that nitrates can be absorbed. Table 7.2 shows the effect of various nitrogen fertilisers on soil acidification.

Table 7.2 Effect of fertiliser on soil acidity

Fertiliser	Effect
Sulfate of ammonia	Most acidifying
Diammonium phosphate	Medium acidifying
Urea, anhydrous ammonia, legumes	Least acidifying

- 24 What appears to cause soil acidification?
- 25 Discuss what else occurs as the soil becomes more acidic.
- 26 How can farmers overcome the problem of acidic soils?

Soil salinity

As discussed earlier in the section 'Water quality' and 'Land use' (see pages 67 and 68), *salinity* occurs most commonly when rising watertables bring underlying salt to the surface layers of the soil, and evaporation leaves salt deposits on the soil surface. In some instances salty water will seep to the surface to form saltwater basins. High salt concentrations in the soil interfere with water and mineral uptake of plants. This results in lower production from plants, plants dying and the surface of the soil being exposed to wind and water erosion. The clearing of deep-rooted vegetation, such as trees, in upper catchment areas in order to gain more farming land is the major cause of this problem in dryland areas. Irrigation of unsuitable soils, overwatering and a lack of proper drainage are common causes of this problem in irrigation areas. The effect of trees in lowering the watertable can be seen in Figure 7.20.

There are several management options for salt-affected soils:

- planting suitable species of tree (e.g. eucalypts or pines)
- planting salt-tolerant grasses (e.g. wheat grass or salt bush)
- planting perennial pastures (e.g. phalaris)
- using fodder trees (e.g. tagasaste)
- installing drainage systems.

This problem is not confined to any one state in Australia. In the southern area of Western Australia it is estimated that 30 per cent to 50 per cent of cleared land could become salt-affected over the next 20 years. In New South Wales, 15 per cent of irrigation land is affected and, in Victoria, land-clearing operations have contributed to higher soil salinity levels. As salty water is discharged into the main river systems the salt content of the river water increases. In South Australia, farmers are now having difficulty irrigating from the Murray River because of the quantity of salt brought down in the water from irrigation areas in New South Wales and Victoria. Figure 7.21 shows typical salinisation damage.



Figure 7.21 Salinisation damage

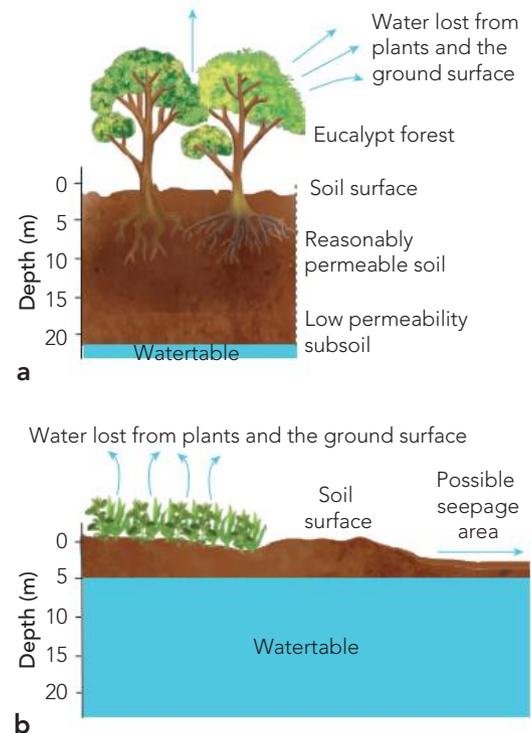


Figure 7.20 The watertable under **a** a forest and **b** a pasture

- 27 Describe the process of soil salinisation.
- 28 Explain the problems that a farmer may encounter as the soil becomes more saline.
- 29 Outline how farmers overcome the salinity problem. Refer to Figures 7.20 and 7.21.

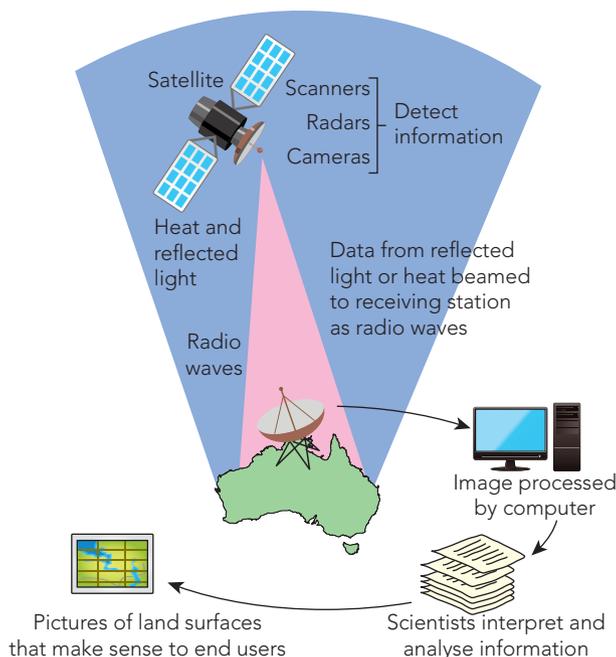
Soil pollution

The soil environment is critical to the establishment and growth of crops. It includes the quality of the air and water in the soil, the solutions (chemicals mixed with water) found in the soil and freedom from materials harmful to plants. When the soil is polluted, natural plant growth is affected.

Recent studies have suggested that many plants rely on forming an association with specific types of soil fungi. The fungi invade the roots and stimulate plant growth by providing nutrients. Successful culture of Australian wildflowers, such as the waratah, and the growth of several species of commercial forest trees rely on the establishment of this plant–fungus relationship, or **mycorrhiza**. The overuse of chemicals and industrial pollution in some areas often upsets this delicate balance.

- 30** Describe the operation of remote sensing systems.
- 31** How could such a system assist in land management?

Remote sensing and land management



Satellites and even drones can provide information on many land characteristics that farmers are interested in:

- vegetation patterns
- soil salinity levels
- mineral and chemical resources.

The satellites detect various wavelengths of light reflected from the Earth's surface and transmit the information to a receiving station, where images are seen on a video display unit, usually connected to a computer system for analysis. As shown in Figure 7.22, the images can be calibrated against known information. In this way, scientists can compare images of unfarmed land with those of farmed areas to see how farming patterns are affecting the land. It is possible to incorporate information giving geographic location and to use computers to enhance or manipulate digital data. Using this information, farmers can pinpoint areas of mineral deficiency or salinity on their farms and specifically tackle the problem.

Figure 7.22 Remote sensing

Land degradation – whose responsibility?

To conserve the soil as a future viable resource, farmers must accept that the preservation of the soil is mainly their responsibility. Most Australian states have legislation and administrative bodies concerned with soil conservation. These bodies have a number of statutory powers:

- to declare areas as erosion hazards
- to place restrictions on land-clearing operations
- to regulate the grazing of arid areas
- to establish community interest in soil conservation.

All states have extension and advisory services to provide information to farmers on land management techniques for controlling erosion. They also provide for the

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Soil research

Search the CSIRO website to locate information on soil research.

construction on properties of capital works projects designed to control and divert water movement or to stabilise the surface soil. Financial assistance to farmers for these projects is available through most state governments. Concessional loans are also available to farmers in some states for soil conservation work. Landcare groups have been developed in many local communities with the aim of overcoming the effects of mismanagement in relation to the soil and the environment. Other state government authorities – for example, the Catchment Management Authority (CMA) – operate in New South Wales to coordinate the work of the Landcare groups in a particular water catchment.

State soil conservation authorities collect information on soil, landform and vegetation characteristics as well as the effect of farm management systems on the soil. In addition, research groups such as the CSIRO are engaged in research on the effects of soil loss on production, the reasons for poor pasture growth, soil water problems and the effects of wind and water erosion.

Land classification

Good quality agricultural land is in limited supply as urban areas grow and some available farming land becomes degraded. The lack of land suitable for farming reduces the sustainability of Australian agricultural production systems. The Commonwealth and state governments are cooperating to coordinate soil conservation measures across Australia. As part of this attempt, several land usage classifications have been developed with the aims to:

- minimise the impact of land degradation caused by poor management practices
- enable farmers to recognise and minimise soil acidification and salinity problems
- improve ways for farmers to predict and manage soil–water balances including soil salinisation and water-flow problems and soil structure decline
- encourage the increased use of geographic information systems (GIS).

There are two techniques for evaluating land in terms of suitability for agricultural production.

- *Rural land capability mapping*, an eight-level system of land classification used by the Department of Land Management for general agricultural use. This system reflects measures needed to protect the land from soil erosion and other forms of degradation.
- *Agricultural land classification*, a five-level system of assessment for suitability of the land to agricultural enterprises, used by the Department of Agriculture. It does not apply to land used for intensive agriculture. Land classified as Class 1 has few limits and is suitable for intensive cultivation. Class 2 is suitable for regular but not continuous cultivation; a limited cropping or pasture phase is required. Class 3 land is suitable for grazing enterprises, with a cultivation phase. Class 4 land is suitable only for grazing. Class 5 land is not suited for agricultural activity but could provide a point of shelter or a wildlife corridor.

Farmers can begin the process of soil conservation at the planning stage of farm management. The placement of fence lines, roadways, waterways and watering points all need to be considered carefully. The area of land under cultivation, the techniques used and the frequency of cultivation also need to be planned.

-
- 32** What are the main roles of the various state soil conservation departments?
 - 33** List eight management techniques farmers may use in soil conservation.
 - 34** Describe three of the soil conservation management techniques listed in your answer to Question 33.



Figure 7.23 Strip cropping

These are some current management techniques:

- contour farming
- strip cropping
- **direct drilling** seed into the soil
- use of a stubble mulch system instead of leaving harvested land lying bare
- use of grassed waterways and contour banks to control water flow
- crop and pasture rotation systems
- less use of aggressive soil cultivation techniques
- controlled stocking rates.

These practices are designed to provide a cover over the surface of the ground and to slow the movement of water over the soil surface. On cultivated lands the use of contour ploughing and strip cropping (Fig. 7.23) is becoming more common. Strip cropping is based on three adjacent strips of land. One contains the commercial crop, the next contains the stubble remaining from the previous crop and the third is a bare fallow strip where soil moisture levels are being recharged in readiness for sowing.

Gullies and tunnels formed by erosion are usually filled in. Water movement down slopes can be controlled by grassed waterways, channels made of concrete or rock-filled wire baskets. In certain circumstances steeply sloped areas on farms are best left timbered. From these examples it becomes clear just how much the individual farmer is responsible for the conservation of our country's soil resources.

Chapter review

Things to do

1 Follow the instructions in Figure 7.24 to plant and grow some native trees.

- 1 Get some native plant seed from your teacher or collect some from trees or shrubs.



- 2 Lightly sprinkle seeds onto potting mix in a container that drains well. Do not overwater. Wait for seeds to germinate.



- 3 Plant seedlings in small pots when they have grown their second pair of leaves.



- 4 Plant these growing trees or shrubs when the soil is moist and no frosts occur.

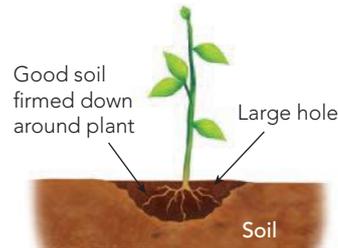


Figure 7.24 Growing native plants

- 2 Study a typical food chain in a natural area, then describe one for a farm in an area that has not been disturbed recently. Finally, describe a food chain in a disturbed area of a farm (one recently cultivated or chemically treated). Take extreme care if you are in a sprayed area and make sure that the withholding period has finished. What differences do you find in the type and number of organisms present and the types of food chains you have drawn?
- 3 Make an accurate map of a farm. On this map use arrows to show major inputs into the system. List major outputs. Describe or show on the map the main subsystems on the farm.
- 4 Examine the details of the following three properties.
- Using this information, construct and complete a table in your notebook using the headings shown on the next page.
 - What farm would you choose to purchase and manage? Give your reasons.

Skysthelimit. This 1560-hectare farm situated in the Hunter Valley of New South Wales has fertile river flats with irrigation, cultivation country for cash cropping and undulating land suitable for grazing sheep and cattle. There are two residences, haysheds, a shearing shed, cattle yards and a machinery shed. Water comes from the Hunter River and spring-fed creeks and dams.

Big Station. This 26 000-hectare property situated in central Queensland consists of open and shaded Downs country suitable for grazing sheep or cattle. There is a four-bedroom air-conditioned homestead, six-stand shearing shed, outbuildings, steel sheep yards and steel cattle yards. Water is supplied from four artesian bores, a pipeline system and eight large earth dams.

Itsadream. This is a 210-hectare farm in the Gunnedah district of New South Wales with mostly arable rolling country. One hundred hectares can be irrigated from the Peel River and a bore. This farm, with its rich, alluvial river flats, is ideal for grape, olive or lucerne production. It has a two-bedroom cottage, steel machinery shed, workshop, 12 000-bale hayshed, cattle yards, irrigation pump, underground mains and two travelling irrigators.

Location	Area	Description of the land	Possible enterprises	Buildings and improvements	Water supply

🔍 Things to find out

- 1 What is Landcare? Find out what Landcare groups do.
- 2 Select a conservation issue that is important for your local area: soil conservation, soil salinity, soil acidity, excessive loss of trees or problems with pesticide spraying. Describe why you consider it to be important. Outline the main effects it has on the farm ecosystem. Discuss what may be done to improve the situation.
- 3 Examine the concept of farming more of our native plants and animals. Would such an approach solve several of the most common environmental problems, or would new problems emerge?
- 4 Farming often results in a permanent change to the environment. Conservationists may oppose such changes. Can farming activities occur without major changes to the environment? Use examples to explain your answers.

+ Extension activity

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New South Wales
Department of
Primary Industries

- 1 Go to the [New South Wales Department of Primary Industries](#) website and search under 'Sustainable agriculture'. List all of the state and federal programs that are contributing towards the development of sustainable agriculture.
- 2 a Go to a paddock on the school farm and study it carefully, observing all the different kinds of organisms that are present. List the names of the organisms you see down one side of the page. If you do not know the name of an organism write a few words that describe it (e.g. insect with wings). Select words from the following list that help describe the organism and write them next to each one: autotroph, heterotroph, omnivore, carnivore, herbivore, decomposer, producer, pest, weed, invertebrate.

- b** Put a red asterisk on the left-hand side of each organism that is directly involved with production in the paddock (e.g. pasture grass and sheep).
- c** On a new page draw a diagram that shows how the organisms you observed may relate to each other. Use labelled arrows to show the relationships.
- 3** Go to the [Department of Agriculture](#) website and read about Landcare Australia. At the same site find out about the Commonwealth's pilot program Environmental Management System (EMS). Discuss the operation of these support services in rural communities to promote long-term sustainable agricultural communities.
- 4** Go to the [New Zealand Ministry of Primary Industries](#) website and use the tab 'environment and natural resources' to locate the unit on climate change, or go to the [Dairy Australia](#) website and look at the section on climate change and the greenhouse effect. Summarise this information and present a 3-minute talk or PowerPoint presentation to the class.
- 5** Research the role of dung beetles on farms. Develop a PowerPoint presentation of five slides or create an A3-sized poster to display your results.

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**Department of
Agriculture**

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**New Zealand Ministry
of Primary Industries**

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Dairy Australia

Click the 'Climate and greenhouse basics' tab.

✓ Test yourself

- 1** In your notebook, write each of these words with the correct definition from the list below.
- biotic, autotrophs, heterotrophs, leaching, greenhouse effect.
- The washing of chemical nutrients down through the soil
 - The level of carbon dioxide is increasing in the atmosphere faster than it is being used by plants and the increased carbon dioxide contributes to warming the atmosphere in much the same way as a glasshouse heats up
 - That part of the environment concerned with living things such as plants and animals
 - Organisms that can manufacture their own food
 - Organisms that feed on other organisms
- 2** When products are marketed from a farm, chemical nutrients are lost from the farm. Describe one way a farmer may try to replace these lost minerals.
- 3** Describe two problems that have arisen because of the use of toxic chemicals to control pests on farms.
- 4** List three management options for salt-affected soils on a farm.
- 5** Write down two goals of sustainable farming.
- 6** Illustrate two pathways nitrogen in a legume pasture plant may take to end up in the wool on a sheep's back.
- 7** Review the concept of land classification.
- 8** Review the differences between agricultural ecosystems and natural ecosystems.

CHAPTER 8

FARM RESOURCES: CLIMATE AND SOILS

Words to know

anaerobic oxygen free

anemometer an instrument used to measure wind speed

climate the average conditions of Earth's atmosphere based on records taken over at least 30 years

dew point the temperature at which water droplets form in the air

diversified farming mixed farming, where more than one subsystem or enterprise exists on a farm

erosion the wearing away of material and the movement of weathered material by various agents such as wind, water or gravity

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

field capacity the amount of water left in a soil that was saturated then left to drain for 24–48 hours

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

mulch a layer of material placed on the surface of any soil

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

ped the unit of soil structure

pore the space between soil particles, usually containing air or water

saturated soil pore space filled with water

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

Stevenson screen external structure used to house instruments needed to measure temperature and humidity

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

weathering the breakdown of rock to form soil

wilting point the point at which a plant can no longer obtain water through its root system from the soil pores

Introduction

When a person buys a farm, factors relating to the soil and **climate** must be considered before any system of farming can be set up. Most physical and chemical characteristics of a soil can be changed by farming practices. Climate and the factors that make up the climate of an area cannot be readily changed. In extensive industries, such as grazing and broadacre cropping, farmers must manage the production system to take into account the rainfall and temperature patterns of the local area. Intensive industries, such as pigs, poultry, market gardens and glasshouse-based industries, can modify the effects of climate on a small scale. This is usually very expensive but, because of high production levels and a rapid turnover of product, it is economically possible for these farmers to construct sheds or special-purpose buildings that provide a particular climate to increase production.

Soils are developed over time from the physical, biological and chemical breakdown of rocks and minerals – the process called **weathering**. The soil that results provides an anchorage for plants, and nutrients for plants and other organisms that live within it. The soil provides protection for plant root systems and is a store of air and water allowing for the **germination** of seeds.

Australian soils are very old. Most are derived from the weathering of rock formed millions of years ago. They have suffered from a long period of leaching and exposure and have lost most of the important plant nutrients, such as nitrogen salts and phosphate minerals. In order to make the soils productive, farmers have added to them large amounts of these minerals in the form of fertilisers. Unfortunately the availability of minerals such as superphosphate is declining and the cost of these necessary inputs is increasing.

In **extensive farming**, where plants or animals are raised over a large area of land, the condition of grazing animals reflects the condition of the pasture. The animals' condition lags behind that of the pasture, but any decision in a grazing system must be based on the condition of the pastures. Pastures deficient in phosphorus and nitrogen result in grazing animals with poor growth rate and reduced fertility.

Farmers need to develop a system of management that allows agriculture to be sustained, and this involves understanding and managing our soils. European-based agriculture has been practised in Australia for only a relatively short period and those farming methods have resulted in a situation where production levels cannot be maintained simply by consuming more inputs, principally water and fertiliser. Since much of the country is arid to semi-arid, systems of agriculture suited to the soil and climate of such areas need to be developed or refined.

Climate and weather

Climate is a term used to describe average weather conditions over a long time. The climate of a district includes the average rainfall and temperature. These averages are calculated from daily recordings over a long period (generally in excess of 30 years). The success of most forms of agriculture in Australia is largely dependent on the reliability of rainfall and a suitable existing temperature range.

Weather is a term describing the short-term changes in the atmosphere from day to day. It is this variation that has an immediate effect on the farm production system. The weather is the result of a number of individual factors acting together to produce certain environmental conditions.

When studying aspects of weather, a meteorologist considers mainly solar radiation, temperature, rainfall, evaporation rates, humidity and wind.

-
- 1 What does the term 'climate' mean?
 - 2 Why can farmers involved in intensive industries afford to carry out environmental modifications?
 - 3 What does a meteorologist do?

- Farmers can get information on weather and climate from a number of places:
- the weather bureau (Bureau of Meteorology)
 - records kept on the farm or in the local area
 - the internet
 - smart phone apps.

Solar radiation

Solar radiation refers to the radiation (light and heat) coming to Earth from the Sun. This radiation arrives at the top of Earth’s atmosphere at a virtually constant rate. Not all the radiation reaches the surface of Earth. Clouds, dust, snow and water vapour reflect some radiation back into space and scatter much of it in the atmosphere, as can be seen in Figure 8.1.

The amount of radiation, which forms an input into a production system, varies from place to place on Earth’s surface, because various land surfaces reflect different amounts of radiation. The radiation that reaches the land surface has many important functions. Plants absorb some of

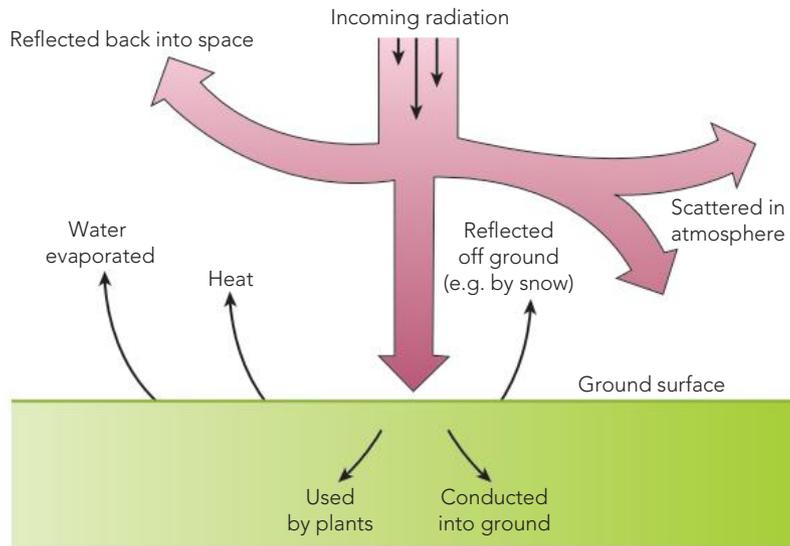


Figure 8.1 The fate of incoming radiation

- 4 Draw a diagram to show what happens to solar radiation as it enters the atmosphere and moves toward Earth’s surface.
- 5 Describe two processes that depend on solar radiation for their functioning.
- 6 Draw and label a detailed water cycle.

it in order to turn carbon dioxide and water, which are low-energy inputs, into the high-energy sugar compounds or carbohydrates required for growth. The plants, in turn, are eaten by animals. Less than 1 per cent of this incoming radiation is used by plants.

Radiant energy is also responsible for *evaporating* water from both free water surfaces and living organisms. The loss of water from plant leaves causes the plant to draw more water from the soil through the root system. Nutrients dissolved in the water also enter the plant.

As moisture in the atmosphere cools, it condenses to form clouds and rain – which then falls to Earth’s surface. This process forms a cycle termed the *water cycle*, shown in Figure 8.2.

The time period over which light is received is also important. Many plants respond to changes in the ratio of daylight to darkness. Often plants require certain periods of uninterrupted darkness in order to flower. Animals also respond to changes in day length, which triggers reproductive behaviour in many species. For

example, many sheep breeds commence to mate as light hours begin to decrease, while poultry respond to increasing hours of daylight. This is called photoperiodism.

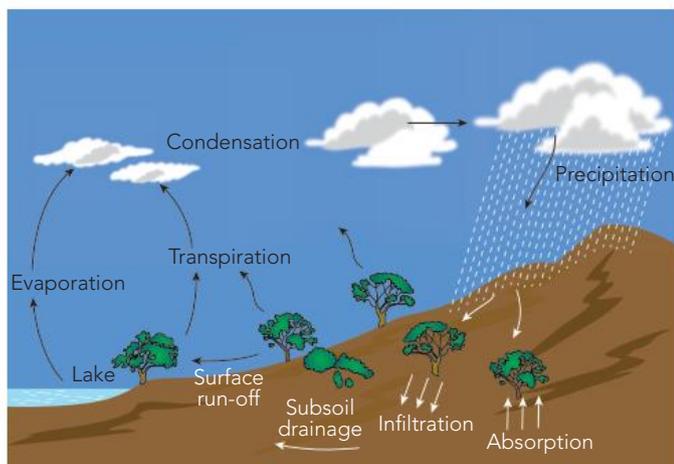


Figure 8.2 The water cycle

Temperature

Living organisms exist within a range of temperatures, the limits of which vary from organism to organism. For all forms of life, a maximum and minimum temperature can be recorded. Table 8.1 indicates a range of critical temperatures for some farm animals. Between the extremes, all organisms have an *optimum* temperature range in which they best function.

Table 8.1 Critical temperature ranges for some animals

Animal	Lower critical temperature (°C)	Upper critical temperature (°C)
Broiler cockerels	16	27
Laying hens	13	24
Adult pigs	21	27
Steer	13	29
Clipped steer	18	31

Temperatures above or below these critical limits may result in death. Farmers must select species of plants and animals that can survive and reproduce in the temperature range that forms an input into the farm. For instance, in situations where animals need to consume more food in winter in order to keep warm, their rate of growth is not as rapid as that of similar groups of animals kept at temperatures that suit them best. Ultimately this would mean more money is spent on food, and the animal would take longer to reach market weight.

Temperature also affects the rate of growth of plants. Many plants (e.g. grapes, peaches and plums) become dormant over winter after losing all their leaves. Summer crops such as tomatoes and maize, on the other hand, die when ice crystals formed during frosts destroy leaf tissue. Other plants such as cabbages and cauliflowers only grow during the colder months of the year.

Temperature is measured using a maximum–minimum thermometer (Fig. 8.3a), which may be suspended in a shed. If kept outside, the thermometer is placed in a specially designed wooden box called a **Stevenson screen** (Figs 8.3b and c). This is placed on a stand and prevents false readings from heat being radiated from other bodies.

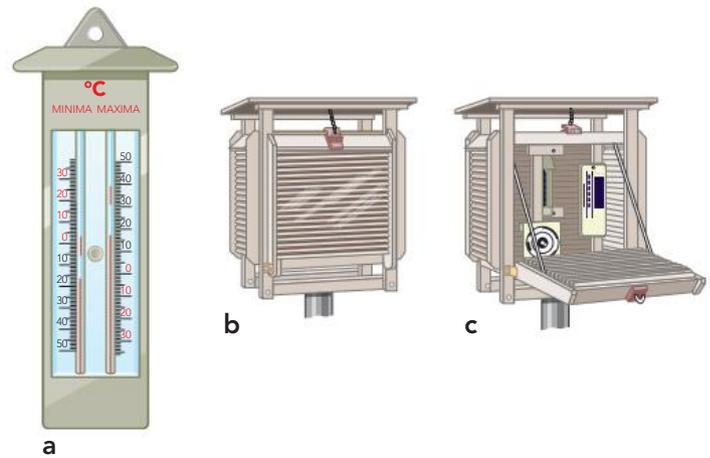


Figure 8.3 Measuring temperature: **a** maximum–minimum thermometer; **b** Stevenson screen; and **c** inside the Stevenson screen showing maximum–minimum thermometer and a wet-and-dry-bulb thermometer

Rainfall and evaporation

Within Australian agriculture, rainfall is the weather and climate component most likely to limit production. A farmer is concerned with the following aspects of rainfall:

- the total amount of rain that falls, which determines if a crop can be grown
- the time of the year rainfall occurs, or its seasonality, which determines when a crop can be grown
- how heavily the rain falls, or its intensity, which determines how much water can be absorbed by the soil
- rainfall reliability, which determines whether the farm is in a drought-prone area
- the amount of water remaining in the soil after evaporation, which ultimately determines how effective any rainfall is in a farm production system.

- 7 Define 'critical temperature'.
- 8 Give an example of how temperatures affect animal production.
- 9 Give an example of how temperatures affect plant production.

- 10 List and explain five aspects of rainfall that would interest a farmer.
- 11 Explain how a rain gauge works. Refer to Figure 8.4.
- 12 Describe the conditions under which the rate of evaporation of water from a plant surface would increase.

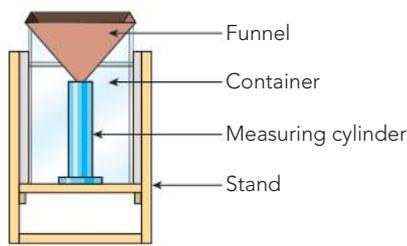


Figure 8.4 A rain gauge

Rainfall is measured using a rain gauge (Fig. 8.4).

Evaporation is measured using an *evaporimeter* (Figs 8.5a and b). The rate of evaporation increases as the air temperature rises. It is also increased during periods of dry, windy weather. When water evaporates from the surface of a body, the body cools. This means that newly born animals with wet bodies can die from exposure if they are not protected from the wind. Plants that cannot replace water lost by evaporation through their leaves will collapse or *wilt*. This will also result in death, if replacement water is not supplied within a short period of time.

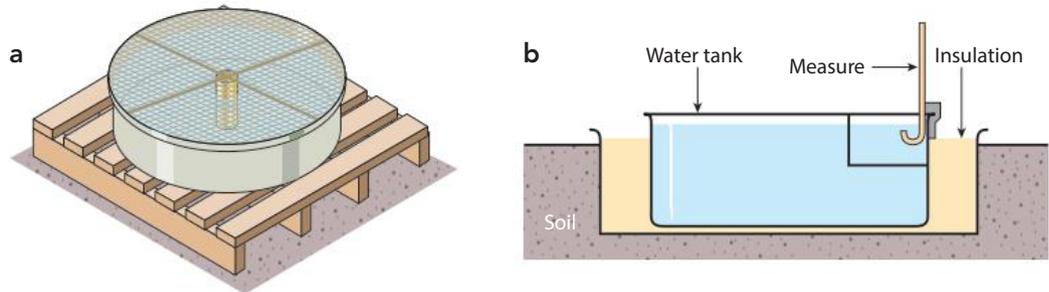


Figure 8.5 a An evaporimeter and **b** the internal view

Wind

- 13** Explain how winds arise.
- 14** What effect on agricultural production could the following climatic factors have?
 - a** Wind
 - b** High rates of evaporation
- 15** Explain how wind speed is measured.

Uneven heating of Earth’s surface by the Sun produces air movements. In climatic terms these air currents are called winds (e.g. the trade winds, the westerlies and the polar easterlies). On a smaller scale, the afternoon sea breeze is an example of this uneven heating of the land and water surfaces. Wind speed is measured with an **anemometer** (Fig. 8.6).

Strong winds cause tall crops (especially those with large and heavy seed heads, such as sunflowers) to fall over, or *lodge*. This makes harvesting such crops difficult, or results in damage to the product. Dry winds cause the pollen grains of crops such as maize to dry out, reducing the number of cobs produced per hectare.

Winds assist in the dispersal of many things in nature: pollen grains, plant seeds and many diseases rely on wind for dispersal.

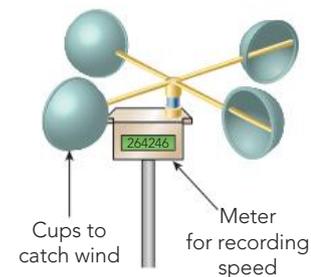


Figure 8.6 An anemometer

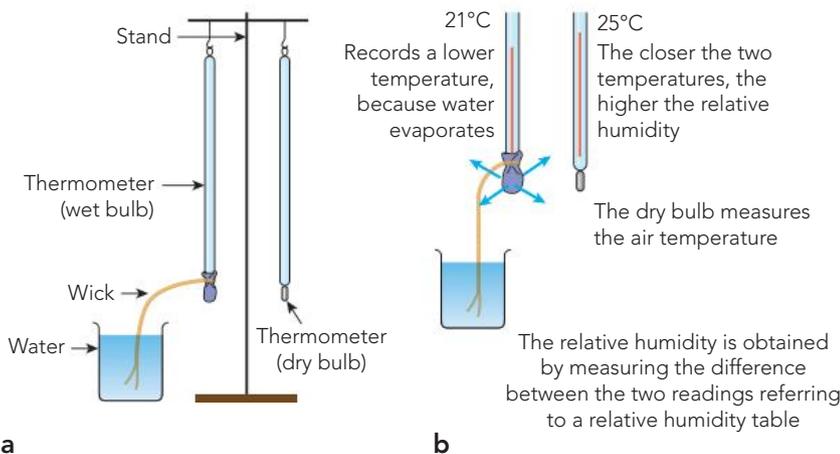


Figure 8.7 a A wet-and-dry-bulb thermometer and **b** a description of its working principle

Humidity

Humidity is a measure of the amount of water vapour present in a body of air at a certain temperature. *Relative humidity* is the term used to describe the amount of water vapour in the air at a particular temperature in relation to the maximum amount of water vapour the air could hold. At 100 per cent relative humidity, fog would form. Figures 8.7a and b show how a wet-and-dry-bulb thermometer is used to measure the relative humidity of the air.

Humidity readings depend on such factors as wind, temperature and moisture, which influence the rate of water evaporation. In agriculture, it is important to know how low the air temperature needs to be for water droplets to form – this is termed the **dew point**.

High levels of water vapour in the air slow the rate of water evaporation from various surfaces. Vegetable gardeners see an increase in the occurrence of moulds and mildews in such periods of high humidity, while on sticky, humid days animals often suffer from heat stress because they rely on water evaporating from their mouth or skin to remain cool.

Automatic weather stations

These structures contain a thermometer for measuring temperature, barometer for measuring atmospheric pressure and a wet-and-dry-bulb thermometer for measuring humidity. An anemometer for measuring wind speed, a wind vane for indicating wind direction and a rain gauge for measuring precipitation are also attached. Many of these stations can also measure solar radiation levels and cloud height. Data is logged from meteorological sensors powered by wind or solar sources. Data is transmitted via a global telecommunications system, based on satellite location.

Climate modifications and agricultural industries

Extensive industries

Droughts are a major concern in all extensive agricultural systems. To overcome the effect of drought – or other natural disasters, such as fire or flood – farmers attempt to be as flexible as possible by adopting strategies such as the following.

- 1 They develop more than one enterprise or production system on a farm – termed mixed or **diversified farming**. These activities should not compete for resources such as labour, but should be complementary. One such combination of farm subsystems would be sheep and wheat. There are several reasons both enterprises can be carried out:
 - their labour demands are at different times of the year
 - they benefit the long-term management of the property (sheep are fed on the wheat stubble while the rate of return of nutrients to the soil is increased by the dung and urine)
 - the products operate on different markets, so if one market is affected by a disaster, income can still be gained from the other activity.
- 2 They ensure the farm has adequate irrigation capacity and sufficient water storage capacity in the form of dams, groundwater reserves, deep rivers or creeks.
- 3 They use suitable dryland farming techniques in areas known to be prone to drought.
- 4 They maintain sufficient reserves of fodder to handle the dry spells.
- 5 They use species of plants and animals that are suited to possible extremes of climate encountered in the district.

Farmers in extensive agricultural industries have few ways of undertaking large-scale climatic modifications, but they can use irrigation, windbreaks and stock shelters.

- 16 Define 'relative humidity'.
- 17 Describe how humidity is measured.
- 18 What agricultural problems are associated with conditions of high humidity?



Figure 8.8 An automatic weather station

Shutterstock/mrfotos

- 19 Describe five ways farmers can attempt to overcome climatic uncertainty.

Irrigation

Irrigation provides sufficient moisture for two uses:

- to grow plants in areas where they normally would not be found
- to plant pastures at high seeding rates, so that the farm can support more livestock.

Although competition for water between plants is high, more plants can be grown because of the availability of extra water.

Most of the water stored for irrigation in Australia is in the area surrounding the Murray River. There are extensive underground water resources, but most of this water is saline. Water is drawn up to the surface by deep-well turbine pumps. Creeks and rivers provide the bulk of the water supply for irrigation.

There are several methods of irrigation:

- flood and furrow
- spray
- trickle.

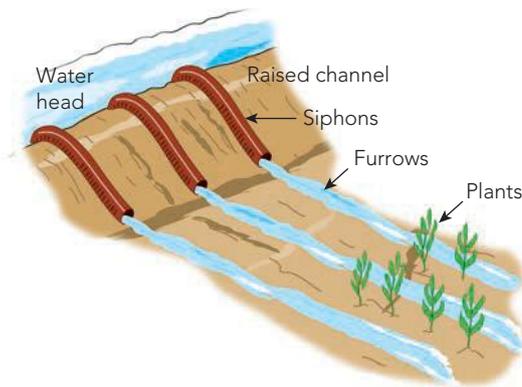


Figure 8.9 A furrow irrigation system

Flood and furrow irrigation

These systems are often found in rice and cotton areas. In the flood system, water can be supplied to reasonably flat land where the soil is not very permeable to water. A series of parallel banks – called check banks – is built, running down the slope. Each pair of banks encloses a bay, usually graded to remove any irregularities. Water is introduced to the bay and allowed to flow down the slope, being absorbed as it goes. Excess water flows into a collection channel at the bottom of the bay. Alternatively, water can be siphoned from a water channel into furrows, which take the water away to be used by various crops (Fig. 8.9).

Spray irrigation

There are several advantages with this type of irrigation:

- it can be used over a wide range of land surfaces
- it can be used on slopes
- there is little waste land (in water channels or banks)
- weed growth is not a problem
- uniform distribution of water is possible
- the system does not depend on the type of soil to be effective.

There are also disadvantages:

- there is a high initial cost to establish the system
- there is a need for careful planning in order to efficiently cover any area
- some time must be spent shifting the lines or sprinkler positions
- windy weather can play havoc with the sprays
- with fine sprinkler systems, evaporation may be a problem.

Spray systems all involve the delivery of water under pressure through pipes to a spray nozzle. The system requires a suction pipe with a foot valve and strainer, which is suspended in the water. A pump and power



Shutterstock/Phillip Minnis

Figure 8.10 A spray irrigation lateral system

unit is needed to take up the water, which flows down a main line and into side lines placed in particular patterns around the field by the farmer. These pipes may be made of aluminium or polyvinyl chloride plastic (PVC). Spray heads are mounted on short lengths called risers. Figure 8.10 is an example of a lateral irrigation system while Figure 8.11 is an example of a central pivot irrigation system, also called a circle irrigation system. The central pivot system relies on equipment rotating around a central point (pivot), watering crops with sprinklers. This system reduces labour costs and uses less water than surface irrigation methods such as flood and furrow irrigation systems. Central pivot systems are easy to set up compared to the lateral aluminium pipe arrangements that move in a straight line.



Figure 8.11 Central pivot irrigation system

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To work out how much water should be supplied to a crop (the frequency and amount of water needed for each irrigation) the farmer needs to know three things:

- the amount of water lost from the soil by evaporation each day
- the water needs of the plant per day (e.g. lucerne requires 5 mm of water per day)
- how much water the soil can hold and make available to the plant.

Trickle irrigation

Trickle irrigation involves a small flow of water at low pressure. This method conserves water, maintains **soil structure** and uses less energy. Low-pressure polythene pipe, 9–12 mm in diameter, takes water from the main line, with one or two outlets going to each plant. The outlets are either long, thin tubes called spaghetti tubes, or drippers. Water is supplied over a period of several hours in sufficient quantity to water over one-third of the plant root system to a depth of 30 cm. A filter is required in this system, or the delivery tubes and drippers rapidly block up (Fig. 8.12).

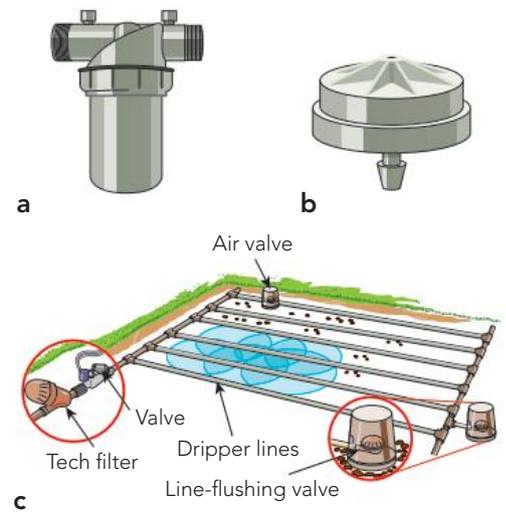


Figure 8.12 Elements of a trickle system: **a** in-line screen filter **b** Turbo-SC™ pressure-compensating drip emitter; **c** a trickle system for vegetables

Windbreaks and stock shelter areas

A belt of trees planted near commercial areas such as orchards or market gardens can help maintain the quality of the product, but the trees must be planted far enough away so that they do not interfere with the other growing plants. Windbreaks protect the other plants from damage caused by destructive winds, although they must allow some wind to pass through. Too thick a planting of trees causes turbulence on both sides of the windbreak, and too thin a planting will allow all of the wind to pass through (Fig. 8.13).

Livestock shelters provide a place for the animals to escape harsh weather and prevailing winds. Shelters can contain several species of tree so that the density of the shelter varies. Care should be taken with the planting, pruning and thinning of these areas to provide maximum benefit.

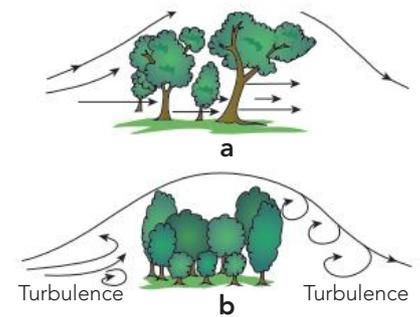


Figure 8.13 A windbreak that is **a** properly constructed **b** poorly constructed.

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Figure 8.14 Intensive egg production

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Figure 8.15 Intensive plant production system

Intensive animal production

A major feature of intensive animal production systems, such as commercial cage chicken sheds and intensive piggeries, is the attempt by farmers to control the environment. This requires specialised management and may involve control of factors such as temperature, humidity, the ratio of daylight to darkness and ventilation levels.

Temperature is important as it directly affects the growth rate of the animals. For example, the temperatures required for poultry vary from a shed temperature of 33°C for day-old broiler chickens to 21°C at 6 weeks of age. Laying hens require a shed temperature of 20–28°C for optimum production. Newborn pigs require an optimum temperature of 27–35°C, reducing to 21°C at 5 weeks of age.

For both poultry and pigs the level of ammonia gas, a waste product, should not exceed 20 parts per million of air for periods of more than 1 hour.

Artificial lighting is provided to encourage hens to produce eggs and to avoid moulting during the autumn and winter. A total day length of 15–16 hours is provided by a combination of natural and artificial light (Fig. 8.14).

Intensive plant production

There are many techniques for modifying the climate of a plant in order to achieve or improve production. For example, farmers may change temperature, humidity and water supply (Fig. 8.15), aspect (the direction faced) or the effect of wind.

Temperature changes

In areas of high temperature, shading is often used to avoid damage to plants. Various types of shade cloth are available, with shading capacity ranging from 20 per cent to 80 per cent. The use of sprinklers or a misting system also lowers temperatures and provides sufficient water to the plant to prevent wilting.

In colder temperatures, glasshouses or similar constructions, or greenhouses with clear plastic or fibreglass walls assist in maintaining a warm environment in which plants can grow. The use of heating cables on bench tops within the glasshouse promotes plant root growth, and heater fans can be used to warm the entire structure.

Farmers also use grass clippings, straw and black or white plastic as a surface cover for the soil. These types of **mulch** affect soil temperature and moisture levels, and control weeds.

Humidity

In enclosed environments it is possible to maintain reasonable levels of humidity by the use of fine misting sprays. Care must be taken to avoid problems with fungal disease – a major problem in intensive plant-raising areas is the movement of contaminated drainage water from diseased to non-diseased plants.

Another problem can be insufficient carbon dioxide. Plants use large quantities of carbon dioxide and in enclosed environments the level of carbon dioxide in the atmosphere may drop quickly. It is then necessary to introduce more carbon dioxide from a cylinder attached to the glasshouse.

- 20** Describe the features of the following types of irrigation: flood irrigation, furrow irrigation, sprinkler or spray irrigation, and trickle irrigation.
- 21** What is the purpose of windbreaks?
- 22** List the ways farmers can alter the climate in intensive animal production sheds.

Water supplies

There are various ways of supplying water to plants to encourage growth. In selecting a particular system, the farmer should consider production needs, cost, efficiency and durability.

Aspect

Slopes facing north receive more sunlight than those facing south, so slopes with a northern aspect will warm up rapidly and require more water. Similarly, easterly aspects receive early morning sun, and westerly aspects receive the afternoon sun, which is harsh in the summer. Aspect often affects the placement of sheds, plants and gardens.

Wind effects

High winds damage plants, limit pollination if the pollen dries out, and lower the quality of soft fruits. Physical damage can also occur. A properly constructed windbreak provides downwind protection up to fifteen times the height of the windbreak. If windbreaks are made from synthetic barriers, there must be provision for the wind to move through the barrier.

- 23** Describe how farmers alter the following factors in an intensive plant system: temperature, humidity and wind effects.
- 24** Why is aspect an important factor in the location of sheds or production areas?

Soil formation

There are five major factors in soil formation: climate, **parent material**, biological factors, landform or topography, and time.

Climate

This is a very active agent in terms of soil formation. Physical forces such as wind and water carry small particles of rock. These particles wear the parent material down by abrasion (Fig. 8.16).

Rainfall has an important influence on soil composition because of leaching – the effect of water moving down

through a soil from its surface and in the process removing soluble chemical compounds from the plant root zone. A farmer must add fertilisers to the soil to make up for this loss in addition to the loss caused by plants removing compounds as they grow.

Water falling onto the surface of a soil, either as raindrops or as a result of overhead irrigation systems, tends to smash surface soil structure (Fig. 8.17). This increases the break-up of the surface soil. Water may also combine with minerals in parent rock to produce pressure that eventually causes the parent rock to fracture and exposes fresh material to the soil-forming forces.

Temperature levels in the surrounding environment will influence the rate of soil formation from parent rock. High temperatures, in combination with water, stimulate many

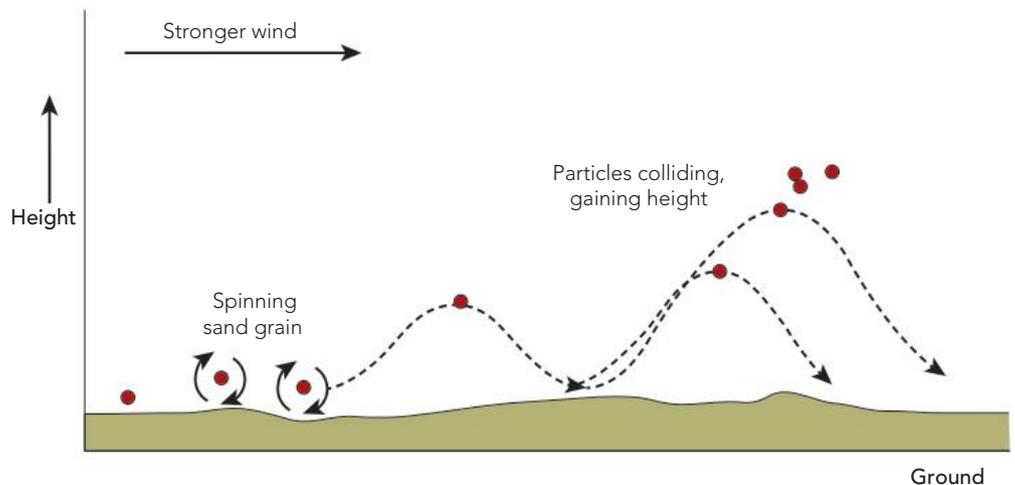


Figure 8.16 Particle movement by wind



Figure 8.17 Rain damage to surface soil structure

- 25 List the main climatic agents that cause the breakdown of parent material into soil.
- 26 For each of the factors identified in your answer, describe with examples how they may lead to the formation of a soil.

chemical reactions. Drastic temperature changes over time may result in sections of surface rock flaking away. In Australia many rocks of volcanic origin (e.g. granite or basalt) break down in this way. Tropical soils may be very deep.

Climate also influences the rate of soil formation because of chemical reactions occurring in the soil itself. These reactions may involve oxygen and water from the atmosphere or various soil solutions. For example, minerals such as augite or hornblende (found in hard volcanic rocks like basalt) slowly combine with oxygen, which hastens the breakdown of the parent rock. Water may also dissolve minerals out of parent rock, or form a solution.

Soil solutions may contain many chemicals. One important solution is a mixture of carbon dioxide and water. The acid this forms (carbonic acid) is often located near plant root areas, where the number of soil organisms is high. This acid acts on many common minerals and as they dissolve they are washed away (in limestone soils, carbonic acid is partly responsible for cave formations).

Parent material

Parent material is the storehouse of future soil material and soils can be classified into one of two groups according to the source of their parent material:

- 1 *sedentary soils* have never moved and have formed from the solid rock that lies under them
- 2 *transported soils* have been carried to their present site by gravity, wind or water. They have little relationship to the type of rock found in the area.

The agents that transport a soil are called agents of erosion. Erosion is the wearing away of material and the movement of weathered material (Fig. 8.18).

The material in the parent rock affects the percentage of sand, silt and clay in a soil, as well as the chemical make-up of a soil and the way soil particles are held together. Sand, for instance, results from the breakdown of sandstone. Sand is chemically inactive and as the sandstone breaks down, individual sand grains are released. Because there is little or no material that can stick these grains together, they form a loose covering over the parent material. Soil material such as sand is readily transported by wind and water. Rocks such as shale, on the other hand, weather to release many materials, several of which act as cementing agents. Shale also weathers to form a very fine particle called clay that is very sticky and can absorb water.



Fairfaxphotos/Andrew Taylor

Figure 8.18 Transported soil – cars left covered in soil particles after a dust storm in Canberra

Biological factors

Many living organisms, both plant and animal, combine to assist in the formation of a soil. Rocky landforms may gain a covering of soil due to a succession of colonising organisms. Next time you walk in bushland, look for greenish-grey or brown-coloured patches on some of the rock surfaces. These are lichens, one of the many types of organism that assist in the breakdown of rock. The rough surfaces possessed by lichens, algae or mosses also trap soil, building up a covering layer over the rock. This allows small grass plants to grow and, over time, even trees can take root in only a few centimetres of soil over a rock.



iStockphoto/theyaha

Figure 8.19 Plant rootball with soil

- 27 Explain how parent material can influence the type of soil that forms from it.

The type of plant growing in a soil may be an indication of the nutrient level of the soil. In general, grasses feed more heavily on chemicals such as calcium, magnesium and potassium than do trees. In grass-covered areas soils may contain higher levels of these chemicals than in heavily timbered areas or bare soil. When the grasses die, the chemicals held in their tissues are released, replacing what has been removed from the soil.

Numerous organisms living in the soil are also responsible for binding the particles together. This is due in part to the sticky substances produced when organic material is broken down. Additionally, plant roots can physically hold particles together (Fig. 8.19).

Landform or topography

Where land has a slope, the rate of erosion increases, exposing further fresh material to be broken down. Soils located on slopes are shallow. On the upper areas of a slope, clay soils are well drained and well aerated, and oxidation results in the formation of a red-coloured oxide of iron. At the bottom of the slope, yellow or blue oxides of iron may be found and a sour smell is often detected, indicating poor drainage and aeration at the bottom of the slope (Fig. 8.20).

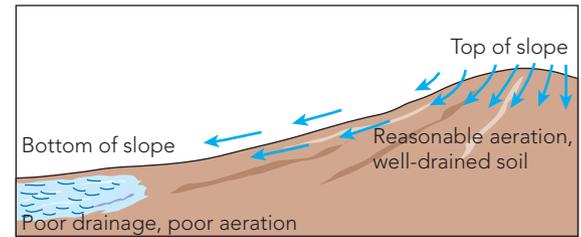


Figure 8.20 Soil relationships on a slope

The influence of time

As the processes of soil formation work on the parent material, a layer of soil forms. In the short term there is little evidence of a layer-like development. As the time span lengthens, the processes of leaching and deposition of material further down in a soil become evident. In the long term, several layers of material may form above the parent material. Each of these layers has a distinct chemical and physical make-up.

Soil profile

A **soil profile** is a vertical section through a soil passing from the soil surface to the underlying parent material. The exposed soil shows different layers, each of which results from the interaction of the soil-forming factors described. A *soil horizon* is a layer

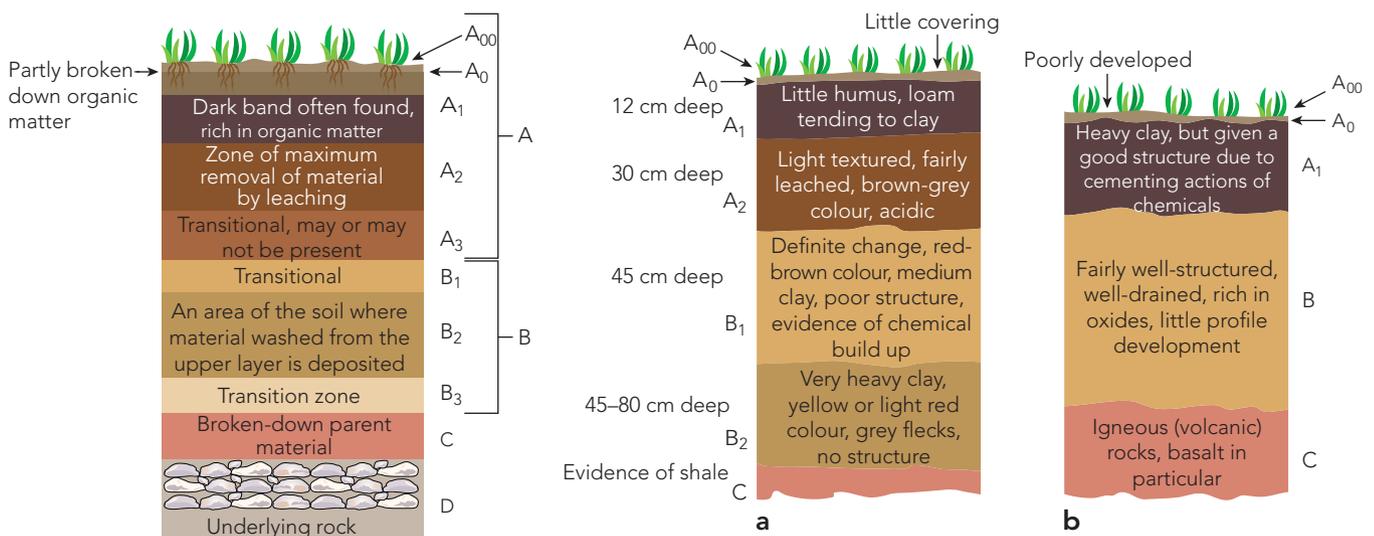


Figure 8.21 A generalised diagram of a soil profile, showing definite horizon formation

Figure 8.22 Two actual soil profiles: **a** coastal podsol (a type of acidic forest soil) and **b** red loam (note the influence of parent material and climate on profile development)

- 30 What is the importance of time in the formation of a soil?
- 31 Draw and label a soil profile diagram.
- 32 Describe how a soil profile could form.

within a soil profile that can be distinguished from other layers within the profile by its appearance, physical behaviour and chemical make-up. Figure 8.21 illustrates the general parts of a soil profile.

In agricultural systems across Australia, several types of soil profile exist. Under high rainfall conditions, the profile is well developed, with very distinct horizons. Where rainfall is low, this definition is not so apparent. Figure 8.22 shows two typical profiles developed under different environmental conditions.

The importance of soil

All soils form a significant resource for various farming systems and, if not managed properly, may rapidly become a limiting factor to farm production. The soil is made up of a number of different particles and there are two simple ways to demonstrate this. You can take a handful of soil and put it through a series of sieves ranging from coarse to fine screens: you will have divided the soil into a number of fractions.

The other way is to place a small amount of soil in a measuring cylinder, add water and shake for a few minutes. Leave it to stand and you will soon notice the soil falling into obvious layers. The particles that make up the soil are settling out according to their size, as shown in Figure 8.23.

The material floating on top of the water is called organic matter. *Organic* here is used with the meaning that scientists have traditionally used, meaning something that was once living and thus its remains contain carbon. The organic products movement uses *organic* slightly differently, meaning natural. Examine the organic matter carefully to identify any living plants or animals and dead material from plant or animal bodies. There may also be black material that has broken down to a point where the plant and animal parts are not recognisable. The remaining parts of the soil are classified according to their size, as shown in Table 8.2.

The soil particles arranged according to size, from the largest to the smallest, are gravel, sand, silt and clay. They are part of the inorganic material that makes up the soil. The remaining inorganic materials include water, air and other chemicals. From these observations it can be concluded that a soil is a mixture of organic and inorganic material. This soil is capable of supporting life.



Figure 8.23 Measuring soil texture by separation of soil fractions in water

Table 8.2 Particles in a soil

Name of particle	Diameter of particle (mm)
Gravel	Greater than 2
Coarse sand	2–0.2
Fine sand	0.2–0.02
Silt	0.02–0.002
Clay	Less than 0.002

- 33 List the main inorganic components of a soil.
- 34 Explain the difference between organic and inorganic material in a soil.

Soil texture

Soil texture refers to the amount of sand, silt and clay in a soil. You may feel it if you take a small sample of soil and dampen it until it just sticks to your fingers and then rub it between your fingers. Soils high in clay feel silky and soft; soils high in sand feel rough and gritty.

Soils are sometimes given names that describe their texture. For example, loam is a soil containing sand, silt and clay, but where there is excess sand, the soil is termed a sandy loam. Where the soil contains more than 30 per cent clay, the sticky properties of clay begin to dominate.

Table 8.3 compares the main properties of sandy soil and clay soil and how they influence agricultural production systems.

The texture of the soil does not alter and it is an important property of soil, because texture influences several important features of the soil:

- drainage of water into and through the soil
- movement of water into a soil
- soil air circulation
- soil structure, to some degree, because particles need to be cemented by particles like clay
- ease with which plant roots move through the soil
- ease with which a seed germinates in the soil
- soil's capacity to hold water and chemicals
- soil's capacity to hold heat.

Table 8.3 Properties of sandy and clay soils

Sandy soil	Clay soil
Consists of large angular particles of quartz	Consists of small particles of various minerals
Coarse texture	Fine texture
Cannot be moulded	Can be moulded
Structureless	Particles form crumbs
Contains few plant nutrients	Rich in plant nutrients
Large individual pore spaces	Pore spaces very small
Well drained and aerated	Poor drainage and aeration unless well structured
Total pore space small (25 per cent)	Total pore space large (50 per cent)
Low water-holding capacity	High water-holding capacity
Warms up quickly	Warms up slowly
Early soils	Late soils
Easy to work	May be hard to work
Not affected by wetting and drying	Becomes sticky when wet, may swell and crack on drying
Improved by adding clay or organic matter	Improved by adding sand or organic matter or minerals such as gypsum

- 35 Describe the major differences between sandy and clay soil.
- 36 Define 'soil texture'.
- 37 What properties of a soil does texture influence?
- 38 Can the texture of a soil be easily changed?

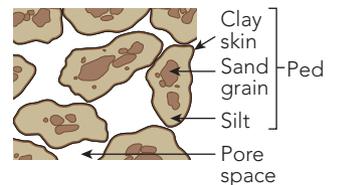


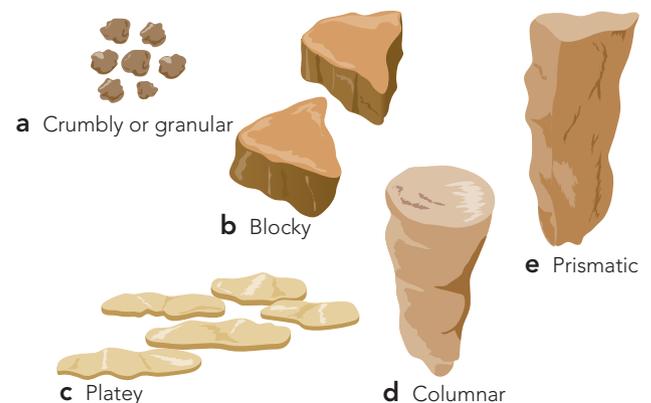
Figure 8.24
The structure of soil peds

Soil structure

Soil structure refers to the arrangement of soil particles in a soil. The particles are the individual sand, silt or clay parts of a soil, and secondary particles are soil **aggregates** or **peds** (Fig. 8.24), which contain sand and silt particles glued together by clay. The appearance of a soil aggregate determines the structural appearance of a soil, as is shown in Figure 8.25.

Soil structure can be altered by changing existing environmental conditions or by adopting different methods of farming. The behaviour of a soil under cultivation depends on the presence of clay particles. A soil will form a stable structure if the clay particles are brought together and held permanently, usually by a combination of chemicals and water.

Figure 8.25 Various types of soil aggregate



- 39 Define 'soil structure'.
- 40 Describe a 'soil ped'.
- 41 What are two ways by which a farmer could improve soil structure?
- 42 What are two ways by which a farmer could ruin soil structure?
- 43 How does the size and number of soil pores affect soil properties?

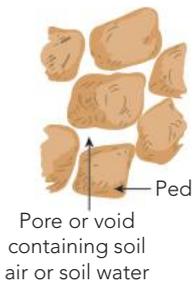


Figure 8.26 Soil-pore space relationships

Soil structure may be developed or enhanced by a number of natural processes, including the movement of plant roots through the soil and successive periods of wetting and drying. The farmer may assist the development of structure in a soil by the addition of chemicals such as lime, gypsum or vermiculite. Overcultivation, overstocking, cultivating when too wet and continuous cropping all destroy the structure. Placing soil under pasture for several years can assist in the improvement of soil structure.

Soil structure is also the key to soil fertility. The arrangement of soil particles determines such things as the size of the spaces or **pores** between particles in a soil (Fig. 8.26). Pores contain either air or water, adequate amounts of which are needed for the growth of plant root systems and the germination of seeds. Soils with large pores allow water to move into the surface layers and through them to be easily and readily available to plants. This avoids problems of surface erosion, although such soils may also lose chemicals through leaching.

Soils with a well-developed structure are less prone to be transported by wind or water. This is because the soil particles are arranged and stick together in well-defined crumbs or peds that are heavier than the individual particles. Sandy soils that have no structure are easily moved by wind or water – standing on a beach during a windy day will give you an idea of how easily some surface material can be moved.

Closely packed soils – that is, those with small pores, such as clay – are very dense. This results in plant root systems having difficulty penetrating to any depth. Machinery designed to be dragged through the soil shows wear more rapidly in such conditions.

Soil water

It is within the soil environment that plants and other living organisms search for air, moisture, nutrients and a suitable temperature to encourage growth. Plants contain between 80 per cent and 90 per cent water. They must replace the water lost through their leaves (by transpiration) by drawing moisture out of the soil through their root system. During this process dissolved nutrients are brought into the plant from the soil solution.

Water is necessary for the transport of plant food materials throughout the plant. Plants use water and carbon dioxide to make sugar (food) during photosynthesis and water is also used in other chemical reactions within a plant. Plants also require water in order to keep their cells fully expanded or turgid. This maintains the shape

of the plant. When a plant is placed in an environment where water is lacking, its cells become flaccid, it wilts and loses shape rapidly.

Plants must draw water out of the soil pores. The smaller the size of the soil pore, the more difficult it is for the plant to obtain water. In a clay soil, with its many small pores, plants may have great difficulty in removing water and may wilt even when the clay soil appears wet or moist.

Figure 8.27 demonstrates several important soil-water relationships. When all the available pore space is full of water the soil is said to be **saturated**. This condition can interfere with growth as air is thus forced out of the pores. The amount of water remaining in the soil (held in the pores) 24–48 hours after

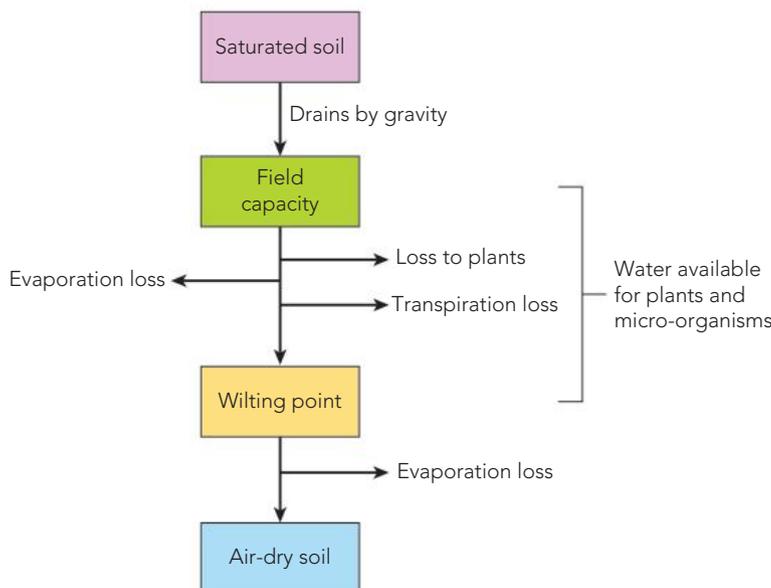


Figure 8.27 Soil-water relationships

saturation by irrigation or rainfall is called **field capacity**. The quantity of water held in the soil between field capacity and the **wilting point** of a plant is the total amount of water available to the plant.

Oxygen

All living organisms require oxygen for respiration (breathing) to release energy in their cells. Oxygen is also required by seeds for germination. In soils where the amount of oxygen available to organisms falls below 10 per cent there is a noticeable decrease in the activity of living organisms. In an environment where oxygen is lacking (an **anaerobic** environment) few plants exist. In these environments, micro-organisms often release minerals to the air rather than recycle them to the soil.

Soil temperature

Clay soils are often regarded as cold, wet soils. Plants grown in these soils are often slow to germinate and seedlings may display slow initial growth. For these reasons clay soils are termed late soils, as plantings must be delayed until the soil warms up. In contrast, sandy soils warm up readily because of the amount of air held by their larger pores, and so allow earlier plantings. Soil temperature also has a marked effect on the activities of micro-organisms. Chemical cycles – for example, nitrogen and carbon (see Chapter 7) – slow dramatically during cooler winter months.

The colour of the surface soil affects the amount of solar radiation absorbed. Dark coloured surfaces readily absorb radiation and consequently warm up rapidly. Such soil surfaces radiate heat, which may affect the above-ground parts of a plant.

Soil micro-organism activity

Soil organic matter is formed mainly from plant material, although you will find evidence of animal remains in a soil. The breakdown product of organic matter is a very small particle called **humus**. Like clay, this particle has the ability to attract and hold both water and minerals. Humus can also cement soil particles together.

Humus is formed by micro-organism activity, and during this process many compounds are released. They range from simple sugars and amino acids to complex waxes and lignins. Water, energy and various gases are also released. In addition, chemicals are freed and become available to plants.

Erosion and organic matter loss

The most common forms of soil degradation are caused by erosion, the removal of soil materials from one place to another by water or wind. Water erosion is common where surface vegetation cover has been removed – the exposed surface layers of the soil are washed away as water runs over them. This is termed sheet erosion (Fig. 8.28). Rill erosion occurs where the speed of this surface water increases and small channels are formed (Fig. 8.29). Fast-moving water will cut deep channels into the soil, causing gully erosion. These gullies may range from 20 centimetres to many metres in depth (Fig. 8.30). Water can also flow through the subsoil, removing it and forming a tunnel that can cave in (Fig. 8.32 shows tunnel erosion).

Wind erosion occurs in semi-arid and arid areas of the country. Overgrazing of sandy and poorly structured soils accelerates this process. The movement of fine soil in this way creates dust storms, surface scalds and the accumulation of drift material against fences and other structures (Fig. 8.31).

-
- 44 Define 'wilting', 'field capacity' and 'saturation'.
 - 45 Explain what 'available soil water' means (see Fig. 8.24).
 - 46 Why is it not a good idea to water a plant only when the soil looks dry?
 - 47 Explain why oxygen levels in a soil may influence the activities of micro-organisms.
 - 48 Outline the difference between early and late soils.
 - 49 How can the colour of a soil influence its temperature?
 - 50 What types of chemicals are released by the breakdown of organic matter by micro-organisms?

- Several factors change the rate of erosion:
- rainfall – amount, intensity, length of showers
 - wind – speed of the wind
 - vegetation cover – extent and type of cover
 - slope of the land – how steep the land is
 - soil type and stability – how well structured the soil is.

Loss of soil organic matter due to overcultivation and various cultivation practices is widespread in Australia. Soil structure and fertility are both affected. Reasons for this problem include loss of natural vegetation cover, overgrazing of semi-arid lands in pastoral areas, clearing and cropping activities in marginal areas, bare fallowing (allowing paddocks to lie bare after harvest) and stubble burning. Conventional farm management systems for cereal cropping involve a pasture phase for up to 5 years,



iStockphoto/gmatrichard

Figure 8.28 Sheet erosion



Shutterstock/Palo_ok

Figure 8.29 Rill erosion



Shutterstock/Yuri Kravchenko

Figure 8.30 Gully erosion



Auscape/© Wayne Lawler

Figure 8.31 Wind erosion



Newspix/Steve Tanner

Figure 8.32 Tunnel erosion

then after several cultivations the land is suitable for planting successive cereal crops for the next 3–4 years. Short fallow periods of between 2 and 4 months are used between successive cereal crops. These fallow periods are needed to conserve summer rains in areas receiving less than 450 mm of rain a year but heavy rains during the fallow period often cause erosion. Several land cultivations are also needed during the fallow period to control weed growth. To prevent the breakdown of soil structure and organic matter loss, several management alternatives are available to the farmer.

Stubble retention – any management system that keeps high levels of crop remains in the soil – can be carried out in two ways:

- ploughing in the stubble with cultivation machines such as disc ploughs, to build up the organic matter levels of the surface soil layers
- *stubble mulching*, by which a protective layer of vegetation material is kept on the surface of the soil until sowing time (this requires specialised stubble-handling equipment).

Conservation tillage systems, which include minimal or reduced tillage methods, benefit the farmer by reducing soil damage, lowering fuel costs and giving the farmer more flexibility with grazing times. Chemical weed control and strategic cultivations are used to control weed growth during the fallow period.

Zero tillage or *direct drill* systems, in which seeds are planted directly into the remains of a previous crop with no prior mechanical seedbed preparation, are now being adopted where practical. The control of previous crop growth is achieved through herbicide application. This approach may be useful where fallowing is necessary, as in southern Victoria, north-western New South Wales and southern Queensland. Some problems exist with this technique.

- Many kinds of weeds must be controlled in the fallow period. This may require several types of herbicide.
- Weeds germinate rapidly after rain, and so several applications of herbicides may be needed.
- There is concern about the effect of chemical residues in the soil, especially on crops that follow the fallow period.
- The cost-effectiveness of mechanical as opposed to chemical weed control methods is often raised.
- The technique makes the use of effective planting machinery necessary.

Farmers need to consider the integration of practices such as direct drilling, minimum tillage and stubble retention into total farm management. Often these techniques are adopted on a financial basis rather than out of concern for conserving the soil as a resource on the farm. Newer management systems also have to prove their superiority over conventional or traditional systems. In addition, research and advisory bodies often spend time describing the processes involved in reduced cultivation methods and preventing land degradation, rather than presenting effective total farm management systems to farmers.

51 Describe the types of erosion that are possible.

52 What factors influence the rate of soil erosion?

53 Describe the traditional system of land cultivation for crops.

54 What management options exist for a farmer wanting to improve the level of soil organic matter?

Managing farm resources

The main unit of production in an agricultural system is the farm. The output or production level of the farm depends on several key factors:

- the genetic make-up of the plant or animal component of the farm
- the efficiency with which solar energy is converted into chemical energy in plants
- nutrition levels (e.g. fertiliser type and level for plants; energy and protein needs of the animals)
- freedom from climatic stress – the suitability of plants and animals to existing temperature, light levels, rainfall and day length

- levels of disease immunity within subsystems
- the effect of predators and natural disasters
- the farm manager's ability and skill level.

How a farmer manages a farm – the way the land is cultivated and the intensity of production – is often determined not by these factors but by combinations of the following:

- *social factors*, such as how the farmer was taught to do certain tasks (usually by family or friends, or through education) and the farmer's philosophical ideals and beliefs
- *economic factors*, such as production costs, availability of money, market prices and the availability of efficient transport
- *physical and biological factors*, such as landform, soil and climate influences, and ecological factors.

Therefore, several factors interact and often compete in determining the success of a farm operation.

The soil as a resource on a farm can limit production efficiency because of the following characteristics:

- structural stability
- aeration levels
- plant nutrient levels
- water levels and water-holding capacity
- organic matter levels
- pH and salt levels
- degree of pollution from chemicals.

The way that farmers manage the soil will often reflect the skills they have learnt, the economic conditions prevailing at the time and market forces.

55 List seven ways that soil can limit farm production.

Chapter review

Things to do

- 1 Draw the following instruments and show how they record changes in the weather.
 - a Rain gauge
 - b Anemometer
 - c Wet-and-dry-bulb thermometer
- 2 Find information on the following ways in which soils form. Draw a diagram to illustrate the process.
 - a The effect of tree roots on breaking up a soil
 - b The effect of low temperatures on rocks
 - c The effect of drought on the surface of a clay
- 3 Construct one of the instruments for measuring weather named in question 1.
- 4 From your local area, collect the following data and graph it.
 - a Monthly rainfall for one year
 - b Average monthly minimum temperatures for one year
 - c Average monthly maximum temperatures for one year
- 5 Obtain some of the following rocks: sandstone, shale, granite and slate. Use a hammer to break up the rocks, then rub and grind the fragments for 10–15 minutes. Place this material under a binocular microscope. Identify the most common particles and draw what you see. What does this tell you about soil formation?
- 6 Write in your notebook observations about the local rainfall and temperature patterns. How do these patterns influence the farming activities around you?
- 7 Visit an extensive farm and list everything the farmer is doing to avoid climatic problems.
- 8 Visit an intensive animal production shed. Record all the methods used to alter climatic conditions in the shed. Record the air temperature, humidity and light levels in the shed and compare these to measurements taken outside.
- 9 Visit a glasshouse or greenhouse. Draw the structure and attempt to show the following features.
 - a How it is ventilated
 - b Why it heats up
 - c Additional features used to control the climate, such as heating cables
- 10 Visit a road cutting or area where the soil is exposed. Draw and describe all the changes you notice as you move from the surface of the soil, down towards bedrock.
- 11 Make up your own soil profile. You may like to do this to scale. Coat some plywood or masonite with wood glue. Place soil taken from various layers of a soil profile onto the wood. You may adjust the depth of these horizons

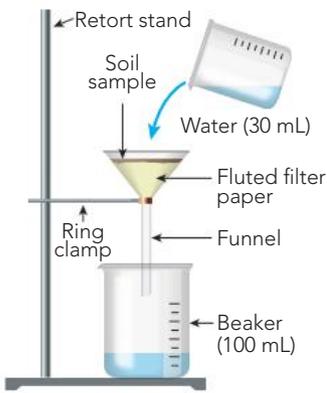


Figure 8.33 Measuring water movement through a soil

to reflect the actual depth in a profile. Shake off excess soil after this has been allowed to dry, then label the horizons.

- 12 Obtain samples of several different soils. Take a handful of soil from each sample and drop it from a height of 1 metre. See how much of the sample forms peds after being dropped.
- 13 Look at Figure 8.33 and set up the equipment shown. Place a sample of clay soil into the filter paper. Add 30 mL of water, gently. Time how long it takes for water to enter the beaker below. Measure how much water is collected in the beaker. Repeat the experiment using a sandy soil. Discuss your results.
- 14 Place thermometers at various depths in a soil. Measure the soil temperature at each depth and graph your results.
- 15 Mark out a series of metre-square grids on an open area of bare soil. Place different types of covering or mulch over the soil in each grid square. Leave for 2 weeks, then measure the temperature of the surface layers of the soil. Which covering most affected the temperature of the soil?
- 16 Either fill a tray with sandy soil and place it on a gentle slope, or select a sloping site outside. Allow water from a hose to move over the surface in a light watering, a medium watering and a heavy watering. After each stage draw the resulting landscape. Try to identify various patterns of erosion.
- 17 Repeat the experiment, but cover the surface with grass, straw or a mulch of your choice. What happens?
- 18 Survey your local area or farm and record all the types of erosion you see. Try to identify the cause and decide how you would prevent the erosion from occurring.

🔑 Things to find out

- 1 What trees and shrubs are most commonly used in windbreaks? What planting patterns are used for windbreaks?
- 2
 - a What is 'cloud seeding'?
 - b How important is this practice in agriculture today?
- 3 Describe how computers are used to record daily weather information.
- 4 Look around the farm at your school.
 - a In which direction do most of the buildings (e.g. the piggeries or poultry sheds) face?
 - b Why are they built this way?
- 5 Use the internet to find information on local weather conditions at websites such as the [Bureau of Meteorology](#) or [Weather Zone](#).
- 6 Visit a valuable piece of agricultural land in your local area. Then visit a poorer section of land. Compare these areas by constructing a table in your notebook. Use the following headings to help you: Soil colour, Types of plants found, Drainage, Aeration, Type of soil, Productivity in terms of stocking rate or cropping rate.
- 7 Find out the systems used on local farms to provide water to each of the following, then draw and describe each system.
 - a Irrigated crops
 - b Orchard trees
 - c Glasshouses

connect

Weather Zone

connect

Bureau of Meteorology

- 8 Why do some vegetable growers prefer white plastic to black plastic as a mulch material?
- 9 Why would potting mixes used for seedlings have a high sand content?
- 10 When deep holes are dug into a clay soil a strong unpleasant smell is often noticed. Why?
- 11 Visit a hilly paddock just after it has been ploughed. Describe any changes in soil type and colour over the length of the slope.
- 12 Collect a series of weather maps from the daily newspapers or internet for 7 consecutive days.
 - a In which direction do the pressure systems move across Australia?
 - b What are the common systems located on the maps, for the period of your observations?
 - c What influence do these systems have on local weather patterns?
- 13
 - a What is the El Niño effect?
 - b What impact does it have on agricultural production?

+ Extension activities

- 1 Describe the yearly calendar of operations on a sheep–wheat farm. Why are these two subsystems commonly combined?
- 2 Use books or the internet to find out the differences between ‘natural erosion’ and ‘accelerated erosion’. List the reasons for the occurrence of accelerated erosion in your local area.
- 3 Discover what is meant by a ‘dust bowl’. Why do these often occur in areas where extensive crop cultivation practices occur?
- 4 Why is clay used in the manufacture of bricks and pottery?
- 5 Analyse climate data for your local area and discuss how these trends affect the type of agriculture in your area.

✓ Test yourself

- 1 The water cycle is an important part of the agricultural ecosystem.
 - a Draw a labelled diagram of the water cycle.
 - b List three important processes that occur in the water cycle.
 - c Explain how one of these processes can be modified by the farmer to increase the output of the system.
 - d Describe one way water may be lost from a production system, and outline a method of reducing this loss.
- 2 Copy the following table for your local soil into your notebook and complete it. Explain how one feature or characteristic of this soil has affected how it is managed in agricultural production systems.

Horizon	Colour	Texture	Structure	pH

- 3 Plants supply food for many living systems but only a small amount of available solar radiation is used for this process.
- Describe what happens to incoming solar radiation.
 - Discuss what factors influence how well plants can use this light to make food.
 - How can farmers improve the yield from their farm by influencing climatic factors?
- 4 Use the information in Table 8.4 to complete these tasks.
- Draw a graph of the available moisture levels of each of the three soils.
 - Decide in which of these soils a plant could survive the longest during a dry period and why.

Table 8.4 Soil moisture levels for three soils

Soil type	Wilting point (per cent)	Field capacity (per cent)	Available moisture (per cent)
Sand	3.1	7	3.9
Loam	6.0	22	16.0
Clay	18.2	39	20.8

CHAPTER 9

AGRICULTURAL CHEMICALS

Words to know

antibiotic a chemical produced by a living micro-organism to control, and usually kill, the growth of neighbouring organisms (generally micro-organisms)

disinfectant a chemical used to destroy disease-causing micro-organisms (generally bacteria)

drench a chemical given orally to animals, generally to control internal parasites

herbicide a chemical substance used to control or prevent the growth of plants (generally weeds)

insecticide a chemical substance used to kill insects

pheromone a chemical substance released by an animal that influences the development or behaviour of other animals of the same species

residual a term used to describe a chemical that remains active and does not break down in the natural system for a period of time

resistance the ability of a group of organisms to survive a particular pest treatment

Introduction



Shutterstock/skydie

Figure 9.1 Pyrethrum daisy

Everything on this planet is made up of chemicals. Sometimes people talk about ‘chemicals’ as if they are all bad. Some chemicals are but it is worth remembering that the air, all the food and water people consume, and even people themselves are all made up of chemicals.

People involved in agricultural production systems use agricultural chemicals for many reasons. Plant and animal growth can be manipulated through the use of various products. Chemicals also help in the control of plant and animal pests and diseases, including the control of weeds in cropping systems. Many chemicals used on farms are naturally occurring substances. The pyrethrum daisy, for instance, is the source of a widely used insect spray. Other plants such as tobacco also produce chemicals that control insects. Chemicals applied to kill insects are termed **insecticides**: some common insecticides are pyrethrum-based sprays, petroleum oil-based sprays such as white oil, or rotenone, a broad-spectrum insecticide.

After harvesting, great damage can be done to food products by weevils, flour beetles and other grain insects. It is necessary to use chemicals to prevent spoilage and maintain the food supply to an ever-increasing population.

Chemicals are also used to prevent animals from suffering unnecessarily from the effects of pests and diseases. Farmers have long known the benefits of applying sulfur, bluestone (copper sulfate) and tar to suffering animals. Since the early 1950s many new chemicals have been developed to help the farmer.

Australian soils are generally very infertile and many farmers rely on the addition of chemicals (in the form of fertilisers) to their soils. These chemicals supply additional nutrients to the plant systems on the farm (Fig. 9.2). Addition of nutrients such as nitrogen, phosphorus and potassium has maintained or increased production levels in many areas of Australia.

Soil conditioners (such as gypsum) are chemicals that are added to the soil to improve its structure. Management practices that improve soil fertility include the use of lime, which influences soil acidity (pH), and green manure crops, which add nutrients to the soil.

Weeds in plant and animal production systems are a major economic problem.

Weeds compete with desired plants for available water, minerals, space and light. This

reduces the yield of the plants. In animal production systems, weeds outgrow many of the more productive pasture plants, such as lucerne, when these pastures are being established. Weeds, apart from having a lower nutritional value than pasture plants, may also cause poisoning, physical damage or extreme reactions in livestock. Weeds may lower the economic value of the output from many production systems: for instance, wool contaminated by a large amount of seed and plant material has a lower value. Chemicals (**herbicides**, e.g. Roundup®) may be used to control weed growth.

There has been a recent trend towards chemical implants in animals to increase growth, especially with cattle. These chemicals are hormones (such as growth hormones, which are

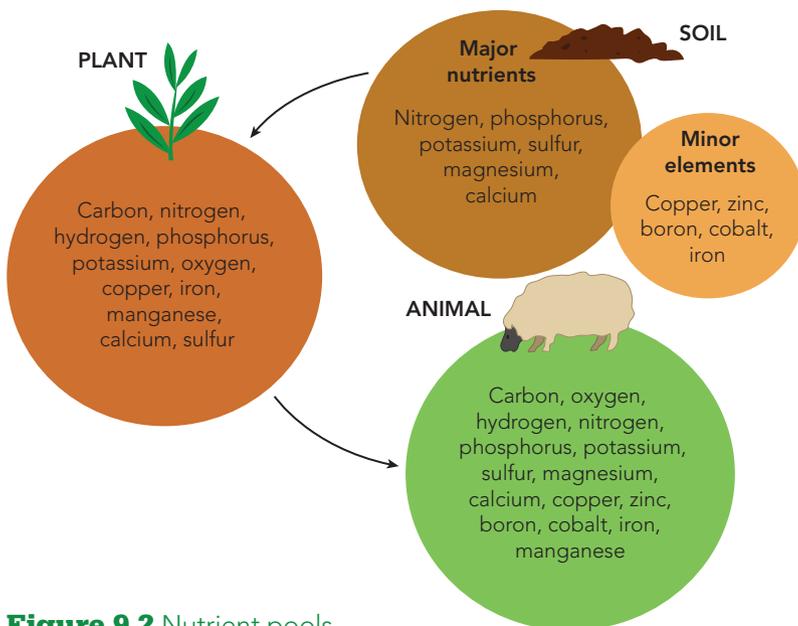


Figure 9.2 Nutrient pools

fatty, waxy-type chemicals produced naturally in an animal's body) that specifically accelerate growth. A small amount of the hormone is implanted (as a pellet) behind the animal's ear. Unless the animals are adequately fed and well managed, little advantage is gained. Use of hormones to promote growth excludes animals from some markets (e.g. Europe), so these animals must be identified on a National Vendor Declaration form (NVD) when they are sold.

Chemicals are similarly useful in promoting the early ripening of fruit. Apples may be picked green and placed into cold storage. When ethylene gas is introduced to the atmosphere of the storage rooms the fruit ripens. This allows farmers to control the number of apples entering the market and provides a year-round supply. Chemicals may also be applied to reduce the amount of fruit on trees. This process is called chemical thinning. The growth-regulating chemical ethephon (ethrel) has been used on apple crops for several years. Fruit remaining on the trees develops to a suitable size, rather than remaining small because of excessive competition.

Insecticides

Insecticides affect the basic processes occurring in organisms, such as breathing, heartbeat and the operation of the nervous system. There are two major types of insecticide.

- 1 Contact insecticides.** These must come into direct contact with the insect; that is, be absorbed by some part of the insect's body. They include various types of oils (e.g. white oil), dusts (such as maldison) and chemical sprays (such as pyrethrum-based insecticides). They may operate by attacking the insect's outside covering or by being absorbed into its mouth and stomach.
- 2 Systemic insecticides.** These are absorbed by plants and circulated (translocated) through the plant system, killing any insect feeding on the plant. They are very effective against sap-sucking insects and can also kill some biting and chewing insects. Most of these insecticides are organophosphates and include chemicals such as diazinon, dimethoate (Rogor®) and fenthion (Lebaycid®) that break down in nature but until they do, are very poisonous to humans and useful insects such as bees (Fig. 9.3).

Chlorinated hydrocarbon insecticides also exist and are a combination of contact and internal types of spray. Chemicals in this group include DDT, chlordane, lindane, dieldrin and heptachlor. Their use has been discontinued because these chemicals do not break down in nature and thus remain highly toxic.

Other types of chemicals used in the control of insects include soil fumigants, controlled environments for food storage using nitrogen as a medium, and plant-derivative extracts including pyrethrum and carbaryl. Plant derivatives are some of the safest insecticides to use, leaving no undesirable residues. Pyrethrum (found in fly sprays) and carbaryl are very effective against a wide range of caterpillars. Soil sterilants sterilise the soil and kill such pests as nematodes.

Insects too produce their own chemicals, which control their behaviour. These chemicals belong to a group called **pheromones**. Many insects use the chemicals to attract mates. Scientists are able to make some of these chemicals artificially, and synthetic pheromones are mixed with insecticide to produce baits. This concept is used to control fruit fly and codling moth in orchards. Naturally occurring plants such as garlic are also known to repel insects, while bay leaves repel weevils.

- 1** What is an insecticide?
- 2** List three examples of insecticides.
- 3** Give an example of a pest that causes post-harvest damage to food products.
- 4** What is a fertiliser?
- 5** List three chemicals that Australian soils are generally deficient in.
- 6** Explain how weeds affect plant and animal production.
- 7** List three uses for chemicals in agricultural production systems.

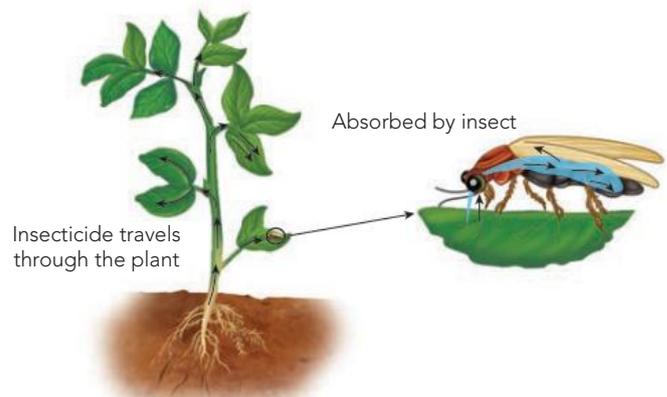


Figure 9.3 Operation of a systemic insecticide

- 8** Describe how two types of insecticide work.
- 9** Give two examples of each type of insecticide.
- 10** Why are many chlorinated hydrocarbons banned for general use today?

Chemical use in plant production

One of the more serious disease-causing organisms in the plant industry is fungus. This can be controlled through the regular spraying of fungicides, which are often copper-based sprays, or the use of modern systemic fungicides such as Fongarid®. Damping-off disease, one fungus that can kill seedlings, can be controlled in this way.

Weed control in crops and pastures is possible through the use of **herbicides**. There are many specific types of herbicide for use in broad-acre crops. These chemicals have assisted farmers in reducing the frequency of cultivation for many crop systems. This results in a saving to the farmer in fuel and machinery costs and is the underlying concept for many minimum-till and zero-till systems of crop production.

Pre-emergent herbicides are applied after sowing and act for a specific period of time. These chemicals kill off emerging weeds but break down before crop

germination occurs. Herbicides applied after crop germination are termed *post-emergent herbicides*. Figure 9.4 indicates the time of application for these sprays.

Care must be taken when controlling weeds in a crop, since spray drift may kill many useful plants as well. Weeds that are closely related to a crop, such as oats growing in a wheat crop, are very difficult to control by chemical means as both plants are affected by the same chemical. Time of spraying is then critical. Other methods of weed control are often needed.

Seeds and stored grains are often treated chemically to prevent insect and fungal damage. Phostoxin and malathion are two chemicals often used for this purpose.

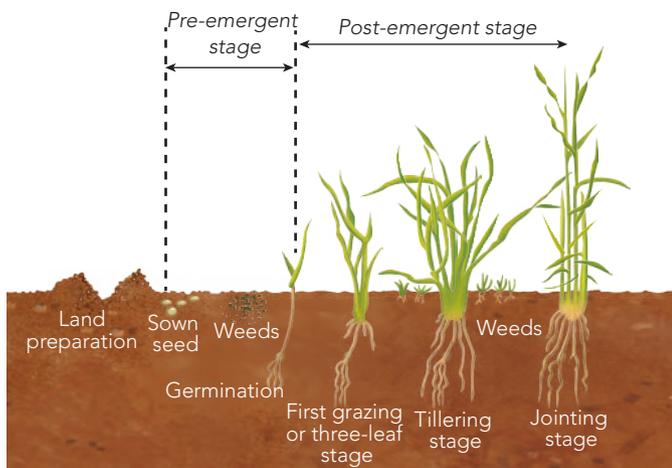


Figure 9.4 Pre- and post-emergent herbicide spraying

Chemical use in animal production

In intensive animal production systems – situations where there are many animals in a small area, such as in commercial piggeries and poultry in commercial cage systems – it is also important that effective disease control measures are undertaken.

In addition to effective quarantine measures, good ventilation, clean water and food and chemicals are often used. Sulfur-based drugs are often incorporated into the feeding and watering systems of commercial poultry farms to control such contagious diseases as coccidiosis.

Managers of extensive animal industries such as sheep and cattle properties need to control external parasites such as flies, and internal parasites such as worms and liver fluke. Chemicals are used to do this, along with good management practice. Sprays can be applied to the animals' coats to control lice, ked and flies. The animals may also be



Science Photo Library/David Aubrey

Figure 9.5 Drenching

dipped, jetted or have spot and pour-on treatments of insecticide directly onto their fleece or skin. **Drenches** are chemicals given orally to animals (Fig. 9.5). Chemicals such as ivermectin control internal worms and flukes and are needed to maintain the health and growth rates in sheep and cattle.

Disinfectants are chemicals used to kill disease-causing micro-organisms. They are commonly used in milking sheds to wash down the udders of cows and to clean equipment after use.

Antibiotics are also important in the control of diseases. These compounds are produced by living organisms (usually fungi) and examples are penicillin and streptomycin. They are used in the control of contagious bacterial diseases in animals (e.g. mastitis in dairy cattle). But the overuse of antibiotics leads to bacteria developing **resistance** to the treatments, meaning that the antibiotics are unable to kill them.

-
- 11** Distinguish between:
- a** fungicides and herbicides.
 - b** disinfectants and antibiotics.
 - c** dips and drenches.
- 12** Explain the difference between pre-emergent and post-emergent herbicides.
- 13** List one problem arising from the overuse of antibiotics.

Fertilisers

The most important fertiliser used in Australia is superphosphate (produced by the action of sulfuric acid on phosphate rock). This rock was imported into Australia from Christmas Island, Nauru, China, Morocco and Jordan. Today most phosphate rock is obtained from Queensland. Phosphate is essential in soils that have been continually cropped and pasture lands rely on phosphate fertiliser to encourage clover growth. But long-term subterranean clover-pasture production coupled with high levels of phosphate fertiliser sometimes leads to an increase in the acid level of soils. The resulting problem is called soil acidification (see Chapter 7).

Overuse of fertilisers results in excess fertiliser being washed into local waterways and creeks. This increase in the mineral level of the water causes algae and surface-floating plants to grow at an increased rate. The end result is a very green creek due to 'algal bloom'. Eventually the plants may take all the oxygen out of the water and prevent sunlight penetrating. In time, all living things in the stream, both plant and animal, may be killed. This is termed eutrophication.

Chemical resistance

Chemicals provide an efficient, rapid way of dealing with plant and animal pests and diseases. With care and selection of the correct chemical, continual application of sprays may not be needed. Chemical expenses still represent a small fraction of total farm costs. Overspraying and using too high a concentration of chemical on the farm may produce problems. If insects or internal parasites survive spraying, the population will over time become resistant to the chemical being used (as demonstrated in Figure 9.6). This resistance can be passed on genetically to the offspring. When this occurs, the chemical is no longer useful and another chemical will have to be used. Scientists in Western Australia have found properties up to 480 km apart where the pest redlegged earth mite (*Halotydeus destructor*; Fig. 9.7) has developed resistance to pyrethrum-based insecticides. The red spider mite, many of the worms infecting sheep, and other types of pest show varying degrees of resistance to most sprays and drenches. Other methods of control are now needed to fight these pests; for example, alternating types of drenches to reduce the development of resistance, or using vaccines.

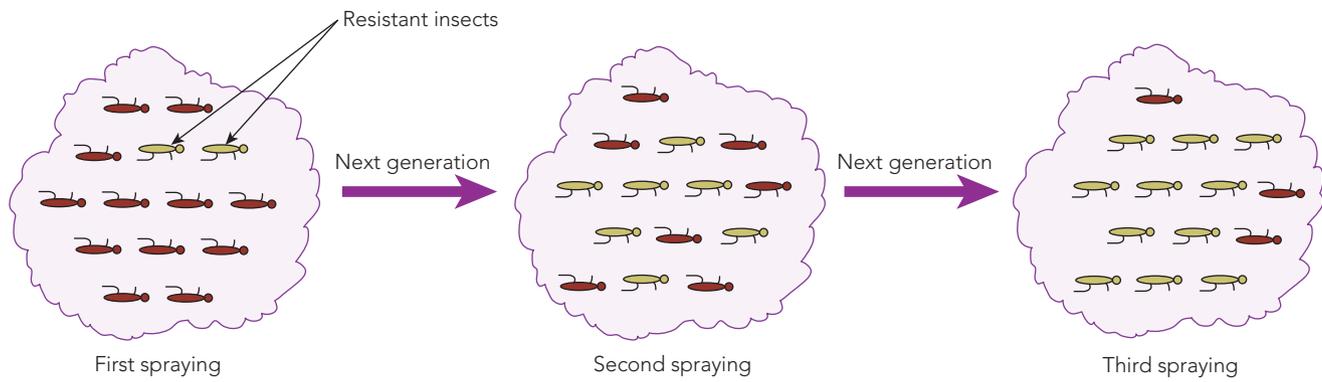


Figure 9.6 Development of increased resistance to pesticides through overspraying and repeated spraying



CSIRO Entomology

Figure 9.7 Redlegged earth mites

The Australian chemical industry

Australian companies specialising in the manufacture of agricultural and veterinary chemicals produce a wide range of products for both plant and animal farming systems. The Australian Pesticides and Veterinary Medicines Authority issues permits for the use of sprays and registers chemicals for use in agriculture.

Chemical products (either synthetic or natural) are only released for general farm use after a long period of research and testing. Many chemicals are tested in laboratories for 1–2 years for their effect on pests and diseases. Substances that show promise are then tested in the laboratory for at least another 5 years. During this time the dosage rates, toxicity levels and the effects of the chemical on non-target insects and animals are assessed. One very important measurement is the chemical’s median lethal dose – the LD 50 rating – how much of the chemical is needed to cause death to 50 per cent of the test animals. This is tested both by application to the skin (dermal basis) and by ingestion (oral basis). The lower the figure obtained, the more toxic the chemical. The final testing stage (taking another 3–4 years) includes the testing of the product in the field to establish safe usage levels and residue levels. After 10 years the new chemical may then be registered for use.

- 14** What are the general steps involved in the manufacture of a new chemical product for use in agriculture?
- 15** Define ‘resistance’.
- 16** Why is insect resistance a concern in agriculture?
- 17** Give two examples of how fertilisers may affect the environment.

Chemical safety

Exposure of the user and friendly or non-targeted organisms to toxic chemicals can be prevented or reduced if chemicals are used safely; that is, with personal protective equipment and with an understanding of the chemicals being used.

When handling toxic chemicals, follow these rules:

- 1 *Read the label carefully.* The toxic ingredient and any other chemical ingredient must be listed on the label. The label must have warning signage (poison schedule, dangerous goods classification). Information about storage and mixing instructions must be shown.
- 2 *Never use a chemical without looking at the directions.* This includes the first aid directions, storage and disposal instructions, crop registrations, application rates and withholding periods.
- 3 *Wear personal protective equipment (PPE).* This includes a hard hat, washable hat, goggles, respirator, rubber boots, thick rubber gloves and spray shields over the helmet when handling a concentrated product.
- 4 *Wear protective clothing.* Most poisons are absorbed through the skin (Fig. 9.8). Poisoning can occur by inhalation of vapours as well as by ingestion.
- 5 *Take care not to spill any chemical.*
- 6 *Only mix up enough of the chemical to use immediately.*
- 7 *Avoid spray drift.*
- 8 *Carefully store any remaining chemicals.* Follow the instructions on the label.
- 9 *Dispose of any leftover chemicals or empty containers.* Ensure you do this in accordance with the instructions on the label.
- 10 *Carefully clean all clothing and equipment after use.*
- 11 *Wash up with soap and water afterwards.*
- 12 *Maintain records of chemical use.* Use chemical data forms available from state agriculture departments.

Material safety data sheets (MSDS) contain a thorough coverage of the physical, chemical and toxic properties of any active ingredients in a chemical product. Information also includes health effects, precautions to follow and emergency procedures. These data sheets are available at the point of purchase of a pesticide.

Farmers also need to ensure that they have any necessary licence; for example, if you are using ground equipment to spray herbicides on another person's property, you will need a Commercial Operator licence.

When storing chemicals, follow these rules.

- 1 Keep the area clean and tidy.
- 2 Always lock the chemicals away in a cupboard out of the reach of children and pet animals, and completely separate from any animal feed.
- 3 Work in well-ventilated areas.
- 4 Never store excess chemicals in an unlabelled bottle or container.
- 5 Follow the directions on the label regarding safe storage temperatures, any need to be kept out of direct sunlight and any other conditions.

18 What rules should be followed for these activities?

- a Handling chemicals
- b Storing chemicals
- c Disposing of chemicals



Figure 9.8 Protective clothing for handling chemicals

Spillage and disposal of chemicals

Unwanted containers and surplus chemicals must be disposed of carefully and according to the manufacturer's instructions. Empty containers should always be disposed of in accordance with the instructions on the label. Do not simply throw empty containers out, wash them or leave them lying around. Remember: do not puncture any aerosol can. The containers can then be buried or taken to a waste disposal site. Unused chemicals must be disposed of at a toxic waste dump. Strict precautions are also needed against contamination of ground and surface water by leaking chemicals.

Chemical residues

19 Define the following terms in relation to chemicals.

- a Residual effect
- b LD 50 rating
- c Withholding period
- d Material safety data sheets (MSDS)
- e Chemical data forms

Chemicals applied to production systems remain active for a period of time. During this time, known as the **withholding period**, the product that was sprayed cannot be harvested. This protects the consumer from buying poisoned food. Each pesticide has a known withholding period during which time it remains active. This also applies to chemicals sprayed on pastures, since it is possible to contaminate livestock if withholding periods are not applied.

The effect of toxic chemicals may be seen immediately (acute toxicity) or chemicals may accumulate in the soil or in a living system, increasing in concentration until the health of animals is affected (chronic toxicity). This **residual** effect has led to the poisoning of many non-target animals, including livestock and humans. Care must be taken to prevent the build-up of chemicals that do not easily break down in the soil.

Chapter review

Things to do

- Obtain samples of commonly used fertilisers such as superphosphate, nitram, sulfate of ammonia, blood and bone, and lime. Draw up a table in your exercise book using the following column headings: Fertiliser, Appearance, Solubility in water, Temperature change when dissolving, and pH. Now place a small amount of each fertiliser into separate test tubes, add water and observe what occurs, then measure the temperature and pH. What can you conclude about the fertilisers you tested?
- With the help of your teacher, obtain soil samples from your local area. Place 20g of the soil into beakers and follow the steps outlined in Figure 9.9, using Universal Indicator or a pH meter to measure the pH (acidity level) of the soil. Repeat the procedure if you have more than one soil sample. What conclusions can you draw regarding the effect of fertilisers on soil pH?

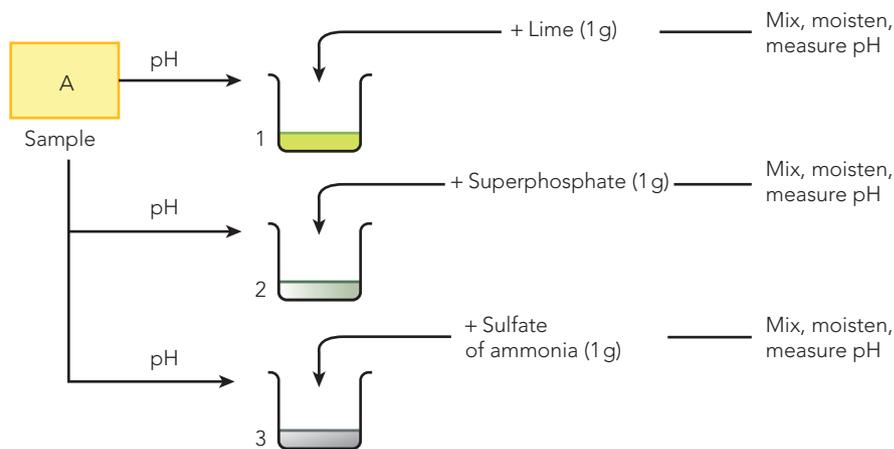


Figure 9.9
Experiment: effect of
fertilisers on soil acidity

- Sow into 12 pots the seeds of either a pea or a bean. Allow 3–4 weeks for the plants to grow to a suitable size. Divide the pots into groups as shown in Figure 9.10.
- Prepare a solution of gibberellic acid, as shown by your teacher. Do not apply any acid to plants in group A, add a low concentration of the acid to plants in group B, and add a high concentration of the acid to plants in group C, while watering each plant weekly.
- Once a week, measure the average internodal length of the plants in each group.
- Graph your results. Write a suitable conclusion for the experiment relating to the effect of gibberellic acid on plant growth.

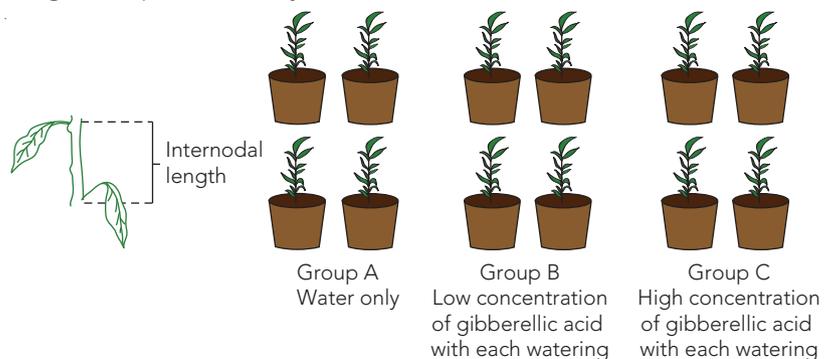


Figure 9.10 Experiment: effect of gibberellic acid on plant growth

🔍 Things to find out

- 1 List five commonly used insecticides in your local area. For each, find out the LD50 rating, withholding period and first aid treatment should poisoning occur.
- 2 Discuss an issue related to problems with the use of toxic chemicals in your local area.
 - a Why have you chosen to discuss this issue?
 - b What type of chemical is involved?
 - c What is the effect of this chemical?
 - d How are the problems being corrected?
 - e What long-term plan would you suggest to prevent further problems?
- 3 Read the label shown in Figure 9.11 carefully, then answer the following:
 - a List five insects that are controlled by this insecticide.
 - b What are the net contents of the container?
 - c List three safety directions to be followed when using the insecticide.
 - d How many litres of the insecticide would be required for application to 3 hectares of land?
 - e How many days before harvest must you cease applying the insecticide?
 - f Obtain and examine an actual label from a real insecticide. Compare and contrast this label with the one in Figure 9.11.

+ Extension activity

- 1 Misuse of agricultural chemicals has become a problem in the farming area around the town of Wedontcare. Your task is to design a safety campaign aimed at reducing this problem by getting farmers to use agricultural chemicals safely. Develop this campaign around the following areas:
 - integrating farm and natural resource management
 - reducing reliance on chemicals
 - minimising risks to human health
 - minimising risks to the environment
 - meeting the standards for chemical residues in food and fibre
 - maintaining trade and market access
 - disposing of unwanted chemicals and containers safely.

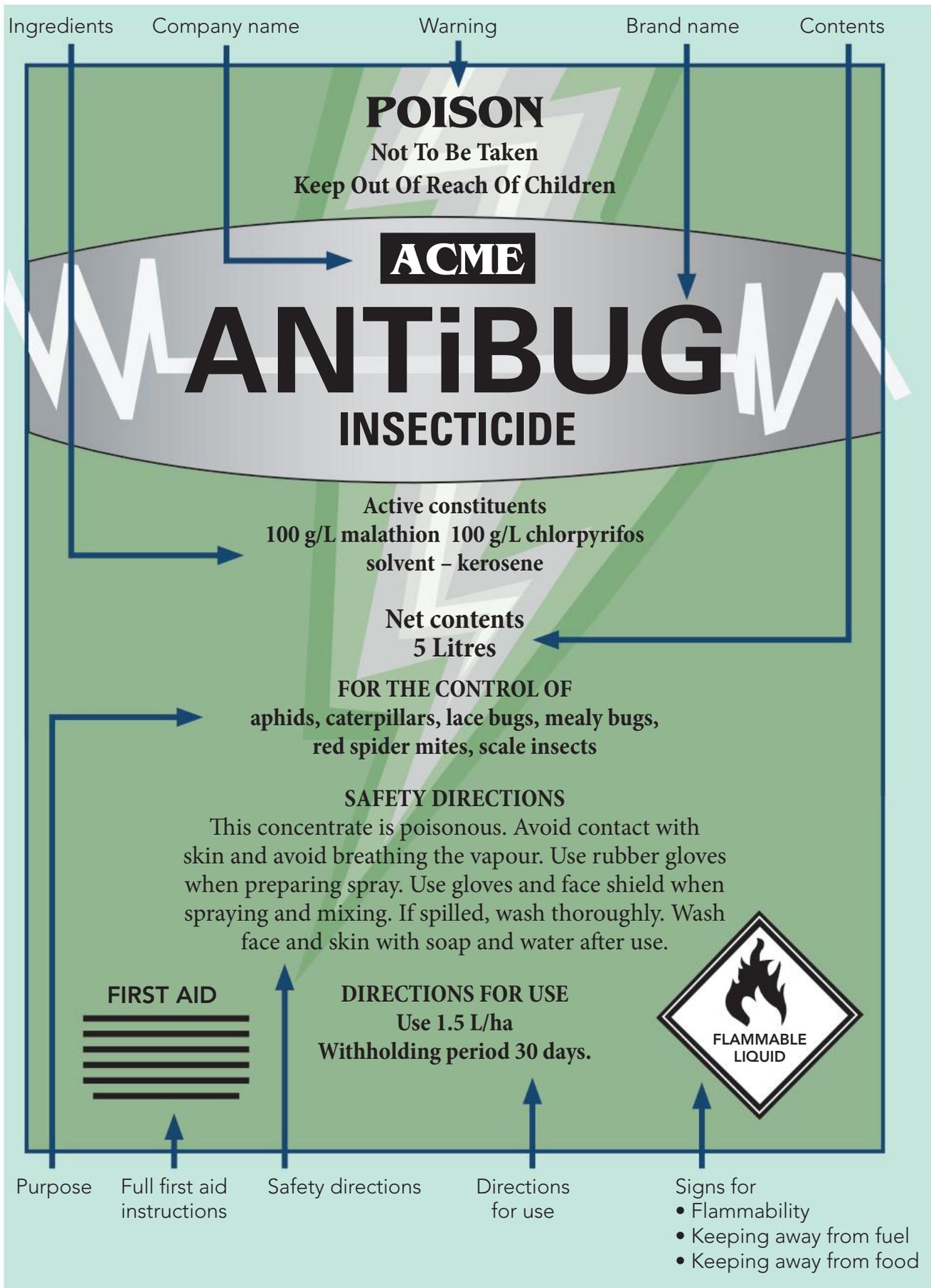


Figure 9.11 An example of a chemical label

✓ Test yourself

- 1** Your task is to present a 5-minute oral report or PowerPoint presentation on a chemical from one of the following classes used in agriculture: a fertiliser, a contact insecticide, a systemic insecticide, a pheromone, a fungicide, a pre-emergent herbicide, a post-emergent herbicide, a drench, a disinfectant, an antibiotic, or a hormone growth promotant. In your report or presentation you must provide the following information:
- the name of the chemical
 - a description of what the chemical is used for
 - the name of the production system in which it is used (e.g. plant production)
 - a description of the benefits obtained by using the chemical
 - a description of a possible negative effect of using the chemical
 - a description of a precaution that should be taken by the person using the chemical.

Your report or presentation will be assessed using the following criteria.

Assessment criteria	Mark
1 Accuracy of content	4
2 All six questions answered	12
3 Presentation (clear speech, looks at audience, does not just read from notes) or well-designed and well-explained PowerPoint presentation	2
4 Timing (takes no more than 5 minutes)	2
TOTAL	20

CHAPTER 10

INVERTEBRATES AND PRODUCTION SYSTEMS

Words to know

arachnid a type of arthropod with only two body segments and four pairs of legs (e.g. spiders and mites)

arthropod the largest grouping of organisms in the animal kingdom; includes insects and arachnids; all organisms have jointed legs and a hard exoskeleton

exoskeleton external body covering of an arthropod

host an organism that supports another one living in or on its body

insect a particular type of arthropod, with a body composed of three body parts, three pairs of legs and one pair of antennae

invertebrate an organism without a backbone

metamorphosis change in body form; some insects have a complete change from larva to adult (e.g. flies)

mollusc soft-bodied invertebrates with a shell, either external or internal, and a muscular foot (e.g. snails)

parasite an organism that lives on or in, and obtains its food from, another living organism (host)

predator an organism that kills and eats another

trachea an air-conveying tube of the breathing system

vertebrate an organism with a backbone

Introduction

The term **invertebrate** refers to all animals without backbones (Fig. 10.1). Many invertebrates have highly specialised structures that allow them to live in a wide range of environments and invertebrates display a much greater variety of form than is found in **vertebrate** animals. (Single-celled micro-organisms are examined in Chapter 11.) Many invertebrates live in marine environments and are an important part of food chains in the oceans of the world; others have considerable input to farm production systems.

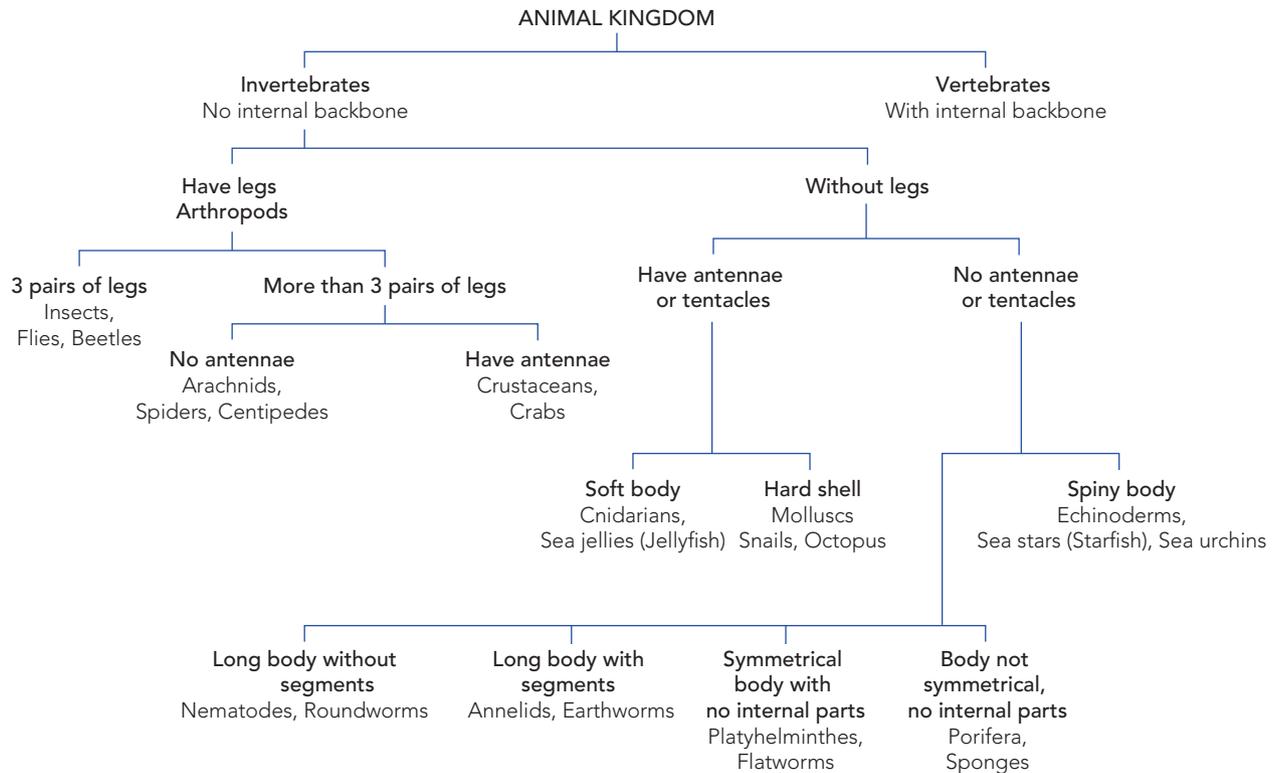


Figure 10.1 Scientific classification of invertebrate animals

Earthworms

Earthworms are examples of segmented worms in the Phylum Annelida, and are a beneficial group of invertebrates to have on a farm. Earthworms burrow into damp soil, helping to aerate it by their burrowing action. They also chew the soil and, in passing it through their bodies, they help to break down the soil and release minerals.

1 How does the earthworm influence soil fertility?

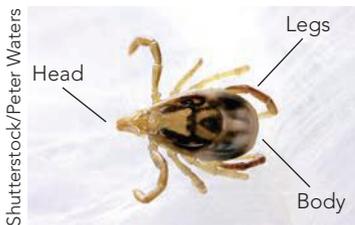


Figure 10.2 The paralysis tick

Arachnids

The **arachnids** are a group of organisms in the phylum Arthropoda closely related to the insect group. They include ticks, mites, spiders and scorpions. These organisms have more than three pairs of legs and only two body parts, as shown in Figure 10.2.

Ticks are particularly important external **parasites** of cattle. They cause serious production losses in the north of New South Wales and in tropical areas. Figure 10.3 illustrates the tick's lifecycle.

Mites are another form of arachnid that causes serious production losses, in this case to poultry. Both red mites and ticks feed on the blood of the host animal, resulting in anaemia, irritation and the spread of disease.

If an arachnid's lifecycle can be disrupted for long enough then control is possible. Control is also possible by chemical means, by either spraying or dipping farm animals with a chemical solution.

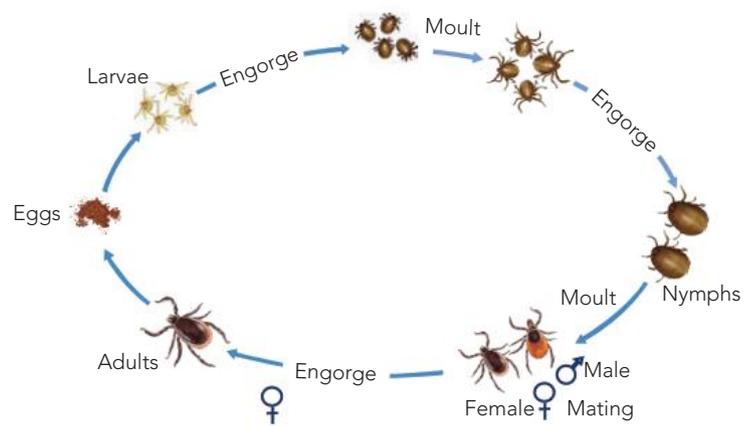


Figure 10.3 Lifecycle of a tick

Insects

Insects are the most successful life form seen on Earth, originating over 350 million years ago. Insects belong to the Phylum Arthropoda (organism with hard skins and jointed limbs). Some of their closest relatives include spiders, crabs, centipedes and scorpions. All of these **arthropods** have the following features:

- an external covering called an **exoskeleton**
- jointed legs and other appendages
- an ability to be split into two equal halves (they are vertically symmetrical)
- a central nervous system composed of a brain and double nerve chords
- a fluid-filled central body cavity in which the vital organs are bathed in fluid.

To be classified as an insect, an organism must also possess the following features:

- a body divided into three distinct sections: head, thorax and abdomen (Fig. 10.4)
- three pairs of legs, attached to the thorax (the thorax may also have wings attached to it)
- no legs attached to the abdomen in the adult stage
- air tubes called **tracheas** (through which the organism breathes).

- 2 List five features of arthropods.
- 3 List four features of insects.
- 4 Describe the three subgroups of insect.
- 5 Draw the two types of insect lifecycle.

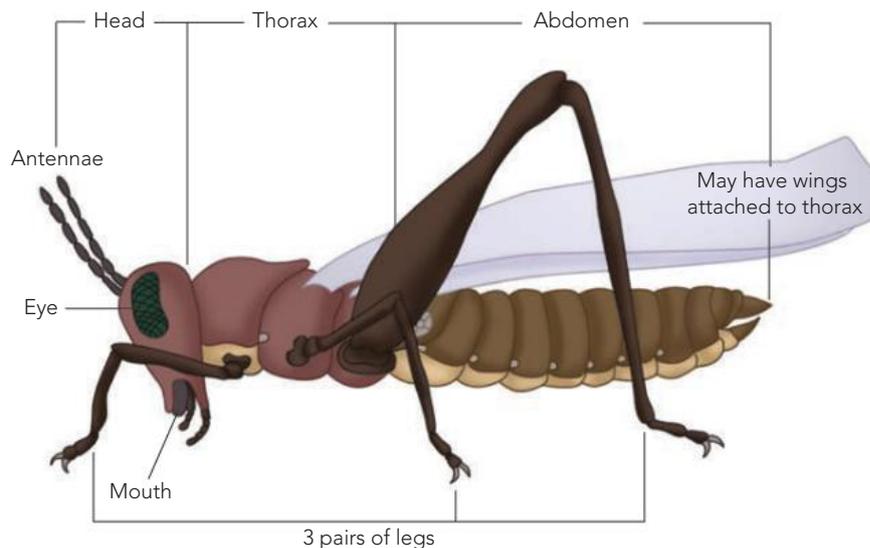


Figure 10.4 Characteristic divisions of an insect

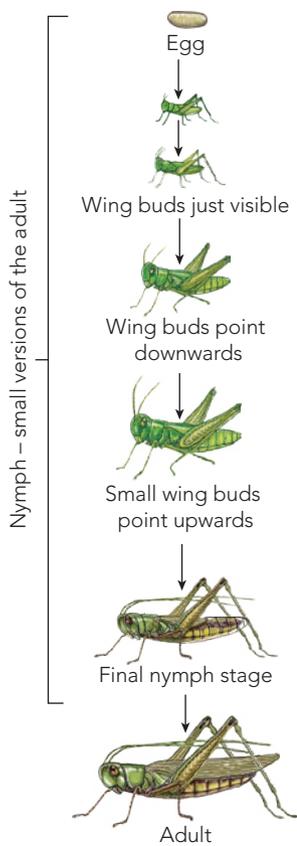


Figure 10.5 Insect lifecycle; incomplete metamorphosis (e.g. grasshopper)

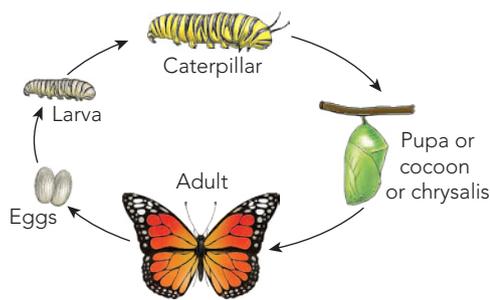


Figure 10.6 Insect lifecycle; complete metamorphoses (e.g. butterfly)

Insects may be divided into three subgroups based on lifecycle and wing development. The first subgroup consists of the most primitive insects, which are wingless and have changed little in form over time (e.g. the silverfish). The second subgroup, which includes aphids and locusts, consists of insects that basically follow the lifecycle illustrated in Figure 10.5. Wings are also present, and are attached externally to the thorax. In this group, the young resemble the adult and insects undergo incomplete **metamorphosis**; there is little change in body form as the insect goes through the different stages.

The third subgroup consists of those insects with a lifecycle similar to that shown in Figure 10.6. Insects in this group pass through entirely different stages – egg, larva, pupa and adult. They are able to exploit different environments as they undergo complete metamorphosis – there are big differences in form, size and shape of the four developmental stages. Examples of insects in this group include bees, flies, mosquitoes and butterflies.

Reasons for the success of insects

Insects represent over five-sixths of all known animal species. There are several reasons these organisms have been so successful.

- **Flight.** Wings enable insects to range wide in search of food and mates. They are able to escape quickly from enemies.
- **Adaptability.** Insects have been able to live in a wide variety of environments, from air, plants and soil to extremes such as boiling water and crude oil, although the sea is still a barrier to terrestrial insects. Some insects have been found at the North and South Poles.
- **Size.** Insects are able to survive when food is scarce because they are so small – length varies from 0.25 mm (small beetle) to over 260 mm (stick insect), while some butterflies have a wingspan in excess of 270 mm. Their breathing mechanism means that they are unable to develop into very large creatures, as they are unable to exchange the amount of gas required to support a large body.
 - **Exoskeleton.** This ‘external coat’ is made up of a number of hard protein-based plates; it gives the insect protection and strength. (It also means that insects have to moult to increase in size.)
 - **Resistance to water loss.** The insect’s exoskeleton has a wax covering that prevents water loss. Also, insects excrete uric acid rather than urine and thus further conserve water.
 - **High rates of reproduction.** In the adult stage, insects spend most of their time seeking mates. Insects produce a large number of eggs and, although losses are very high, sufficient numbers survive to the next generation. Aphids, for example, are able to reproduce 7 days after birth and females do not require fertilisation from the male. Thus aphids can reproduce at a very rapid rate. A few insects, such as the blowfly, can lay live young (e.g. the maggot of the sheep blowfly, which burrows into the moist flesh of a sheep and can cause a painful death for the sheep).

6 Why are insects such a successful group of organisms?

Insect damage

Insects feed by a variety of means:

- the locust is a chewing insect with several mouthparts designed to strip leaves (Fig. 10.7)
- the butterfly has a sucking mouthpart (this sucking tube is seen coiled under the animal's head) (Fig. 10.7)
- the housefly has a sponging mouthpart through which it can dissolve its food then suck it up.

Because of this variety of feeding methods insects may damage plants in many different ways, as illustrated in Figure 10.8.

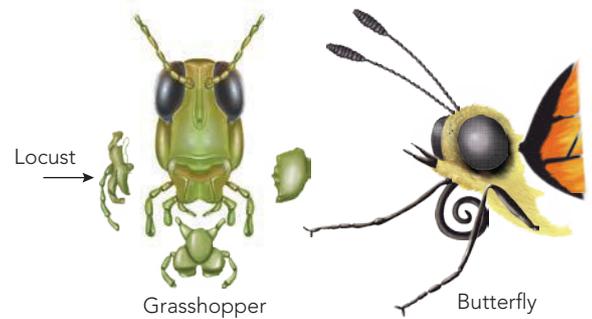


Figure 10.7 Insect mouthparts

Control of insects

Most insects do not interact directly with humans, but some insect species are pests, particularly in agriculture, so it is important that insect numbers be controlled. Insect pests affect both plant and animal production systems. Insects can cause extensive loss of production from agricultural systems in developing countries through their effect on plant growth and production levels and their effect on stored food. There are five main methods of insect control: quarantine, biological controls, insecticides, cultural methods and integrated control.

Quarantine

This can prevent insects from entering an area in which they do not already exist. For example, pieces of fruit and cartons or boxes of fruit cannot be brought into Victoria from New South Wales. This is an attempt to prevent the spread of fruit fly.

Biological control

This involves the identification, careful study and final release of particular insect enemies or **predators**. It is critical to establish that the predator to be released does not also attack any desired plants or insects. Some examples of biological control are:

- the control of the cottony cushion scale in citrus orchards by the use of the Australian ladybird
- the use of wasps and chalcid wasps, which lay their eggs on the caterpillars of many insect pests; for example, the *Apanteles* species of wasp controls infestations of cabbage white butterfly in this manner
- the use of certain bacteria such as *Bacillus thuringiensis*, which is known to attack the cotton bollworm

There are many other examples.

- The screw worm fly was successfully eliminated from the island of Curacao by induced sterility as a means of regulating the insect population. Sterilisation was

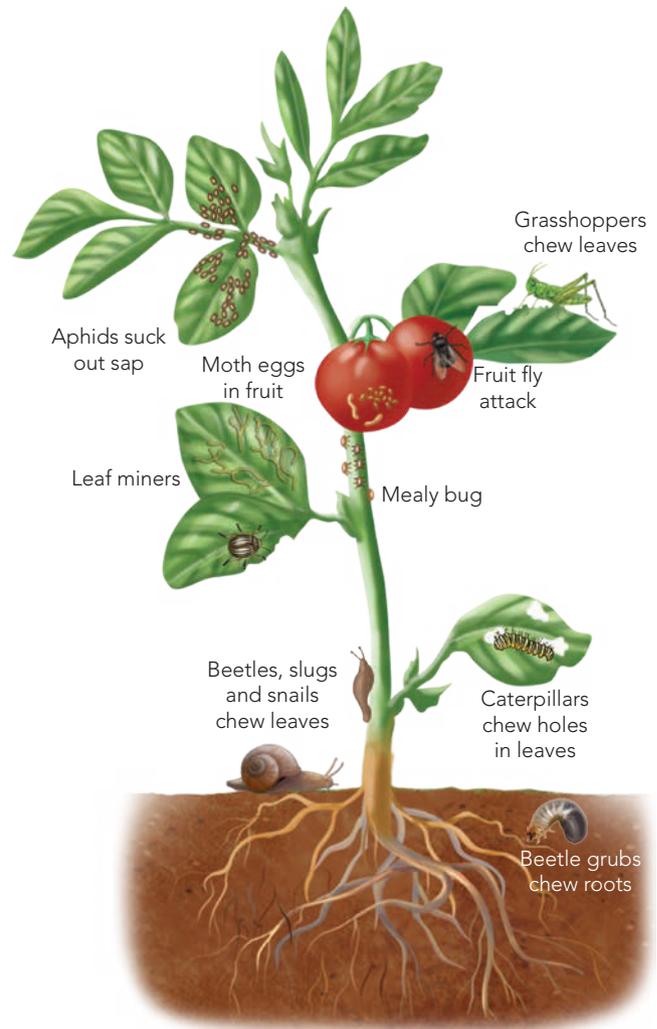


Figure 10.8 Types of plant damage by insects and molluscs

7 What impact do insects have on plant growth?

connect

Biological control

Listen to the video clip and then answer the questions on the site.

achieved by exposing pupae to the isotope cobalt-60 and sterile males were then released into the natural population.

- Similar success occurred with the melon fly on the island of Rota in the Pacific Ocean. Eradication was achieved within 6 months. (There is still much ongoing research into the use of chemosterilants that can induce sterility in both males and females. However, their use is considered quite hazardous because of possible harm to human health.)
- Chemical lures are used to attract males of the Queensland fruit fly into a trap that also contains insecticide, which kills the insect. This has been reasonably successful, especially when used with a reduced amount of low range insecticide (specific insecticide designed to kill a limited number of pest species).

Insecticides

The choice of an insecticide will depend on its ability to kill the insect pest, its possible side effects, the cost of the insecticide and its ease of application. (The effects of these chemicals were discussed in Chapter 9.)

Cultural methods

Numerous methods based on sound farm management are included in this category; for example, removing rubbish and fruit that has fallen from trees prevents insects from breeding in these neglected areas and eradicating weeds removes alternative food sources for insects.

Another example is in the control of fruit fly, where it is necessary to use lures and to spray trees. The fallen fruit must be removed and placed in a sealed container. Fruit such as loquats must be removed from all trees early in the year to prevent a rapid build-up of this fly.

Integrated control or integrated pest management (IPM)

Insecticides brought a revolution in insect control but their use has caused some serious problems in certain instances. The aim of integrated control is to use a variety of techniques to control insects. This combines pesticide use with other methods such as biological control and effective management (cultural control methods). IPM in cotton is discussed in Chapter 17.

- 8 Describe the five ways to control insect pests.
 - 9 Which method would be the most popular in your area?
-
- 10 What effect do molluscs have on agricultural systems?



Figure 10.9 A gastropod

Molluscs

Molluscs are soft-bodied invertebrates with shells. Sometimes these shells are internal. The largest group of molluscs is the snail or gastropod group (Fig. 10.9). Their shells are in one piece and are usually coiled in a spiral shape. Slugs are also gastropods but they have internal shells. (Ocean molluscs include clams, oysters and mussels, squid and octopus.)

In agriculture, molluscs are most commonly encountered in the garden and in intensive plant production nurseries. Snails and slugs may cause damage to plants by eating them.

Not all snails destroy plants – some are carnivorous and attack other snails. Snails and slugs require damp surroundings in which to live. They move on a large suction pad called a foot, leaving a trail of mucus. This mucus seals the snail in the shell and keeps it moist.

11 Explain the importance of roundworms.

Roundworms

Roundworms, in the Phylum Nematoda, may be parasitic or free-living organisms (Fig. 10.10). They have an elongated, round body that is pointed at both ends. Within this group are some very damaging internal parasites affecting many farm animals, especially in the coastal areas. The barber's pole worm (several species of *Haemonchus*) and the nodule worm are two very common roundworms. Adult females lay thousands of eggs in the digestive tracts of infected sheep or cattle; these eggs pass out with the faeces to contaminate pasture. When stock graze on this, reinfection occurs. This is a major reason that young animals should not have access to pasture too soon after older animals have grazed it. On small farms animals are quickly reinfected with worms, even if a drenching program is used.

The soil nematode is also a roundworm, and it infects the root system of many plants, especially tomatoes, cabbages and cauliflowers. Figure 10.11 shows the root knot or root gall damage that may result.



Figure 10.10 A roundworm

Shutterstock/Marcel Jancovic



Figure 10.11 Root system damage caused by nematodes

Corbis© Nigel Cattlin/Visuals Unlimited

Flatworms

Flatworms, in the Phylum Platyhelminthes, are fairly flat, with distinct upper and lower surfaces (see Fig. 10.13). Their mouth leads directly to the inside of their bodies rather than a special gut or stomach. They do possess definite reproductive and excretory organs. Most free-living flatworms resemble the planarian in Figure 10.12 and feed on animal remains.

Science Photo Library/Herve Conge/ISM



Figure 10.12 A planarian worm

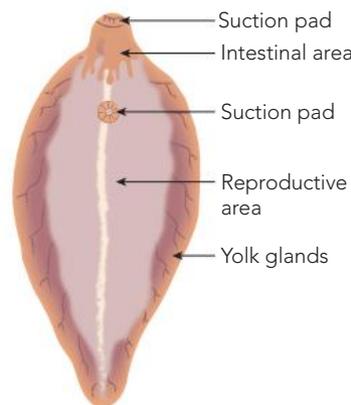


Figure 10.13 A flatworm

Some flatworms are animal parasites. A parasite is an organism that must live directly on or in another living organism or **host**. Parasitic flatworms attach themselves either to the intestinal wall of the host animal or to the bile ducts leading to the animal's liver. The sheep liver fluke lives in the bile ducts in the liver of its host. This organism has suckers and a spiny outer covering to prevent it

- 12 Draw the lifecycle of the liver fluke in your notebook.
- 13 Draw the lifecycle of the tapeworm in your notebook.
- 14 In Figures 10.14 and 10.15 identify where the lifecycle of these parasites could be broken in order to control them.

from being dislodged. Adult flukes produce eggs that are passed out of the sheep in the faeces. These eggs hatch in or near water and burrow into water snails. Here they develop into larvae, then re-emerge in the water and move to plants nearby. When sheep eat these plants, the larvae burrow through the stomach lining and lodge in the bile ducts. Figure 10.14 shows their lifecycle. This parasite may infect cattle and native grazing animals. It is found only on the coast, tablelands and in irrigated areas.

Another flatworm that can cause problems in humans is the tapeworm (Fig. 10.15).

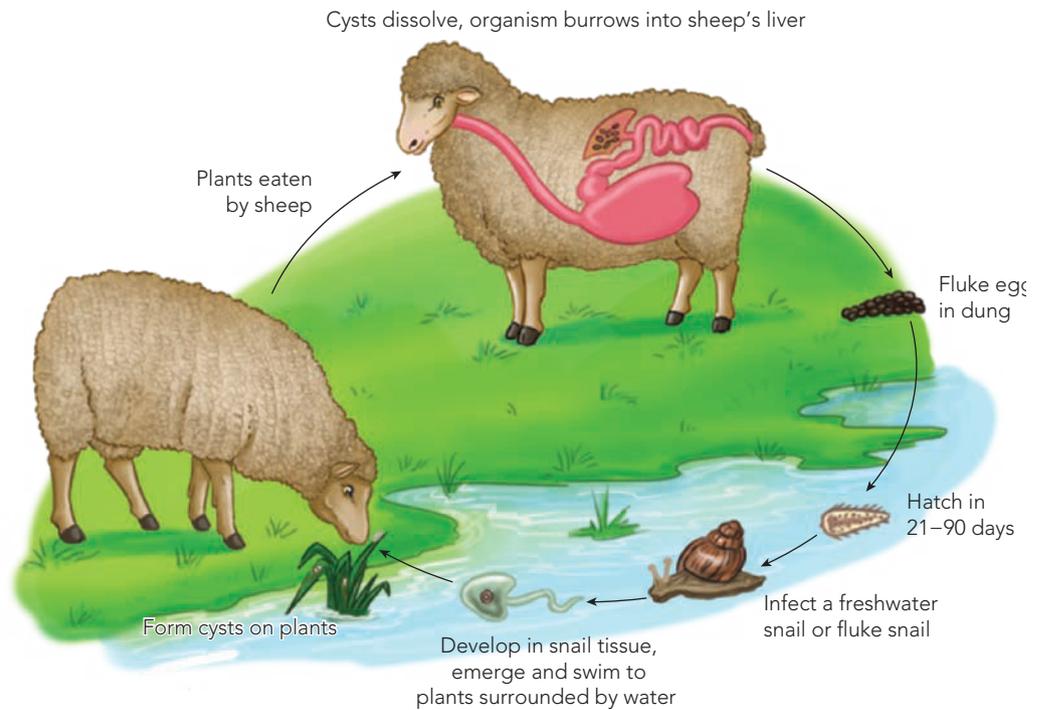


Figure 10.14 The lifecycle of a sheep liver fluke

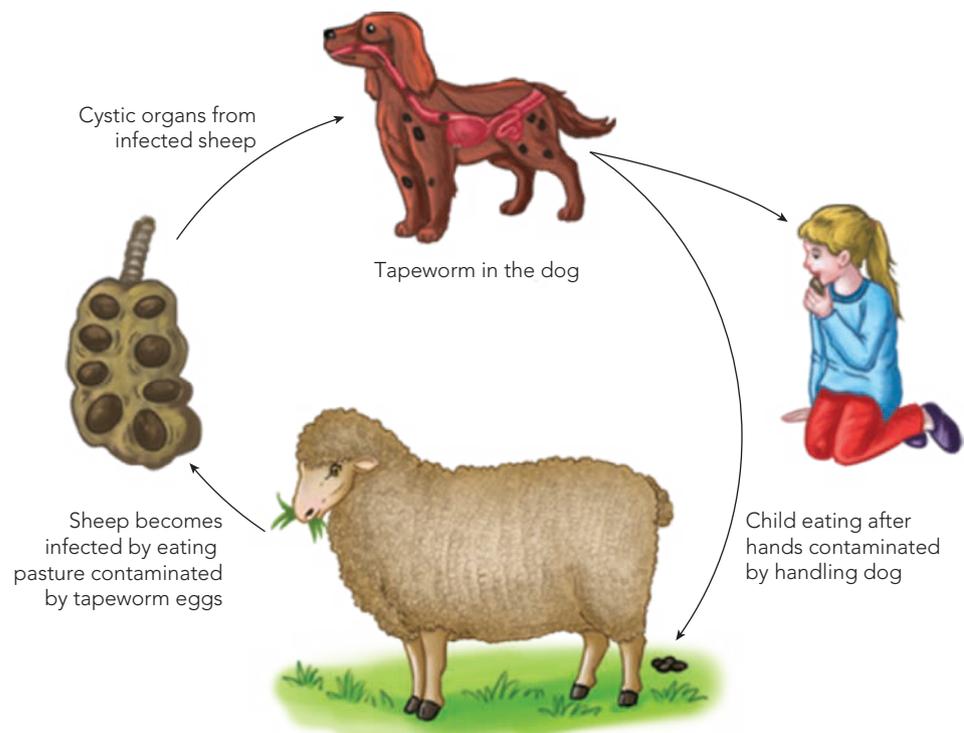


Figure 10.15 The lifecycle of a tapeworm

Chapter review

Things to do

- 1 Look at three different types of insects; for example, bees, butterflies and ants. List their physical characteristics and note all the differences you can find between them.
- 2 Collect 10 different insects. Try to name each one.
- 3 Grow a caterpillar to full size. Allow it to form a cocoon and emerge. How long does each stage take?
- 4 Look around the outside of your home, in the garden and any sheds or outbuildings. Draw as many different kinds of insect eggs as you can find. Do you know what insects come from the eggs?

Things to find out

- 1 What is the largest insect in the world? How big is it and where does it live?
- 2 Some insects 'farm' other insects. Why do ants farm aphids?
- 3 How do insects communicate with each other?
- 4 Some plants 'eat' insects. Study one of these plants and find out how it lives.
- 5 Find out how some insects can hide (even when in sight!) and give some examples.
- 6 Find out how insects are able to taste, see, smell and feel things around them.

Extension activity

- 1 Some insects are 'farmed' to produce products that are used for food and fibre. The silkworm is one of these insects. Find out:
 - a what silkworms produce and what the product is used for
 - b which countries in the world have silkworm industries
 - c why the silkworm industries are located in these countries
 - d how the silkworms are farmed
 - e how the silk is harvested and processed.
- 2 New research suggests that by 2030 up to 3000 Australians will face severe reactions to fire ant stings if the pest is not eradicated. Go to the [Queensland Department of Agriculture, Fisheries and Forestry](#) website and summarise the reasons why fire ants need to be controlled. Assess their future potential as a serious pest in Australia.
- 3 Evaluate five main methods or strategies of insect control. For each strategy give:
 - a a brief description of the method of control
 - b the advantages of the method
 - c the disadvantages or problems with the method.

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**Queensland
Department of
Agriculture, Fisheries
and Forestry**

✓ Test yourself

- 1 Copy and complete the table by filling in the missing words.

Organism	Examples	Parasite (Yes or No)	Place in agriculture
	Tapeworm, liver fluke		Infect cattle and sheep
Roundworms			
Earthworms	Earthworm		Help break down the organic matter in soil, releasing mineral nutrients
	Snail, slug	No	
	Tick		Cause serious losses by sucking blood from animals

- 2 Describe two ways insects can damage plants.
- 3 Explain how biological control of insects works.
- 4 Arrange these stages in an insect's lifecycle in the correct order: pupa, egg, larva, adult.
- 5 Insects are a very successful group of animals. Give two reasons for their success.

CHAPTER 11

MICRO-ORGANISMS AND PRODUCTION SYSTEMS

Words to know

active immunity resistance acquired in animals after exposure to a disease

algae photosynthetic plants without stems, roots or leaves and ranging in size from single-celled to multicelled organisms, such as giant seaweeds

antibody a protein made by animals in response to bodily invasion by pathogens; it combines with the pathogen (or poison), rendering it harmless

bacteria single-celled microscopic organisms; some cause organic material to decay or cause disease; others are important in the formation of cultured dairy products and fixing nitrogen both in the soil and in the roots of legumes

contagious disease a disease that spreads from sick to healthy organisms

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

fungi organisms including rots, mildews and moulds that lack chlorophyll and possess threads (hyphae); can be parasitic or feed on organic matter

hyphae thread-like structures that are part of the structure of fungi

immunity resistance to a disease

mycelium a mass of fungal hyphae

natural immunity resistance due to natural barriers (e.g. skin)

nucleic acid a chemical that occurs in all cells and determines the type of organism and its genetic make-up

passive immunity resistance acquired by injection with antibodies produced by another individual or source

pathogen a disease-causing organism

protozoa single-celled organisms having many animal-like features

silage plant material that is stored with little drying, in anaerobic conditions, where it slightly ferments and is preserved; used for stock feed

spawn spores that have germinated and formed mycelia

spores reproductive structure of fungi and some bacteria

viruses parasitic, non-cellular organisms

Introduction

Micro-organisms (or microbes) occur in large numbers in all environments. They are so small that special methods are needed to study and identify them. Our knowledge of these organisms has increased since better microscopes have become available, and as scientists have learnt how to distinguish micro-organisms by using different chemical tests and colour stains.

Micro-organisms possess some features of plants and animals. Many types show primitive levels of organisation in their cells. For this reason they are often grouped together and classified as 'halfway houses' for life between the plant and animal kingdoms. For instance, some **algae** (including seaweed) and **fungi** (e.g. mushrooms or toadstools) can appear plant-like but only algae have the green-coloured chemical called chlorophyll used by plants to produce food. Although some algal-like organisms are green they do not have the internal structures seen in algae or plants. Similarly, animal-like microbes called **protozoa** (such as the amoeba) are lacking in features common to animal cells.

Some organisms called **bacteria** are primitive in their cellular makeup. **Viruses**, rickettsia and mycoplasmas are almost non-living in many respects as they have only a protein coating around a **nucleic acid** such as DNA or RNA. Because these organisms can grow and reproduce, they tend to be classified as living rather than chemicals.

Micro-organisms are important to humans and the environment because of their effect on living systems. They have a key role in a number of different areas:

- 1 List the main types of micro-organism.
 - 2 State two characteristics that distinguish living organisms from non-living objects.
 - 3 List six ways that micro-organisms interact with living systems.
- plant and animal **diseases**
 - chemical cycles, such as the nitrogen and carbon cycle
 - food manufacture, such as that of cheeses and yoghurt
 - spoilage of foods
 - drug manufacture, such as that of penicillin and vitamins
 - waste disposal and sewage treatment
 - fermentation, and wine-making, brewing beer and spirit-making
 - genetic engineering and the production of such products as interferon (an anti-virus agent)
 - recycling the remains of deceased organisms through decomposition.



Figure 11.1 Typical fungi: mushrooms

Shutterstock/Aleksander Bolbot

Micro-organisms and agriculture

Algae

These plant-like organisms are found in both freshwater and saltwater and contain chlorophyll, allowing them to perform photosynthesis. They are a very large and diverse group of simple organisms (Fig. 11.2), ranging from single-celled to multicellular forms, such as the giant kelps that grow to 65 m in length. In closed systems such as an aquarium, algae are often a food source for fish and other creatures. Blue-green algae, which are very primitive and now classified with the bacteria, are able to fix nitrogen in oxygen-free (anaerobic) situations. In rice paddies, these organisms supply the rice plant with nitrogen. Blue-green algae can produce poisons harmful to humans, domestic animals and fish. Algae also provide the material called agar, which is used as a medium for growing micro-organisms. In many Asian areas, a giant alga called kelp is farmed as a source of food, chemicals and cheap garden fertiliser.

4 Describe three situations where algae can be beneficial to humans.

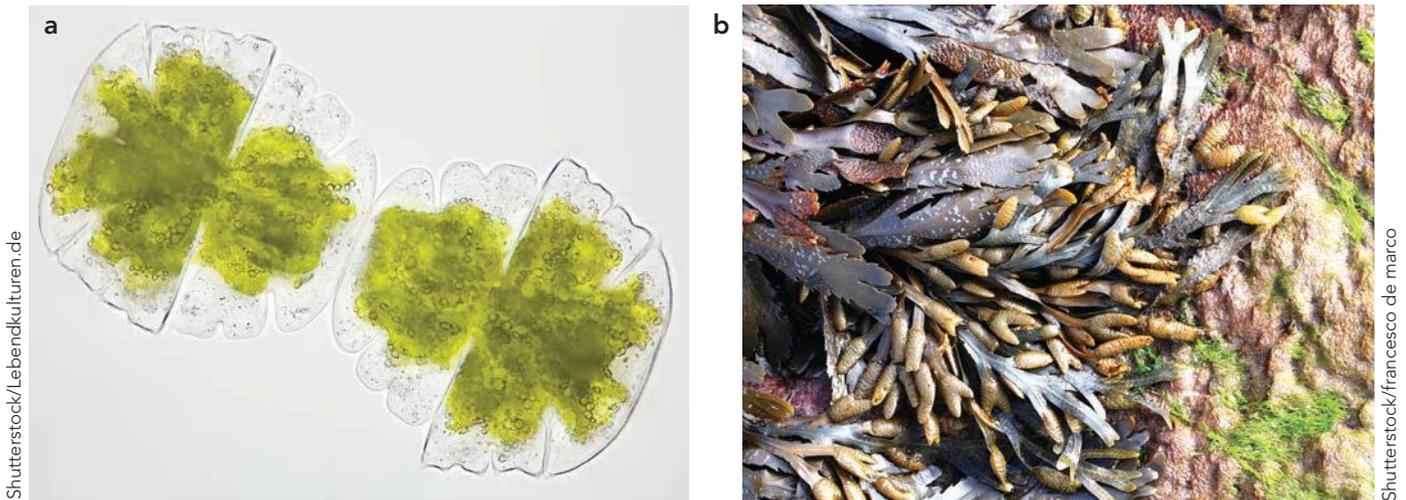


Figure 11.2 Some algae **a** *Microcystis truncata* **b** *Fucus gardneri*

Bacteria

There are several types of bacteria, classified according to their shape (Fig. 11.3). Several types of bacteria can be grown or cultured on agar plates and the colour, shape and size of the colonies can be used to identify the bacteria type.

Bacteria are involved in various chemical cycles in nature; for example, the nitrogen and carbon cycles. Bacteria release and recycle chemicals that were once part of a living system. Other bacteria, such as the nitrogen-fixing bacteria found on the roots of clovers, are responsible for the incorporation of gases into living systems. Bacteria are also the cause of many plant and animal diseases. Plants can die from soft rots and galls caused by bacteria. Dairy cattle may suffer from bacterial diseases such as mastitis or tetanus.

5 Discuss why bacteria are important.

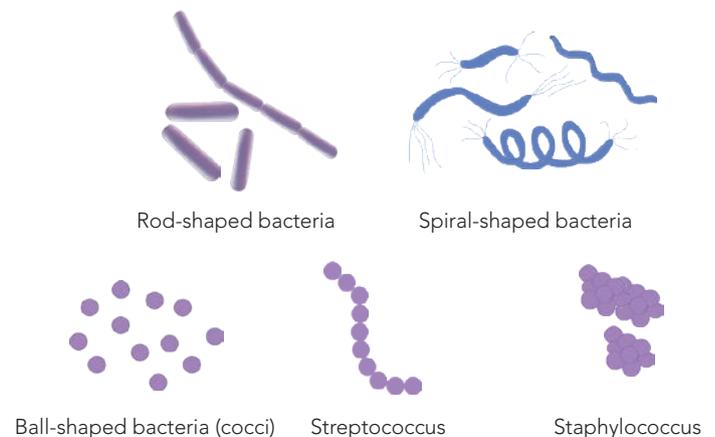
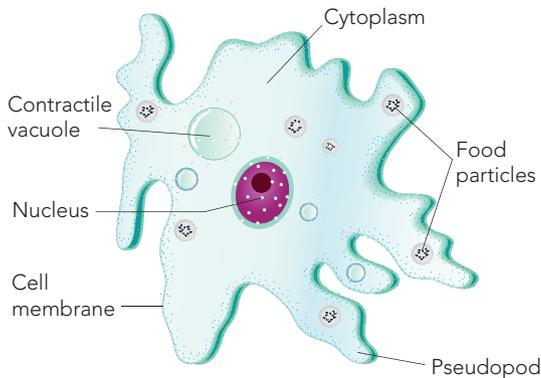


Figure 11.3 Some bacteria types

Protozoa

Protozoa are single-celled organisms with a nucleus that commonly show characteristics usually associated with animals, such as not producing their own food, but obtaining it from their surroundings. Despite these characteristics, they are not animals. Protozoa play a key role in maintaining the balance of bacterial, algal and other microbial life. They are also themselves an important food source for larger creatures.



Shutterstock/snapgalleria

Figure 11.4 A protozoan

Some protozoa are part of the normal make-up of animals and live in the stomachs of insects and mammals (including humans), helping to break down complex food particles.

In animals, these organisms may cause harmful effects including problems such as dysentery (spread when the animals are allowed to drink from dirty water troughs). One of the more important protozoans is coccidiosis, an internal disease in poultry.

Another of the more important protozoans relies on a mosquito to transmit it to the human host, where it causes malaria (Fig. 11.5).

6 Explain why protozoa are important.

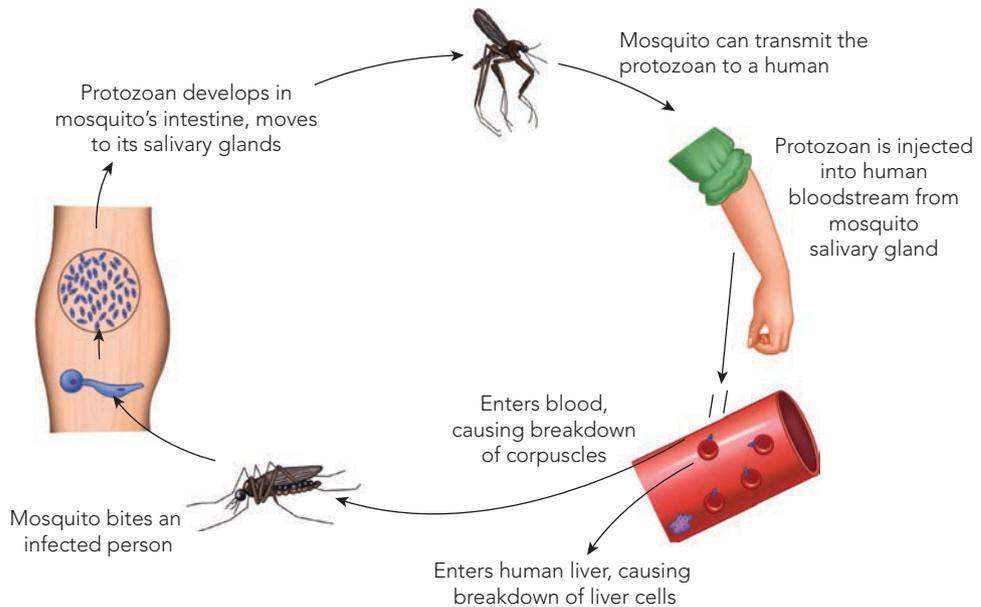


Figure 11.5 The malaria protozoan lifecycle

Viruses

Viruses are the smallest of all the micro-organisms. They are unique because they are only able to live and multiply inside the cells of other living organisms. There are now a number of non-cellular organisms recognised as being viruses or virus-like. These include rickettsia and mycoplasmas. All of these organisms are obligate parasites – they must spend their entire life living off another living organism or host. Figure 11.6 illustrates their general life cycle.

Viruses cause a variety of plant and animal diseases that can be easily spread from sick to healthy animals (i.e. they are **contagious diseases**). These diseases include, in humans, smallpox, cold sores, mumps and polio and, in animals, three-day sickness, blue tongue and foot-and-mouth disease. In plants, colour streaking in leaves and flowers is often due to virus infection. Eradication of infected plants and animals may be necessary to prevent further infection by viral diseases.

Viruses are spread by food and water, through droplets in the air after sneezing or coughing, through body contact and through insects that have bitten infected animals. For these reasons many farmers quarantine diseased animals and use various techniques to limit the spread of diseases from one area of the farm to another.

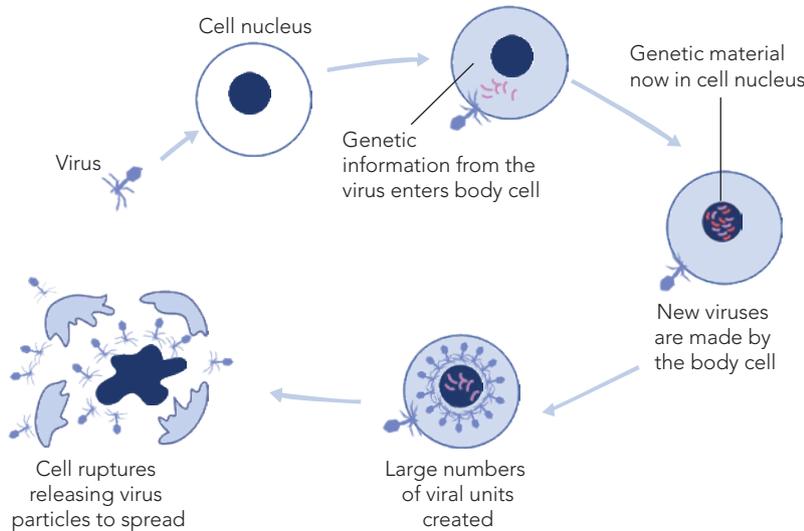


Figure 11.6 A virus lifecycle

Fungi

Fungi are neither plants nor animals but have some characteristics of each. They cannot move about like an animal but do consume organic matter. Unlike plants, they have no chlorophyll, and cannot photosynthesise.

Fungi range from the single-celled yeasts, important in the manufacture of alcoholic products and bread, to the multicellular mushrooms. Fungi are composed of fine branching threads called **hyphae**. A mass of these threads is called a **mycelium**.

Fungi reproduce by means of **spores** that can be easily carried by the wind. They can cause disease in production systems. Rust, an important wheat disease, is a fungus. The seed heads of many cereals turn black after infection by fungal organisms called smuts.

One important fungus is the mushroom. Before 1945, Australian mushroom production was on a very small scale, but today it is an expanding production system. The first step in growing mushrooms is to collect the spores from mature mushrooms. The spores are allowed to grow to form a mycelium; by this stage the spores are called **spawn**. These highly cultured mycelia are grown on sterile grain and usually supplied to the farmers in containers. Once obtained, the spawn is placed over the surface of a well-constructed compost bed and lightly mixed in. The surface of the compost bed is then covered with a layer of peat or sterilised soil – the spawn will not produce mushrooms without this step. Provided the beds are in draft-free areas and the temperature and

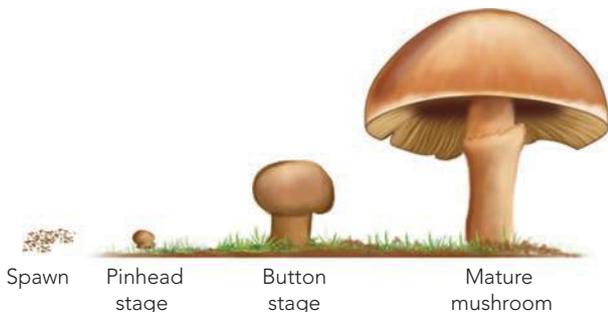


Figure 11.8 The development of a mushroom

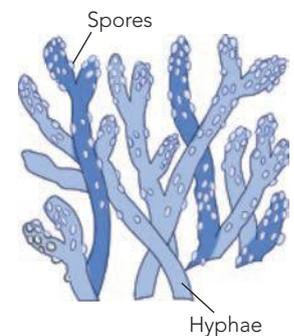


Figure 11.7 Hyphae and spores of a fungus

- 8 Explain how mushrooms are grown.
- 9 Draw three examples of mushrooms that are available in supermarkets and grocery stores. You may also wish to use the [Mushroom Chef](#) website for information.

connect

Mushroom Chef

humidity remain constant, small mushroom pinheads will appear after 14 days. The pinhead structures increase in size very rapidly, and within another 7 days a mature mushroom has developed (Fig. 11.8).

Micro-organisms and disease

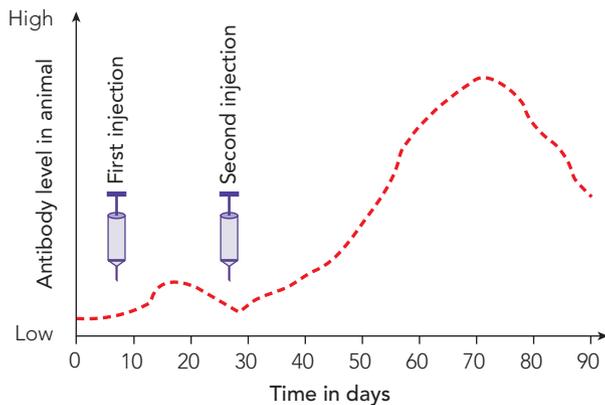


Figure 11.9
Developing immunity
in animals by serum
injection

A **disease** occurs when there is a change in the normal functioning of a plant or animal. Disease-causing agents are called **pathogens**. Diseases may cause death, but many reduce production levels over a period of time and are called erosional diseases. Microbes are one of many causes of disease in plants and animals.

For a disease condition to develop, a special relationship must be created between the disease-causing organism, the host plant or animal and the environment. For example, the bacterium causing tetanus can only cause the condition if it enters a deep wound in an animal. Additionally, if a vet or farmer is able to diagnose disease symptoms correctly, an animal

may be able to be treated – for example, with an injection – to prevent the disease from fully developing.

To prevent loss through viral infections, farmers must plant crops specifically bred to resist the particular disease, or treat animals in advance if a particular disease is known to occur in the local area. This technique is called *immunity resistance* and it takes three forms.

- 1 Natural barriers may exist against infection, such as an animal's skin. These amount to a **natural immunity**.
- 2 Animals that have been exposed to a disease may produce antibodies to fight the pathogens. The more antibodies produced, the better the animal's **immunity**. Protection can be given to an animal through the injection of a suspension of living or dead pathogens into the animal's bloodstream. This is called a vaccine. Live vaccines contain pathogens no longer able to cause disease, called *attenuated strains*. Live vaccines are used, for example, in the treatment of brucellosis, while dead suspensions of pathogens are used for polio and cholera injections in humans. Blackleg and tetanus are prevented through the injection of bacteria-free toxins or poisons into the host, to encourage **antibody** production. Gaining immunity through exposure to a disease or by use of vaccines is called **active immunity** (Fig. 11.9).
- 3 Blood may be removed from organisms that have been vaccinated or exposed to disease, and the fluid or serum portion can then be separated from the blood sample. This serum will contain antibodies and can be injected into an animal to give short-term protection from the disease. Immunity gained in this manner is called **passive immunity** and the injections should be repeated at regular intervals.

Plants have natural barriers to disease such as a waxy cuticle but do not have an antibody system. Once a pathogen has invaded, plants rely on other mechanisms to resist disease. For example, the plant might kill all the cells surrounding the infected area and effectively isolate the pathogen or it may also produce chemicals that hinder the growth of the organism. Some fungi can invade plant cells directly but other organisms must find an opening from the surrounding environment. For instance, some fungi may enter through the pores in a leaf; insects that suck sap from plants may transmit viruses from sick to healthy plants; bacteria may enter through the roots; and a farmer may encourage disease through poor pruning techniques or in failing to use disease-free plants or seeds.



Figure 11.10 Plant
roots affected by
stem rot

Continuous planting of the same crop on one area of land also results in a build-up of disease organisms in the soil.

A farmer can also control disease in several ways:

- using virus-free or other pathogen-free stock
- vaccinating livestock
- effectively quarantining areas of the farm to limit the spread of any disease
- removing weeds and rubbish that provide a continual source of disease
- rotating crops, so that disease-causing organisms do not build up in the soil over time
- spraying with an appropriate chemical
- planting resistant varieties to limit disease damage.

-
- 10 Define 'contagious disease'.
 - 11 Discuss the conditions needed for a disease to develop.
 - 12 Define 'immunity'.
 - 13 How can immunity be developed in animals?
 - 14 How do plants resist disease-causing organisms?

Micro-organisms and food manufacture

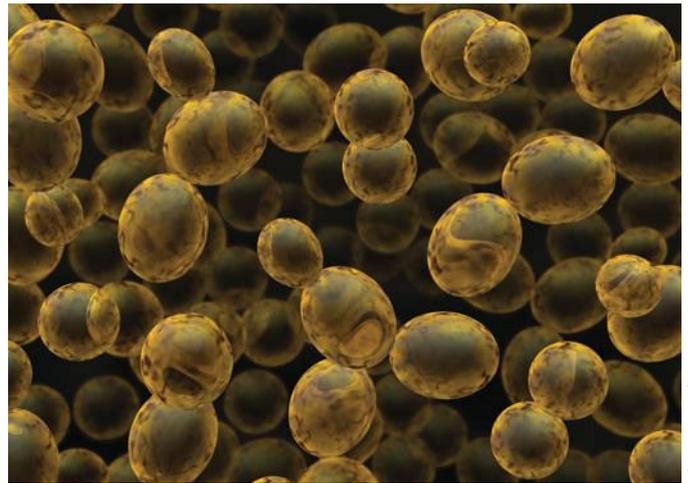
Many microbes assist in making food. Yeast, a single-celled fungus, is one example. In the presence of oxygen, yeast turns sugars (carbohydrates) into carbon dioxide and water – and the carbon dioxide helps in the making of bread. In the absence of oxygen, yeast turns sugars into alcohol, in a process called fermentation. Under these conditions, yeast can be used to manufacture beer and other types of alcohol.

Micro-organisms are important in the manufacture of **silage** on the farm, and in helping grazing animals such as cattle and sheep to digest grass. Silage is made in oxygen-free (anaerobic) conditions when freshly cut fodder crops, such as maize or oats, are placed into sealed, air-tight containers. Bacteria naturally found on the plants develop and pickle the plant material, producing the silage. Silage, providing it is not exposed to the air, can be stored on a farm for many years.

On the negative side, many microbes also cause food spoilage. Food contains large amounts of water, carbohydrate and proteins, used by bacteria and fungi to grow and reproduce. To prevent foods from being destroyed, or people from being poisoned, care must be taken when handling and storing food.

Several methods exist for preserving food using various combinations of heat and pressure, low temperature, drying and salting. Foods are canned under conditions of combined high temperature and pressure to kill bacteria that could otherwise survive by producing heat-resistant spores. Milk undergoes a heat treatment called pasteurisation to kill microbes. Many dairy and fish products have their shelf life extended by being stored at low temperatures to slow down micro-organism activity.

Salting, smoking, preserving with sugar (e.g. jams) and drying out (dehydrating) of food materials make it difficult for microbes to obtain moisture, consequently limiting their activity.



Shutterstock/Knorre

Figure 11.11 Yeast cells reproduce by budding

-
- 15 Outline how yeast behaves in the presence and in the absence of oxygen.
 - 16 Describe the process of silage manufacture.
 - 17 List four methods of food preservation.

Chapter review

Things to do

- 1 Collect some pond water to examine under a microscope. Draw as many microbes as you can. Refer to diagrams in this chapter to help identify the particular micro-organisms.
- 2 Take some hay or grass and place it in a jar. Cover it with water for 3–7 days. Use an eye dropper to place samples of the water onto a microscope slide. Examine the water and draw what you see. What would these microbes be doing?
- 3 Moisten some slices of bread. Leave the bread exposed to the air for a few days then examine the fungi using hand lenses or a binocular microscope. Identify the hyphae, mycelium and spores. Draw these.
- 4 Make some agar plates. Add sugar to the agar for half the sample, and a stock cube to the other half. Expose the plates to the air, soil and water. Seal them with tape and incubate for 3 days at slightly above room temperature.
Draw the results, but do not open the containers because an organism dangerous to humans may have been grown.

Things to find out

- 1 List three important contagious plant or animal diseases in your area. What organisms cause each of these diseases? How do the farmers prevent the spread of the disease?
- 2 Describe in detail how yeast is used in the production of one product.
- 3 Describe how milk is treated so that it is safe to drink.
- 4 What is an electron microscope? Why is it useful for viewing viruses?

Extension activities

- 1 Purchase a mushroom kit from a nursery or hardware store. Carefully follow the instructions that come with it. Measure the weight of mushrooms you produce. Find out the price of mushrooms in the supermarket or fruit and vegetable shop and calculate the value of your mushrooms. Subtract the cost of the mushroom kit from the value of the mushrooms you produced to see if you made a profit.
- 2 What is Bovine Johne's disease (BJD), and what species can become infected with BJD? Visit the [New South Wales Department of Primary Industry](#) website for more information; click on the 'J' tab.
- 3 What is the MAP program associated with the control of BJD?
- 4 Outline the changes that are occurring in the management of this disease (BJD) in both sheep and cattle.

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**New South Wales
Department of
Primary Industry**

✓ Test yourself

- 1 Copy and complete this passage by selecting words from the following list to fill in the gaps:

alcoholic, algae, coccidiosis, nitrogen, plants, viruses, diseases, cycling, foot-and-mouth, bread.

Blue-green _____ are useful in rice paddies where they fix _____ making it available to the rice. Bacteria are important because they are involved in the _____ of chemicals such as nitrogen and they cause diseases in _____ and animals. One important disease in poultry caused by protozoa is _____. _____ can only live in living things and they cause many diseases in animals. _____ is one such disease. Fungi are used in the production of _____ products and food such as _____ and mushrooms. They also cause important plant _____ such as rust.

- 2 Define 'pathogen'.
- 3 Micro-organisms are involved in food manufacture.
- Describe one example of a micro-organism having a useful role in the manufacture of food.
 - Describe one example of micro-organisms having a negative effect on food manufacture.
- 4 Explain how active immunity is developed in an animal by using vaccinations.

CHAPTER 12

TECHNOLOGY AND PRODUCTION SYSTEMS

Words to know

coolant a liquid that circulates through the engine and radiator of the tractor and keeps it cool; the coolant is usually water but may have some special chemicals added to it

draw bar a tractor fitting for a trailing machine to be attached so that it can be pulled along

drill a machine used to sow seeds of a crop in evenly spaced rows at the correct depth

furrow a continuous hollow or trench made by the tine of a tillage machine as it passes through and disturbs the soil

germination a process occurring in the seed when it absorbs water, swells and begins to grow, sending out roots and a shoot

harvester a machine that gathers in the mature crop for sale or storage (e.g. combine harvester, forage harvester)

head (of a plant) the part of the plant where the grain or seed forms – usually near the top

hydraulic system system used to transfer power by pumping oil through pipes to operate pistons that in turn move parts of the machine

implement a machine attached to or drawn by a tractor to carry out a particular operation (e.g. ploughing)

lubrication the application of a 'lubricant' such as grease or oil to a part of a machine to reduce friction where two metal surfaces rub together (e.g. an axle in a bearing)

market garden a small farm used for producing vegetable or flower crops

plough a machine for turning soil; there are various types such as mouldboard, chisel and blade

potato tubers (seed potato) planting material, ideally the size of a matchbox with a minimum of two 'eyes'; used for planting the next crop

primary tillage implement used to break up the soil in the first stages (e.g. ploughs)

scarifier a secondary tillage machine used for cultivating the soil, mainly to break a surface crust and remove some weeds

secondary tillage implement used to further reduce the size of soil aggregates, after primary tillage

soil aggregate a desirable natural lump or small clod composed of many soil particles held together; ideally aggregates form after soil breaks, following cultivation

straw, stalk remains of a cereal crop (e.g. wheat)

sugarcane sets short pieces of sugarcane cut so that each piece has at least 2 buds or growing points on it

tine a long steel point on a fork or tillage implement, which 'disturbs' the soil; there is usually more than one tine on a tillage machine

windrow a raked row of cut plant material ready for drying

Introduction

One of the authors of this book remembers a time when, as a student, he listened to the principal of his school read a letter from the father of a fellow student who had been killed in a tractor accident. The letter described in detail how the accident happened – the boy had been using the tractor for something that racing cars are designed to do. It rolled over and he was pinned underneath. The father's letter also told of the anguish of his son's friend, who could do nothing to stop the overturning tractor slowly crushing the life out of the boy.

Lives are lost and people injured on farms each year, because people have not used their tractors and machinery carefully and safely.

Whenever you use tractors and machinery, please use them carefully and only for the purpose for which they were designed.

The tractor

The tractor provides the power to pull and run much of the machinery used on a farm. Tractors range in size from small 4- or 5-kilowatt tractors used in nurseries and small **market gardens**, to huge 480-kilowatt tractors used on large wheat growing farms or in broadacre farming; for example, grain sorghum, sunflowers or wheat.

A tractor's power is used in at least four different ways.

- 1 It pulls **implements** such as **ploughs**, seeding machines, **harvesters** and trailers.
- 2 It provides the power to run machines such as mowers, slashers, harvesters and fertiliser spreaders. (The power is transferred to the machine through the power take-off or PTO.)
- 3 The hydraulics of the three-point-linkage system enables machines attached to the tractor to be lifted and carried. The operator can easily set and adjust the height or depth at which the machine works.
- 4 Remote hydraulics allow machines (e.g. a plough or harvester) hauled by the **draw bar** of a tractor to be adjusted for height and depth. The tractor's **hydraulic system** may be used to run hydraulic motors in the trailing machine. For example, in a haystack-handling machine, hydraulic motors run the elevators that move the 2-tonne bales out of the machine when they are made.

Tractor care

A farmer needs to care for a tractor to ensure that it will do the work it is designed to do for many years. Daily checking of engine oil and **coolant** levels, and regular routine maintenance, such as **lubrication**, changing engine oil and replacing air and oil filter elements, will help ensure the tractor remains in good condition.

Performing a pre-start check before using the tractor will also help keep it in good condition and safe to use. A basic pre-start check is an overall observation of

- 1 List several operations a tractor can be used for on farms.



Shutterstock/Christian Lagerek

Figure 12.1 Hydraulic machinery

the tractor to ensure it is free from excessive wear and tear or damage and is ready for the task at hand. Pre-start checks can include these tasks:

- observing all guards are present and not broken
- identifying any leaks
- ensuring tyres are pumped up at the correct pressure, that there are no large cracks or foreign objects stuck in them, and that the wheel nuts are tight
- checking dual brake pedals engage evenly
- checking the fuel tank has enough fuel for the task to be completed
- checking lights and electronics are in working order
- removing any debris from the front grille and radiator guard
- topping up coolant, if necessary
- checking that implements are correctly attached

A daily maintenance schedule is a simple physical check that ensures the tractor will work efficiently and last longer. This maintenance can include these tasks:

- checking and maintaining the level of fluids in the tractor; for example, hydraulics, oil and coolant
- checking and repairing air and oil filter elements
- lubricating any moving joints.

When operating tractors, drivers should keep an eye on all the gauges in front of them. The gauges show such things as the engine temperature and the level of fuel in the tank.

2 Recall two things that are important in caring for a tractor.

3 Briefly outline the main rules for safely operating a tractor.

Tractor safety

Safe operation of a tractor means observing and obeying some simple rules.

Figure 12.2 Tractor safety



CAUTION! Only one person on a tractor.

- 1** Only one person at a time is to drive or operate the tractor, unless there is a properly fitted passenger seat. Small children should never ride on a tractor. If someone falls from a tractor while it is in motion, they are very likely to be run over by the trailing implement, if not by the tractor itself.



CAUTION! Do not drive near the edge of a ditch or gully.

- 2** Tractors should not be driven close to the edge of creeks, rivers and eroded gullies. The banks are likely to give way under the weight of the tractor.

- 3 Tractors should not be driven at high speeds. They are designed for hauling and providing power – not speed.



CAUTION! Fast driving causes many accidents. Couple the brake pedals together and always drive at safe speeds.

- 4 Always make sure the power take-off is disengaged when not in use. When it is being used, make sure all the protective safety covers are in place. A revolving PTO shaft can catch clothing and drag the wearer into it in a fraction of a second, with very painful or even fatal consequences.



CAUTION! Disengage the power take-off when not in use.

- 5 When driving down slopes, the tractor must be in gear. This allows the engine to assist with braking.



CAUTION! Always keep the tractor in gear when going down steep hills or grades.

- 6 All tractors should be fitted with a rollover protective structure (ROPS) that gives the driver some chance of escaping should the tractor tip over.



CAUTION! Always have a safety frame.



- 7 Always wear correct personal protective equipment (PPE) such as sturdy boots with grip, short sleeves or buttoned cuffs, no loose or flowing materials and straight-legged pants.



- 8 Only ever start the tractor while sitting in the operator's seat.



- 9 Mount and dismount a stationary tractor only, using three points of contact at all times.



- 10 Always wear the seatbelt when operating the tractor. Use of the seatbelt with an approved ROPS maximises driver protection.



- 11 Never operate a tractor when fatigued or under the influence of drugs or alcohol.

Tillage machines

Tillage machines are **implements** used to break up the soil and prepare it for the sowing or planting of crops. The earliest tillage implements were hand-held digging sticks. Gradually, tillage implements have improved and become larger. The development of tractors meant more power to pull the tillage machines and now their size is limited only by the power of tractors. As well as this increase in size, there has been an expansion in the variety of machines to satisfy the wide range of purposes they are used for.

Tillage implements can be classified according to the order in which they are used in the preparation of soil for planting or sowing. **Primary tillage implements** are machines used to break up the soil in the first stages of preparing a seedbed. **Secondary tillage implements** are used to further reduce the size of the **soil aggregates**. There are also rotary hoes that are capable of preparing the soil in one pass.

- 4 Describe the difference between primary and secondary tillage machines.

Primary tillage machines

Mouldboard plough

The mouldboard plough is the oldest type of **primary tillage implement**. As it is pulled through the soil it cuts a slice of soil and turns it over completely (Fig. 12.3). All plants are completely buried so it is useful for killing weeds. The mouldboard plough takes a lot of power to pull and is not used very frequently now.



Shutterstock/Horst Kanzek

Figure 12.3 A mouldboard plough

Disc plough

A disc plough has dish-shaped discs (Fig. 12.4), which are pulled through the soil at a slight angle. A slice of soil is cut and partially turned over. As the soil rides up the disc and falls back to the ground, it is broken up. The disc plough buries most of the plants that were growing in the soil. Because the discs roll, a disc plough is easier to pull. There can be 20 or more discs on a large disc plough.

Regular use of disc ploughs reduces soil aggregates to small particles and produces a compacted layer that prevents air, water and roots penetrating the subsoil. When it rains, soil particles on the surface collapse together to form a crust that limits air and water entry into the soil, making it difficult for seedlings to break through.



Shutterstock/VanHart

Figure 12.4 A disc plough

Chisel plough

A chisel plough has **tines** with chisel-shaped points that are dragged through the soil (Fig. 12.5). The effect is to break up the soil rather than turn it over as the mouldboard and disc ploughs do. Each tine is spring-loaded so that it bends back, rather than breaks, when it hits an object in the soil such as a rock or stump. Once it has passed over the obstruction, the tine springs back into place.



Shutterstock/Taina Sohlman

Figure 12.5 A chisel plough



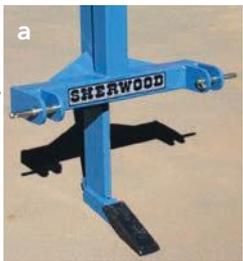
Tintinara Engineering Services



Figure 12.6 A blade plough

- Describe the types of ploughs available and, for each, list its primary function.

Sherwood Machinery



Wikimedia Commons/
Leslaw Zimny

Figure 12.7 **a** A single tine ripper and **b** a subsoiler

Courtesy of Tractorama,
www.tractorama.com.au



Figure 12.8 A scarifier

Shutterstock/Verkhovynets Taras



Figure 12.9 A disc harrow

- Outline the differences between a scarifier and a chisel plough.
- Explain why the discs on some disc harrows are scalloped.

Blade plough

The blade plough is designed to cultivate the soil while leaving as much plant matter lying on the surface as possible (Fig. 12.6). Plant matter is often useful on the soil surface because it reduces the eroding effects of wind and water. Each tine of the plough has a flat, slightly swept-back share. Each share is up to 1 m wide. When the plough is working, the share is pulled through the soil so that it is parallel to the surface. The roots of the plants are cut off and the soil is disturbed as the share passes under it.

Ripper

A ripper is sometimes used to penetrate and break up soil to a depth of up to 1 m. The idea is to break up the subsoil and allow better drainage and plant root growth. Some tillage machines tend to compact the soil below the level at which they work. A ripper can be used to break up this compacted soil (sometimes called a *hard pan*), to improve drainage and aeration (Fig. 12.7).

Secondary tillage machines

Scarifier

A **scarifier** looks very much like a chisel plough but the points at the ends of the tines are much wider (Fig. 12.8) and do not disturb the soil as deeply as they pass through. Any weeds that might have germinated since the first cultivation are thus destroyed. Scarifiers can be very large and can cultivate a strip of land up to 30m wide at a time.

Disc harrow

A disc harrow consists of two rows of discs, one behind the other. The two rows of discs are set at a slight angle to each other. The first row cuts and tosses the soil in one direction and the second row cuts and tosses the soil back again. The discs are often scalloped, which helps in cutting up the remains of plants from the first cultivation (Fig. 12.9). Disc harrows are mainly used to break up the soil after primary tillage to eliminate clumps and loosen the soil if it has been compacted.

Diamond harrow

A diamond harrow consists of steel frames criss-crossed in 'diamond' shapes. At each point where the pieces of steel cross there is a steel peg about 15 cm long, pointing downward (Fig. 12.10). As the harrows are drawn across the land, the pegs break up the soil and tear out weeds that may have germinated. Harrows are often drawn behind seed-sowing machines to help cover the newly sown seed.



Figure 12.10 A diamond harrow

Roller and cultipacker

These implements are sometimes used to firm the soil down around seed that has been sown by a broadcasting method. The idea is to crush soil clods and remove air pockets to bring the soil into close contact with the seed, which will then more easily obtain the necessary moisture for **germination**.

One-pass tillage machines

The main machine in this group is the rotary hoe. This has a rotor with blades on it resembling hoes. As the rotor turns, the blades chop the soil in much the same way as a hand hoe would (Fig. 12.12). Because of the speed of rotation and the power of the machine, the soil is flung up against the metal housing that covers the revolving hoes. This smashes or shatters the soil aggregates and the result is a fine seedbed produced in one pass of the machine. Plant material that was on the surface is chopped up and buried in the soil. Rotary hoes range in size from very small garden types with a 30-cm cut, to large tractor-mounted hoes which cut up over 8 m. They are often used in market gardens for cultivating between the rows of the growing crops to control weeds. Overuse results in a loss of soil structure and the formation of a hard surface pan.



Figure 12.11 A roller



Figure 12.12 A rotary hoe

Seeding and planting machines

Seeding and planting machines plant the seeds or parts of plants that will grow into the crop that will be harvested. These machines place the seed or plant parts in the soil in a situation that is as near to ideal as possible for the germination, establishment and growth of the crop. These machines can be classified into three broad groups according to what they do.

The first group is made up of machines that sow seeds for crops and pastures. Crops sown by these machines include barley, canola, cotton, maize, oats, rice, soybeans, sunflowers, wheat and many more. The second group includes machines that place parts of plants in the soil from which the new crop will grow; for example, **potato tubers** and **sugarcane sets**. The third group consists of machines specially built to transplant seedlings.

Seeding machines

There are seven main machines used for seeding.

Broadcaster

A broadcaster is a basic machine (Fig. 12.13) that is just a small advance on throwing the seed over the prepared soil, as people did in the earliest agricultural systems. It is therefore not used



Figure 12.13 A broadcaster

- 8 Describe a situation where diamond harrows are most likely to be used.
- 9 Describe how a rotary hoe produces a seedbed in one pass.
- 10 Recall the three broad groups of planting and seeding machines.

as widely as other types of seeding machines. It is more likely to be used for spreading fertiliser than seeds. The seed drops from a storage unit onto a rotating disc and is flung away. This machine is not very precise and leaves the seed on the soil surface. Since soil dries out quickest on the surface, broadcast seed is less likely to germinate and establish itself than seed sown by other methods.

Seed drill

This implement places the seed in evenly spaced rows in the soil, at a set depth and then covers them. The seed is held in a bin and is dropped down a tube into the soil behind a cultivating tine. A series of presses or metal discs then cover the seed with soil. This means the seeds are able to take maximum advantage of available soil moisture, and increases germination rates and crop yield.

Combine

The seed **drill** was further developed when a bin was added so that fertiliser could be placed in the soil with the seed. The resulting machine is known as a combined *seed and fertiliser drill* (Fig. 12.14), or *combine* for short, because it ‘combines’ the operations of seed sowing and fertiliser application. Seed drills and combines give accurate spacing between rows but do not give the same accuracy of seed spacing in the row itself.

Shutterstock/Leonid Ikin



Figure 12.14 A combine seed and fertiliser drill

Shutterstock/f-f-f-f



Figure 12.15 An air seeder

Precision seeder

This was developed to improve the placement of seed in each row, not just the even spacing of rows that the seed drill achieves. The seed is placed very accurately and the soil is firmed down by individual press wheels for each row. This makes the crop very even and makes harvesting easier because all the plants mature at the same time. Precise planting is very important for such crops as cotton, grain sorghum, maize and soybeans.

Air seeder

The air seeder (Fig. 12.15) uses a stream of air to move the seed and fertiliser from their boxes to the tines of the machine in the soil. This air stream is created by a fan driven either by the tractor’s PTO, a hydraulic motor or a small engine. The advantage of the air seeder is that it can be attached to a chisel plough or scarifier, rather than having to be used as a separate machine and process. Air seeders have to be carefully adjusted so that the airstream takes an even amount of seed and fertiliser to all the tines.

Shutterstock/ekina



Figure 12.16 A direct drill

Direct drill

The direct drill (Fig. 12.16) is very similar to the combine. It is of heavier construction because it is designed to sow into an unprepared seedbed. Instead of cultivating the soil in the traditional manner with tillage machines, the weeds are brought under control by using herbicides. Tines or discs are used to open up the soil and make a **furrow** into which the seed and fertiliser are dropped. A disadvantage with direct drilling is that the plant material or trash left on the surface can be caught up in the tines and clog up the machine. Direct drilling has been developed to help reduce soil erosion and increase the quantity of organic matter in the soil.

Aerial sowing

Aerial sowing is a method rather than an implement. Aeroplanes or helicopters are used to 'sow' seed in steep and rugged areas that cannot be sown with tractor-drawn machines. Pasture seed and fertiliser are dropped from the low-flying aircraft using a broadcast method of seeding. Rice can also be sown from the air – partially germinated seed is dropped into the flooded paddies. Oats and ryegrass seeds can also be air-sown. Aerial sowing is often used to spread different grasses and legumes to large areas of land that are in need of vegetation after fires to prevent or reduce erosion hazards and suppress weeds.

Planting machines

There are two main planting machines in use in Australia: the sugar planter and the potato planter.

Sugar planter

A sugar planter cuts sugarcane into short lengths called *sets* (Fig. 12.17). Each set has at least two growing points. The sets are then placed in a furrow in the soil. As each set is placed, it is sprayed with chemicals to prevent attack by insects and disease. Fertiliser is applied by the planter in bands next to, but not in contact with, the sets. The sets are finally covered with soil.



Figure 12.17 A sugar planter

Potato planter

Seed potatoes (which are not seeds, but small tubers) are planted with a machine that does much the same things as the sugar planter. The potato planter places the seed potatoes in the soil, with fertiliser, in rows. The spacing of the rows is very important. It must allow cultivating machinery to operate between the rows without damaging the roots of the potato plants.

Transplanting machines

Some vegetable crops are grown in large areas, and transplanting by hand would involve too much costly labour. Tractor-drawn machines have therefore been developed to transplant the seedlings. As they move along they dig a small hole in the cultivated soil and a seedling is planted in it.

Harvesting machines

Harvesting machines harvest mature crops so that they can be sold. There are many different types and they have been developed so that one person can do the work of several people, in a shorter time. The combine harvester is the most common harvesting machine in Australia and it can be used for many crops.

Several other crops, such as cotton, potatoes and sugarcane, have specialised machines to harvest them. There are many varieties of haymaking and silage-making machines and, because of the high cost of labour, machines have also been developed to harvest various fruit, nut and vegetable crops.

-
- 11** Describe the difference between a seed drill and a combine.
 - 12** Why are broadcasters not used very much these days?
 - 13** Discuss which sowing method could be used to sow pasture seed in very rugged country that cannot be driven over with a tractor.
 - 14** Assess why many farmers are now turning to direct drills to sow their crops.

-
- 15** Outline the similarities between the sugar planter and the potato planter.

-
- 16** Outline two reasons for the invention of harvesting machines.

Combine harvester

The combine harvester, or header harvester (Fig. 12.18), was developed to harvest cereal crops, particularly wheat. It is called a 'combine harvester' because it combines into one machine the functions of what were once three separate machines. These three machines were the stripper, thresher and winnower. The stripper cut the grain heads off the wheat plants; the thresher beat the husks off the grain; and the winnower blew the husk away, leaving the grain behind. HV McKay (1865–1926) first put all three operations together in one machine.

Today's combine harvesters are very large when compared to the early horse-drawn machines. The harvester either has its own engine and is self-propelled, or is driven by the PTO of the tractor hauling it. The width of crop they can harvest at one pass ranges from 3.5–10 m. As the combine harvester travels through the crop the grain heads are cut off, collected, threshed and winnowed and the grain put into a storage bin. When the bin is full it is emptied into another storage bin in the paddock or onto the back of a truck. The stalks can also be harvested to produce straw.

The combine harvester is used to harvest many crops apart from wheat, including barley, canola, linseed, lupins, oats, rice, safflower, sorghum, soybeans and sunflowers. The machine is specially adjusted for each crop, and in some cases is modified in some additional way, but the principle is basically the same.

Specialised harvesters

Cotton harvester

The cotton harvester is designed to pick the cotton from cotton plants (Fig. 12.19), which was once done by hand. The machine is self-propelled and works by poking rotating 'fingers' into the cotton bolls on the plants. The cotton is caught and pulled off the plants. It is then blown by a stream of air into a big bin on the machine. The cotton harvester can pick cotton from up to six rows of cotton plants at once.

Potato harvester

A potato harvester digs the potato tubers up from underneath the soil and separates the tubers from the remains of the plants and the soil. The tubers are then elevated to a point where they are moved towards the back of the harvester to a picking table where people pick out by hand the stones and reject clods. The tubers are then placed in bags ready for trucking to market (Fig. 12.20).

Sugarcane harvester

A large machine used to harvest and partially process sugarcane, the sugarcane harvester cuts one or two rows of cane at a time as it moves through the crop (Fig. 12.21). It cuts the stalks at the base, strips the leaves off and then cuts the cane into segments and throws them into a bin or trailer behind it.



Shutterstock/mihalec

Figure 12.18 A combine harvester

17 Recall the names of the machines that did each of the three operations now performed by the header harvester.

18 Describe how a combine harvester harvests a wheat crop.



Shutterstock/Alaettin Yidirim

Figure 12.19 A cotton harvester



Shutterstock/J. Marijs

Figure 12.20 A potato harvester



Shutterstock/cvilchesmonzon

Figure 12.21 A sugarcane harvester

Fruit and nut harvesters

Because of the high cost of labour needed to harvest fruit and nut crops, machines are being developed to replace hand pickers (Fig. 12.22). One such harvesting machine is designed to take hold of a tree round the trunk and shake it, causing the



Leonie Scarlett/Ruralphotos.com

Figure 12.22 A macadamia nut harvester

fruit or nuts to fall off into a catching device that looks something like an upside-down umbrella. One of the main problems in developing machines for harvesting fruit is handling the fruit gently enough so that it is not bruised. Newer technology in robotics is also being designed to replace humans, using suction grippers so bruising of fruit during harvesting is reduced.

Mechanical grapevine harvesters work by beating the vine with rubber sticks to force the fruit to drop onto a conveyor belt that moves the fruit to a holding bin. But these harvesters cannot distinguish between ripe, unripe and rotten bunches, and they also have the potential of bruising the skins, which can cause undesirable qualities in the wine.

Machines for haymaking and silage making

The first step in haymaking is to cut the crop or pasture. There are two basic kinds of mowers for doing this. The *reciprocating mower* has a comb-like arrangement that directs the plants into a cutter that moves back and forth cutting them off. The *rotary mower* (Fig. 12.23) works very much like a lawn mower. The rotating blades cut the plants. The reciprocating mower cuts the crop or pasture very neatly while the rotary mower tends to bruise the plants a little more.

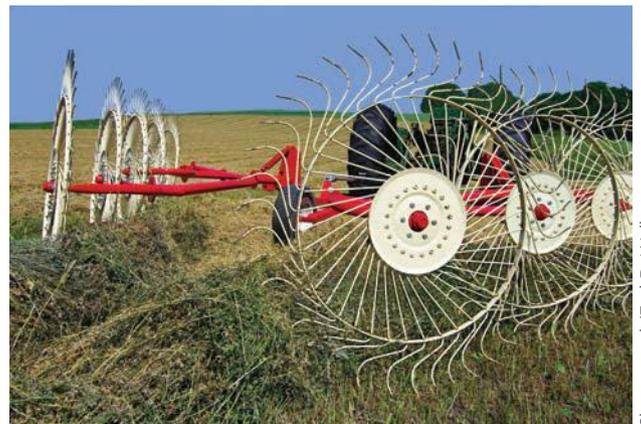
Once the hay has been cut it must be raked into **windrows** to be picked up by the baling machines. The most common hay rake is the *finger wheel rake* (Fig. 12.24), which consists of several large wheels made of radiating spring-steel spikes. As the rake is pulled along, the wheels turn in a similar fashion to the discs on a disc plough and rake the hay into a windrow.

Modern haymaking has combined several operations into one machine. This machine cuts the hay, conditions it, and forms it into a windrow all in one pass. ‘Conditioning’ involves passing the cut hay through rubber rollers that bend and crimp the plant stalks. This



Shutterstock/TFoxFoto

Figure 12.23 A rotary mower



Shutterstock/Earl D. Walker

Figure 12.24 A finger wheel rake

19 Describe how the cotton harvester, potato harvester and sugarcane harvester separate the product being harvested from other unwanted materials.

20 Explain why harvesting machines have been developed for fruit and nut crops.

has the effect of making the stems dry out at the same rate as the leaves. It thus takes less time for the hay to dry out and be ready for baling.

After drying in the windrows, the hay is ready for baling. The *pick-up baler* (Fig. 12.25) picks the hay up from the windrow and presses it into a bale, tying it with either wire or twine. The bales were once all the same rectangular style, weighing about 30 kg, but now a variety of bales is made by different balers. There are large rectangular bales, large round (cylinder-shaped) bales and bales so large they are mini haystacks – with 2 tonnes of hay in them.



Stockphoto/© esemelwe

Figure 12.25 A pick-up baler

- 21 List these machines in the order they would be used to make hay: pick-up baler, reciprocating mower, finger wheel rake.
- 22 What operations are combined in a modern haymaking machine?
- 23 Describe what a forage harvester does.

Crops being made into silage are cut or chopped by a forage harvester (Fig. 12.26). The choppers or blades swing from a rotating horizontal shaft, cutting the plants. The chopped material is collected and blown into a bin that trails along behind the harvester. The bin is emptied into the silo where the silage is made.



Shutterstock/nikshor

Figure 12.26 A forage harvester

Machinery care

Machinery needs regular care and maintenance to ensure that it will be able to work for many years (Fig. 12.27). Machinery can be very expensive – a secondhand combine harvester can cost several hundred thousand dollars – so no farmer wants to have to replace them too often.

With modern machines, the time needed for daily care and maintenance has been greatly reduced. Old-style bearings, which had to be lubricated by grease through a grease nipple every day, have been replaced with more modern, sealed bearings. Sealed bearings do not let the grease out or abrasive dust in: the grease is packed and sealed into the bearing when the machine is made, and lasts for a long time.



Newspix/Kim Woods

Figure 12.27 Checking a seeding machine

The care of farm machinery usually involves:

- inspecting and checking the machine regularly for wear, and replacing worn parts
- lubricating all moving parts and bearings as directed by the manufacturer's instruction book
- regularly checking the machine when it is operating, to see that it is adjusted properly and is efficiently performing the task it was designed to do
- taking care of the machine when the job is done; cleaning it and putting it away in a shed where it will be protected from the elements
- ensuring all protective guards are fitted, free moving and not broken or worn.

- 24 Outline the reasons for machinery care and maintenance.

Machinery safety

Operating machinery safely means following some simple rules.

- 1 Be familiar with the manufacturer's instructions for using the machine.
- 2 Adjust the machine only when it is stopped and switched off.
- 3 Make sure all safety guards covering belts, drive chains and dangerous, moving parts remain on the machine. They are sometimes not replaced when machines are repaired or adjusted and loose clothing can be caught on these parts. If this happens serious injury is likely.
- 4 Use a machine only for the tasks for which it is designed.

25 Predict what might happen if each of the safety rules for using machines was not followed.

Recent developments in farm equipment technology

The application of technological innovations into agricultural production systems enables agricultural enterprises to boost their levels of productivity. But the adoption of new technology or equipment is a very slow process in general. Some farmers readily adopt new technologies; the majority wait to see the progress of early adopters then follow; finally, there are a few who never take up the innovations. Cost is very much a deciding factor in this process, followed by effective training opportunities for farmers.

Precision agriculture includes the use of satellite navigation and automatic steering technologies based on global positioning systems (GPS). This automatic steering capability removes stress from drivers and prevents equipment going over the same ground more than once. Wireless communication can allow combine harvesters to transfer data to tractors and other machines such as chaser bins so the tractor controls the movement of these connected machines. The driver can monitor the unloading and status of the chaser bin. Spillage is limited through this process and vehicle movements are coordinated and controlled.

Variable rate technologies allow farmers to change the rate of application of inputs such as fertilisers, seed and chemical sprays. This technique improves cost effectiveness as application rates can be changed according to soil type, moisture levels and paddock characteristics affecting yield of a crop. Adjustments can also be made for weed or pest concentrations within a paddock. Processes based on controlled delivery, such as fertiliser applications or herbicide spraying, require detailed paddock maps generated by computers. Delivery rates of the fertiliser or sprays are based on data from GPS-controlled yield and crop sensors, soil testing data and remote sensor data often from satellites or drones. The paddock maps obtained from the data gathered and mapped by computers can then be divided into various management zones. This allows inputs to be delivered at variable rates through machines such as fertiliser spreaders that have GPS-linked computers mounted on them to interpret the paddock maps and consequently allow the machines to vary delivery rates.

Chapter review

Things to do

- 1 Under the teacher's supervision, learn to drive the school's tractor.
- 2 Carry out the routine maintenance of the school tractor. For example, grease it, change the engine oil and check the level of fuel, oil, water and battery acid. Check the air pressure in the tyres.
- 3 Learn to safely operate the school's rotary hoe.
- 4 Harvest some wheat by hand. Cut the heads off with a pair of scissors and rub them in the palm of your hand until the grains come out. Blow the husks away and the grain will be left in your hand. What three operations have you just carried out?
- 5 Watch crop-planting and seeding machines in operation. Record each of the following:
 - a the kind of machine used
 - b the crop being planted or sown
 - c whether or not fertiliser was being applied at the same time
 - d the type of fertiliser
 - e where it was placed
 - f the depth of sowing
 - g the spacing between the rows
 - h the spacing between the plants or seeds within the row.
- 6 Compare the effect on the soil of digging it with a spade, with a garden fork and then with a hoe. Explain which of the three tools is most suited to primary tillage. Explain which is most suited to secondary tillage.
- 7 Plant a vegetable crop such as beans or radishes using two different sowing methods: 'broadcasting', and sowing the seed in evenly spaced rows, with an even space between the seeds in each row.
 - a Which method gives the best germination and establishment of seedlings?
 - b Which method produces the most product to harvest?
- 8 Sow a vegetable crop in rows. Use two different methods of applying fertiliser: first, place it in the row with the seed; and second, place the fertiliser in rows by itself, very close to the rows of seed.
 - a Does the placement of the fertiliser make any difference to the germination and establishment of the crop?
 - b Does it make any difference to the final yield of the crop?
- 9 Visit a farm where a crop is being harvested and observe the harvesting machines operating. Name the machines used and discuss the skills required to operate the machines.
- 10 Create an A3-size poster publicising safety rules for the use of tractors.

🔍 Things to find out

- 1 What is a stump-jump plough and why was it invented?
- 2 Obtain an owner's manual for a tractor, and list the routine maintenance operations that should be carried out (e.g. changing engine oil) and how often they should be carried out.
- 3 Obtain the owner's instruction manual of a farm machine and see if there is a list of safety instructions, rules or precautions for its use. Write the list out.
- 4 What is a rod weeder? How does it work? Why was it invented?
- 5 Make a list of the crops that can be harvested with a combine harvester.
- 6 In your own district, what machines are used in the preparation of soil for the planting of a crop?
- 7 What machines are used for sowing crops in your district?
- 8 Describe how pastures are sown in your district.
- 9 How are young pine trees planted when a new forest is being established?
- 10 What machines are used to harvest the crops in your district?
- 11 Is there a crop that is not yet harvested by machine? Why hasn't a machine been invented to do this?
- 12 Go to the library and find out what was happening in Australia at the time when HV McKay invented the Header Harvester. Could this have been the reason he invented the harvester?

+ Extension activities

- 1 The emphasis on farming today is on 'minimum' or 'zero tillage'. Suggest which implement(s) can be used for this type of tillage and justify their use. (Suggestion: obtain pictures or diagrams of the implements used.)
- 2 Discover how the following types of cultivation machinery affect soil structure.
 - a Mouldboard plough
 - b Disc plough
 - c Scarifier
 - d Disc harrow
 - e Rotary tiller
- 3 Search the internet for information relating to the safe operation of tractors in Australia. Find some guidelines for the safe operation of tractors. Look for statistics on the number of deaths caused by tractors. Find out why people are run over by tractors. The [Workcover](#) and [Safe Work Australia](#) websites may help; search either or both for 'tractor safety'.
- 4 Go to the websites of the major farm machinery manufacturers and list the machines they have for sale that could be used on a wheat farm, an orchard and a vineyard.
- 5 Copy and complete the following risk management checklists for the machines, equipment and practices on a farm (school, local or own farm) in the presence of a teacher or farmer.

connect

Workcover

connect

Safe Work Australia

connect

John Deere

connect

Massey Ferguson

Identify potential problems	Y	N
What machinery do you have?		
Tractors		
Are they fitted with a ROPS and seatbelt?		
Are operators trained on 4WD utes?		
Are seatbelts fitted and working, in good condition?		
Vehicle is in roadworthy condition (e.g. tyres and lights)?		
Are operators trained on quad bikes?		
Are employees wearing helmets?		
Are passengers being carried?		
Fitted with a roll bar?		
Are operators trained on trucks?		
Seat belts fitted and worn?		
Vehicle in roadworthy condition?		
Headers		
All safety guards in place?		
Seat belts fitted?		
If driven on road, is it roadworthy?		
Are escorts provided?		
Cotton pickers		
All safety guards in place?		
Seat belts fitted?		
If driven on road, is it roadworthy?		
Are oversize escorts conducted on road?		
Load shifting (e.g. graders etc.)		
Compliant with WHS regulations?		
Motorbikes		
Are helmets worn at all times?		
General machinery checks		
Is all the machinery up to date with OHS standards?		
Has any machinery or equipment been modified?		
No modifications can be performed unless approved by the manufacturer then submitted for approval		
Equipment safety covers and PTO covers fitted		
Seeders		
Ploughs		
Slashers		
Balers		

Identify potential problems	Y	N
Bole buggy		
Module builder		
Chaser bin		
Are staff competent?		
Mobile field bin		
Mill and mix machines		
Windmills		
Has working at heights training been conducted?		
Ring tanks		
Do employees drive on top of the banks?		
Environmental hazards		
Power lines running through your property ?		
Is white paint or reflective stickers in use for lines running across farming country?		
Irrigation channels		
Are signs, speed limits, barriers and reflective stickers in use near channels?		
Methods of irrigation		
Pipe?		
Overhead/pivots/lateral/traveller?		
Flood?		
Sheds		
Workshop shed?		
Machinery shed?		
Shearing shed?		
Hay shed?		
Chemical shed?		
Is there a shower, wash basin, first aid kit and MSDS book attached to the chemical shed?		
Grain silos (are employees trained to work at heights?)		
Livestock		
Do you have any horses? Are helmets non-slip boots available?		
Do you have any sheep?		
Do you have any cattle?		
Employee competency		
Statements of attainment		
Machinery tickets		
Letters of proof of experience		

Identify potential problems	Y	N
Property boundaries		
Do you slash outside your property boundary on a public road? Appropriate licence required		
Do you have ramps/grids on property? Are they maintained?		
Power tools		
Have tools and power leads been tested recently?		
Are inspection tags with dates used?		
Do they have all their guards on?		

Identify potential problems	Y	N
Do you have a pit in the maintenance shed?		
Is the pit covered?		
Does it have safety rails?		
Does it have ventilation?		
Do you have a wash down pad for vehicles?		
Do you have a 'Weed and Seed' declaration?		
Are public roads running through the property?		
Are Stop, Give Way and speed limit signs in place?		
Are there speed limit and signs warning of children placed near houses?		

Tractor checklist to be completed by a trained operator

Tractor make and model:

Registration no.:

Visual checks	Conducted with the engine off	Y	N	Function checks	Conducted with the engine running	Y	N
Warning decals	Readable			Moving parts	No unusual noises		
Fluid leaks	No fluid leaks under machine			Controls	All controls operate correctly		
Engine oil	Level correct			Reversing beeper	Operates when in reverse		
Transmission oil	Level correct			Rotating beacon	Operates		
Hydraulic oil	Level correct			Lights	Functioning		
Brake fluid	Level correct			Driving inspection	Conducted while moving slowly		
Coolant	Level correct for temperature			Steering	Firm. No unusual noises		
Radiator and grille	Clean of debris			Brakes	Firm pedal action		
Battery	Bracket and terminals secure and clean			Handbrake functioning	Holds on slight incline		
Battery electrolyte	Levels correct and caps in place			Brake test	Test by travelling forward and reverse		
Tyres	Inflation correct and no damage			Steering brakes	Pedals even. Brake evenly when joined.		
Wheels	No cracks. Nuts and studs secure			Other checks	Cross out if not applicable		
Hydraulics	No leaks or damage			Fuel	Sufficient for the day's work		
Seat and seatbelt	Good condition and functional			Attachment security	Attachment secure and pins secure		

Visual checks	Conducted with the engine off	Y	N	Function checks	Conducted with the engine running	Y	N
PTO guards (on tractor and shaft)	Secure and good condition			Attachment damage	Attachment not damaged		
Horn (use before starting)	Operation and volume						
ROPS/FOPS (Falling Object Protection System)	Secure						

Warning! Do not operate if machine is not safe to operate!

If any are ticked N for NON-COMPLIANT, tag machine and refer this sheet to a supervisor to ensure repairs are carried out.

Faults identified:

Maintenance required/administered:

Operator/inspector name:

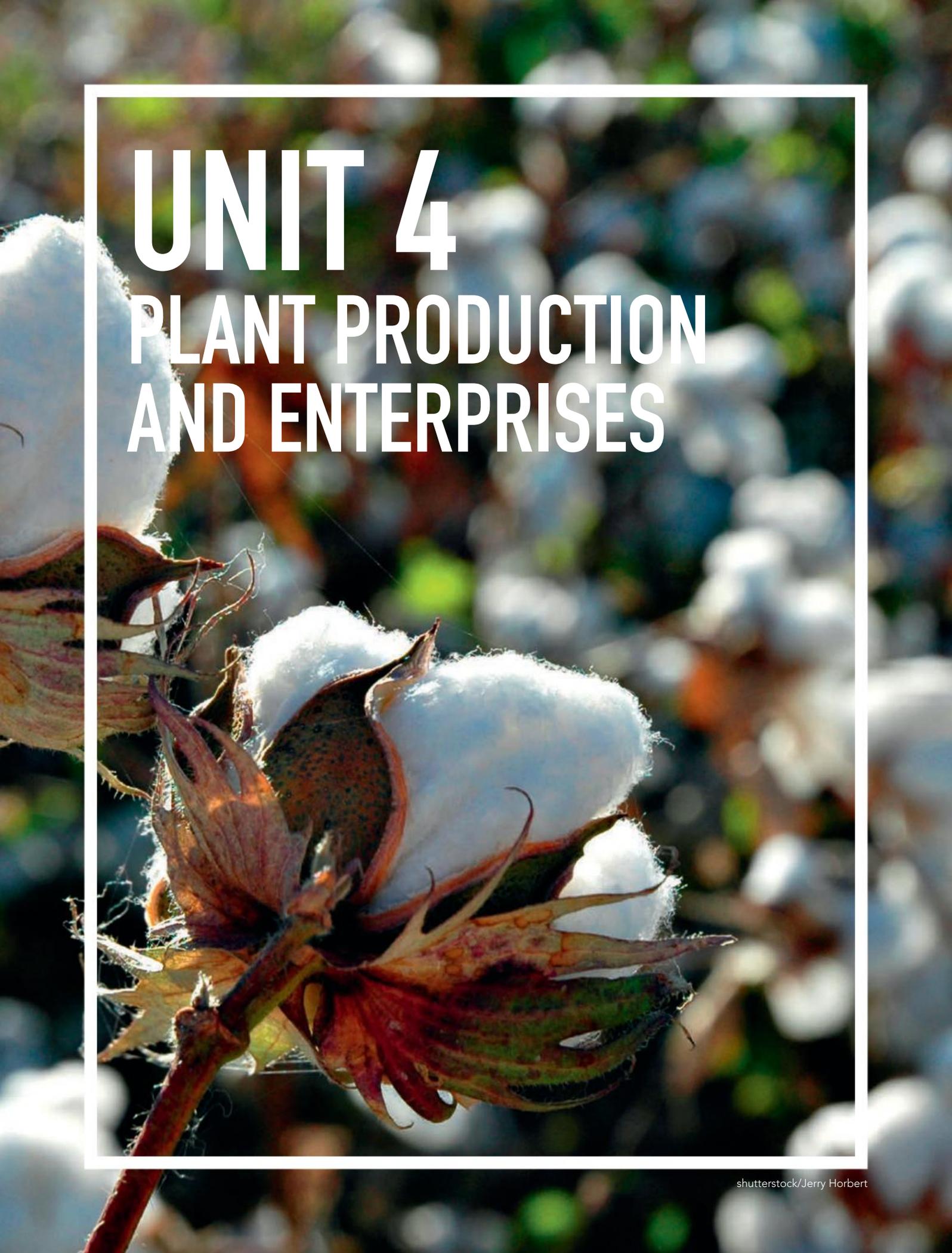
Signature:

Date:

Hours/odometer:

✓ Test yourself

- 1 Describe the operations that a combine harvester carries out.
- 2 Name and describe two machines used for sowing or planting a crop.
- 3 List three machines in the order they would be used to make hay.
- 4 Using examples, show that you understand the difference between primary and secondary tillage machines.
- 5 Imagine an accident on a farm involving a tractor where the operator did not follow one or more of the tractor safety rules. Write a paragraph describing what happened. Write another paragraph explaining how the accident could have been prevented if the operator had followed the tractor safety rules.



UNIT 4

PLANT PRODUCTION AND ENTERPRISES

CHAPTER 13

PLANT STRUCTURE AND FUNCTION

Words to know

adventitious roots formed from areas of the plant other than the underground root system

chlorophyll a green, light-sensitive pigment in plants that absorbs light energy and enables the process of photosynthesis

chloroplast the structure in the cells of the plant that contain chlorophyll

cotyledon the food source of a seed embryo

crosspollination pollination between flowers of different plants of the same species; in fruit trees from one variety to another

dicotyledon one of two classes of flowering plants, a plant with two cotyledons (e.g. clover, canola)

dormancy delayed germination of a seed

embryo a young plant in the seed

endosperm the food store surrounding an embryo in a seed (if it is not absorbed by the embryo)

fertilisation occurs when the male sex cell from the pollen grain unites with the female sex cell in the ovule. The fertilised ovum develops into a seed.

inflorescence the arrangement of flowers on a plant

longevity the time period over which a seed can germinate

monocotyledon one of two classes of flowering plants, a plant with one cotyledon (e.g. grasses, palms and bananas)

osmosis movement of water from an area of high water concentration to an area with little water, through a selectively permeable membrane

phloem living vessels that move food in the form of sugars throughout the plant

photosynthesis manufacture by plants of food, by converting light energy into chemical energy in the form of sugars

plumule the stem section of an embryo

pollination movement of pollen from the anther to the stigma of a flower

radicle the root section of an embryo

scutellum the cotyledon of a grass embryo

self-pollination movement of pollen from the anther to the stigma of the same flower

stoma an opening found mainly on the underside of leaves, allowing air and water to exchange with the atmosphere

testa the outer covering of the seed

translocation movement of sugars through the plant from areas of manufacture to areas of storage or active growth

transpiration water loss from the plant through the stomata

viability the ability of a seed to germinate

xylem dead, hollow vessels conducting water and minerals from the plant roots to the rest of the plant

Introduction

Plant production is the basis of agriculture. In the green leaves of crop and pasture plants, light energy from the Sun is converted into chemical energy and stored. Plants are a source of food for humans and for the animals used by humans for food and fibre production.

Modern technology has made plant production more efficient. In Australia, crop yields have been increasing, mainly because crops are being planted in soils that have been made more fertile by pasture legumes. There have also been great increases in pasture growth in many parts of Australia, chiefly because of fertiliser use. We can expect further increases in crop and pasture yields because modern methods produce better plant growth.

All cultivated crop and pasture plants have developed from wild plants. They have been improved over time by selecting for features desirable for our use and by breeding from these selected types. Some crops, such as wheat, barley and the millets, have been cultivated for thousands of years. Other crops, such as the potato, sunflower and maize, have only been cultivated by Europeans for a few hundred years.

Classifying crops

Crops can be classified in many ways. We may group them according to the kind of food they produce, the plant family to which they belong or the purpose they serve on the farm. The following list shows how crops may be classified by the product obtained from them.

- Cereal or grain: wheat, oats, barley, rye, rice, maize, grain sorghums, millets, triticale
- Drug: tobacco, mint, pyrethrum, opium, herbs
- Fibre: cotton, flax, ramie, hemp
- Green manure: cowpeas, velvet beans, dolichos, red clover, phasey beans, mung beans, field peas
- Hay: lucerne, Sudan grass, millets, oats, pasture.
- High protein forage: velvet beans, mung beans, dolichos, phasey beans
- Legumes grown for seed: peanuts, field peas, soybeans, navy beans, lima beans, lentils, winged beans
- Low protein forage: sweet sorghums, sudax, grasses, rape, kale, chou moellier, maize
- Oil: sunflower, linseed, soybeans, safflower, castor bean, maize, cottonseed, canola
- Root: sugar beets, mangolds, turnips, sweet potatoes, cassava
- Rubber: rubber tree, Russian dandelion, guayule
- Sugar: cane sugar, sweet sorghums, sugar beet
- Tuber: potato, artichoke (Jerusalem)

Crops in Australia

Growing crops is a very important part of Australian agriculture. Some of the yearly production is used locally, but much of it is exported to other countries. Wheat is by far the most important single crop and Australia usually ranks as the third or fourth largest wheat-exporting country. Other important crop exports are barley, cane sugar, rice, preserved fruits, fresh fruits and dried fruits.

Parts of a plant

The seed

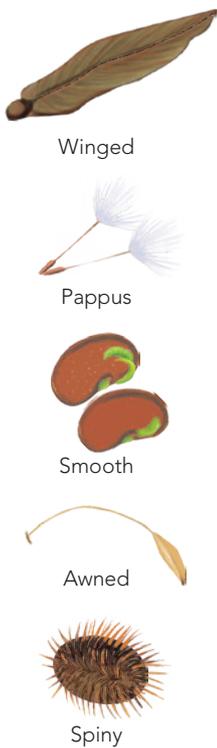


Figure 13.1 Shapes of seeds

The lifecycle of most plants begins and ends with a seed. In between, the processes of germination of the seed and of growth produce roots, stems and leaves. The plant enters a sexually reproductive phase involving the production of flowers and, if **fertilisation** is successful, seeds and possibly fruit will result.

The seed is designed for the survival and reproduction of plants. Seeds have many shapes and sizes to assist in their dispersal away from the parent plant. Figure 13.1 shows various seed shapes.

Inside a fertile seed lives a small plant or **embryo**. Figure 13.2 shows the external and internal structure of a bean seed. Compare this with Figure 13.3, which shows the external and internal structure of a wheat grain. The bean seed can be split easily into two equal halves. The embryo in the bean seed occupies all the space and consists of a **radicle** (root), a **plumule** (shoot) and **cotyledons** (the part of the embryo that contains dissolved food). The wheat grain cannot be easily split into two equal halves. The embryo occupies only a small area of the seed, but it still contains a radicle and a plumule. The **scutellum** structure is used by the embryo to absorb food stored in the **endosperm**. This food is better known as starch, the main reason for growing cereal crops such as wheat.

Cotyledons form the first leaves of many plants. In the world of plants there are two large groups: monocotyledons and dicotyledons. **Monocotyledons**, such as wheat and all the cereals and grasses, have seeds with a single cotyledon similar to that in Figure 13.3. **Dicotyledons** are all other types of flowering plants, including legumes such as beans. These seeds can be split into two equal halves like the bean in Figure 13.2.

For seeds to germinate they require water, temperatures suitable to the type of plant, and oxygen. Sunlight is not important for germination; greater success is often obtained if seeds are germinated in the dark. During the process of germination the seed absorbs water and swells. Starch in the seed is converted to simple sugars, such

- 1 Look at Figure 13.1 and identify the seeds that would be spread by wind. Which shapes indicate that wind is the main agent of dispersal?
- 2 Which seeds in Figure 13.1 would be spread more easily by animals or machinery? Why?
- 3 Which seeds in Figure 13.1 could be spread by the action of water? Why?

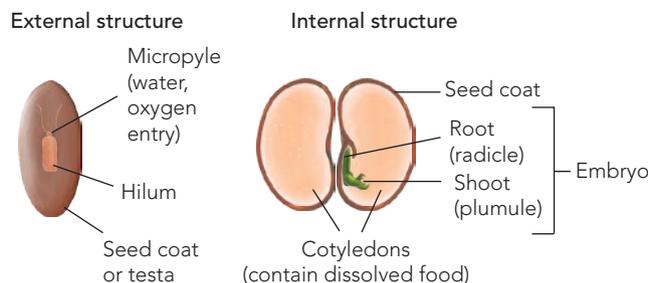


Figure 13.2 Bean seed

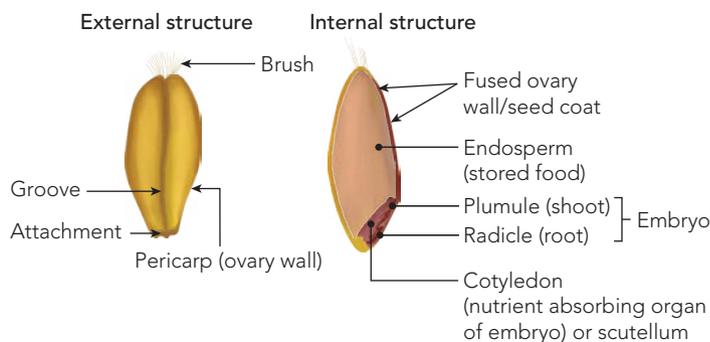


Figure 13.3 Wheat seed

as glucose, which are absorbed by the embryo. The growth of the root or radicle actually splits the seed coat or **testa**. The shoot emerges and the cotyledons expand.

The capacity for a seed to germinate is called **viability**, and the length of time the seed can be stored and still be capable of germinating is called seed **longevity**. Celery seed can be kept for up to 4 years; cotton for over 20 years. **Dormancy** refers to the ability of a seed to delay germination. This often occurs even when conditions that normally allow for germination exist; for example, up to 20 per cent of subterranean clover seed remains dormant for over a year. The delay in germination of some seed ensures that not all seeds will perish in a disaster, and thus the species will survive.

The main mechanism to ensure dormancy is the very thick seed coat of many seeds. The thick seed coat is typical of many Australian native plants; they are impermeable to water and air but break down over time or under heat conditions such as fire. Other plants, such as saltbush and tomato, have chemicals in their fleshy and watery fruit that prevent seed germination until they are washed out of the seed coat. Some seeds have special temperature requirements; others have immature embryos that must develop over time. These mechanisms also ensure that seeds are removed from the immediate area of the parent plant before germination, thus preventing unnecessary competition, and encourage germination in favourable climatic conditions. In commercial situations many hard (thick-coated) varieties of seed are either chemically treated or scarified (abraded) to ensure germination.

The flower

Scientific observation and the examination of fossil evidence suggest that flowers may have developed from slight modifications of leaves. Flowers of many dicotyledon plants are highly coloured and they are often scented. Plants that rely on insects for **pollination** use the colour of the flowers, the scent and the nectar to attract insects. Some plants, such as orchids, have flowers that mimic the shape of certain female insects, so pollination occurs when the male of the species attempts to mate with the flower. Not all plants have highly developed flowers. The grasses, or monocotyledons, have very simple flowers, with the male parts of the flower freely exposed to the wind. These plants rely on the wind to spread pollen from one plant to another. Figure 13.4 shows the structure of a typical flower. Compare it with Figure 13.5, which is typical of the flowers of many grasses. **Crosspollination** – spreading pollen from one plant to another – enables a mixing of genetic material. This encourages greater diversity in nature. Plants in which **self-pollination** occurs breed true to type but lack the genetic variations that are so often an advantage when the environment is altered.

The common parts of a typical flower (Fig. 13.4) are the:

- receptacle or base of the stem on which the flower is positioned – this protects against insect and pathogen entry
- sepals, which enclose the flower bud (In many plants the bracts are green in colour but in ornamentals such as bougainvillea they are brightly coloured. A bract is a modified leaf that subtends a flower or cluster of flowers; it may be thought of as a sepal.)

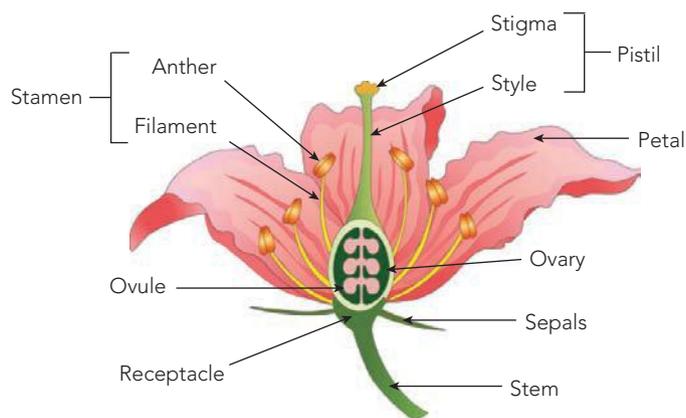


Figure 13.4 A typical flower

Figure 13.4 shows the structure of a typical flower. Compare it with Figure 13.5, which is typical of the flowers of many grasses. **Crosspollination** – spreading pollen from one plant to another – enables a mixing of genetic material. This encourages greater diversity in nature. Plants in which **self-pollination** occurs breed true to type but lack the genetic variations that are so often an advantage when the environment is altered.

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- 4 What are the main functions of a seed?
- 5 Copy Figures 13.2 and 13.3 into your books and label them fully.
- 6 Define the following terms.
 - a Embryo
 - b Radical
 - c Plumule
 - d Cotyledon
- 7 Describe the difference in seed structure between monocotyledons and dicotyledons.
- 8 What factors are needed for seeds to successfully germinate?
- 9 Define these terms.
 - a Viability
 - b Longevity
 - c Dormancy
- 10 List three mechanisms found in plants to delay seed germination.

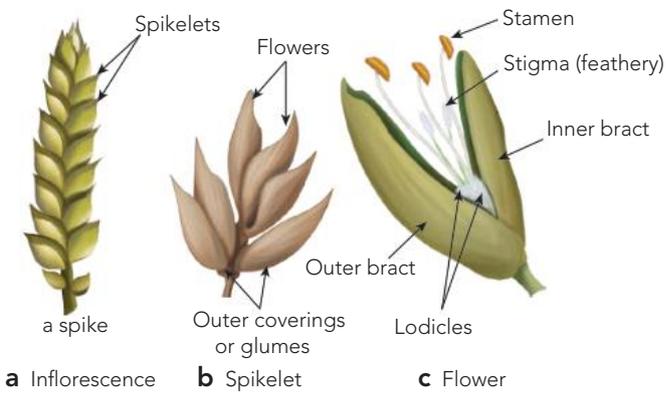


Figure 13.5 A wheat flower

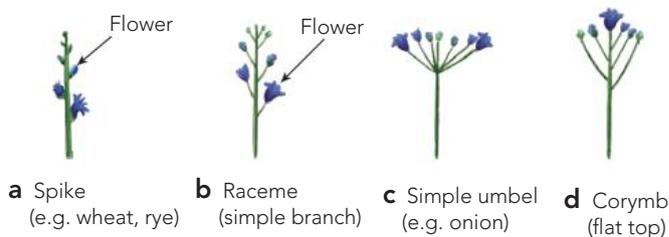


Figure 13.6 Inflorescence (flower arrangement)

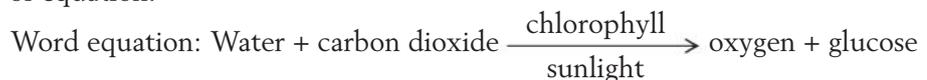
- 11** Describe the structure and function of a typical flower.
- 12** Using Figure 13.6 as a basis, draw and label three examples of common inflorescences.
- 13** Describe how the flowers of a plant pollinated by insects differ from flowers of plants that are wind pollinated.

- petals – very delicate in form; are brightly coloured but many of the patterns and colours are visible only to insects
- anther – part of the male portion of the flower; contains the pollen that is the equivalent of sperm in animals
- filament – the stalk to which the anther is attached
- stamen – a collective name for both the anther and the filament
- stigma – the top of the female part of the flower; it is sticky and pollen grains become attached to it
- style or hollow tube reaching into the ovary, down which pollen grains grow
- ovary – contains ovules or female eggs that, when fertilised, form the seed
- pistil – a collective name for the female portion of a flower; comprising the stigma, style and ovary.

The arrangement or cluster of flowers on a stem is the **inflorescence**. This is a useful feature for the classification of plants. Figure 13.6 shows some inflorescence arrangements.

The leaves

The leaves are perhaps the most important part of the plant. They carry out **photosynthesis** – the process of trapping energy from sunlight and using it to combine carbon dioxide and water to form high-energy sugars such as glucose. These sugars are then used to make all the other compounds found in a plant, including cellulose, starch, proteins and oils. This process can be expressed in two styles of equation.



As shown in Figure 13.7, many plant leaves consist of three main parts: the blade, the petiole and the stipules, which are appendages at the base of the petiole or leaf

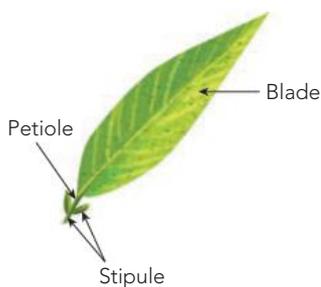


Figure 13.7 Leaf structure

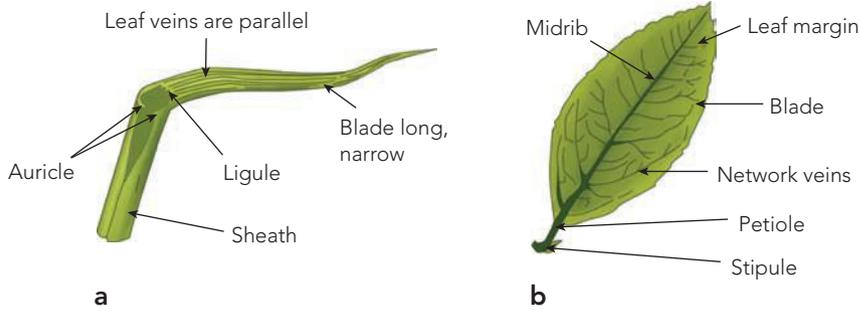


Figure 13.8 Leaf structure of **a** a monocotyledon and **b** a dicotyledon leaf

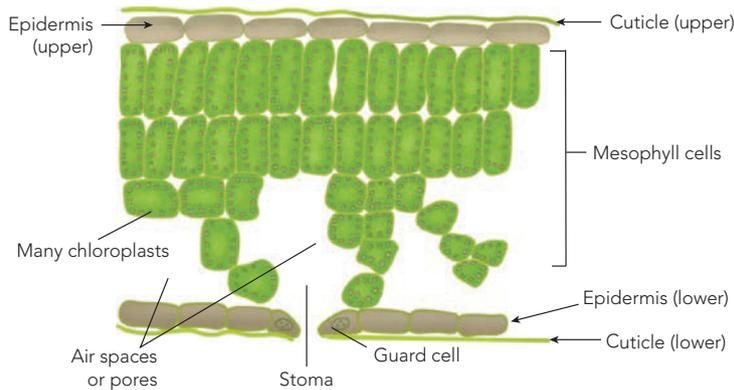


Figure 13.9 Internal leaf structure

stalk. In many instances these structures are modified or reduced to a point of insignificance. Again there are significant differences between monocotyledons and dicotyledons in the general structure of leaves (Fig. 13.8).

Leaves are in general thin and flat, to maximise the interception of sunlight and to allow for the easy diffusion of gases between the leaf and its surroundings. The internal structure of a plant leaf is shown in Figure 13.9. The light-sensitive pigment, which is green in colour, is called **chlorophyll** and is contained in a specialised structure called the **chloroplast**. Chloroplasts are the site of photosynthesis. Figure 13.10 shows that red and blue light wavelengths are needed for the process of food manufacture to occur at top pace. Green wavelengths are of little use to plants. Green leaves reflect most green wavelengths, which is why we see leaves as green coloured. Other light-sensitive pigments include the yellow-orange coloured carotenes and various purple coloured chemicals which enable plants to photosynthesise in different light conditions; for example, red algae can photosynthesise in deeper water where light penetration is limited, while green algae are common near the surface of the water.

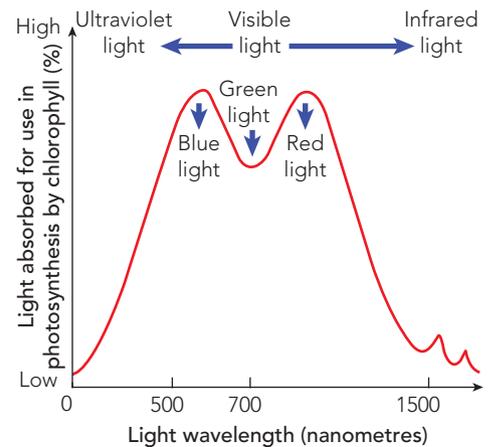


Figure 13.10 Light and photosynthesis

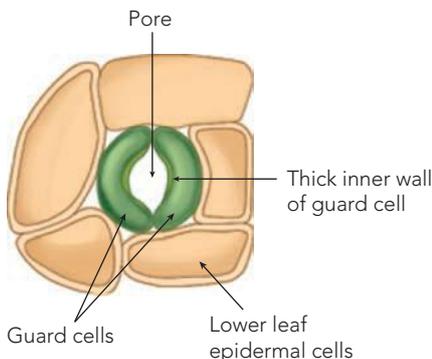


Figure 13.11 Stoma structure

Gases and water vapour are exchanged through openings usually found on the underside of plant leaves. These openings are called **stomata**. The structure of a stoma is shown in Figure 13.11. Loss of water

transpiration occurs through these stomata. The process of transpiration is discussed in detail in Chapter 14.

- 14** Draw and label the external features of a monocotyledon and a dicotyledon leaf.
- 15** Draw and label the internal structure of a plant leaf.
- 16** Describe the processes of photosynthesis and transpiration.

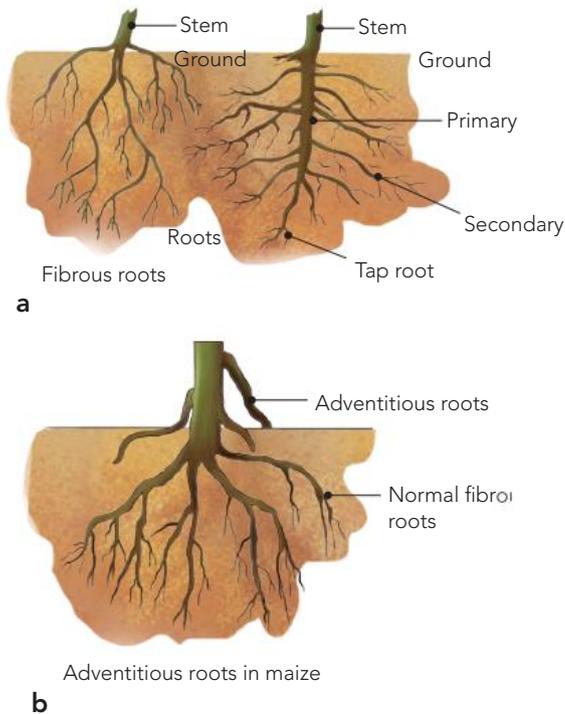


Figure 13.12 a Primary root systems
b adventitious roots

through the stomata is called **transpiration**. The plant must balance the need to take in carbon dioxide for the purpose of photosynthesis and the loss of water that will occur through the stomata. During the hottest part of the day the plant will close its stomata and the rate of food manufacture will decline.

The cuticle layer of the leaf is made of wax substances to prevent water loss or entry and to provide protection from the invasion of pathogens and insects. The epidermal layers offer some physical protection to the food manufacturing cells as well.

The roots

The roots anchor the plant in the soil. They absorb water and dissolved mineral nutrients from the soil and supply the stem, leaves and reproductive system. Roots are another place where food made by the leaves can be stored. Plant root systems may be classified as:

- fibrous or tap root systems developed from the primary or seminal (seed) roots (Fig. 13.12a)
- **adventitious** root systems that arise from the lower portions of unmodified plant stems, e.g. corn (Fig. 13.12b)
- root systems formed from modified stems (Fig. 13.13).

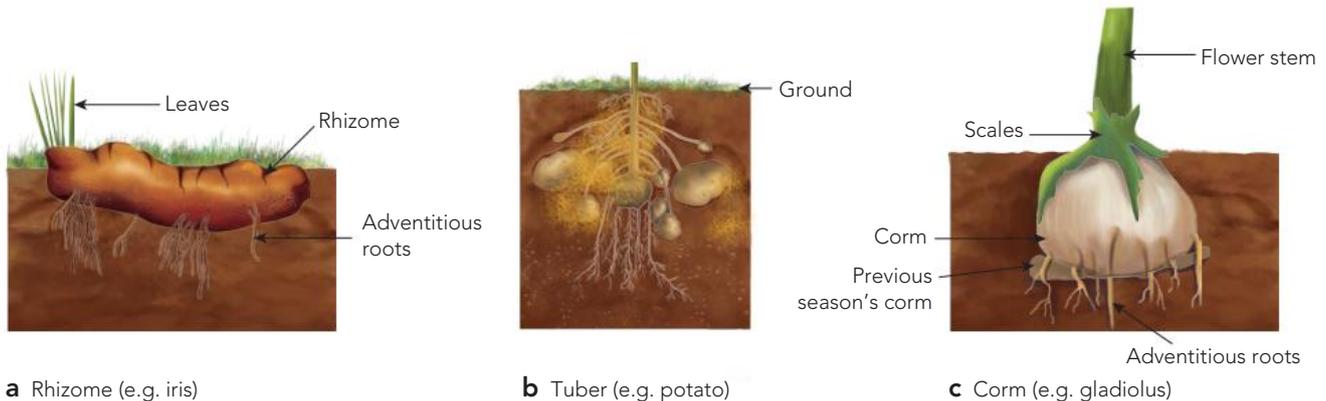


Figure 13.14
Water entry into plants

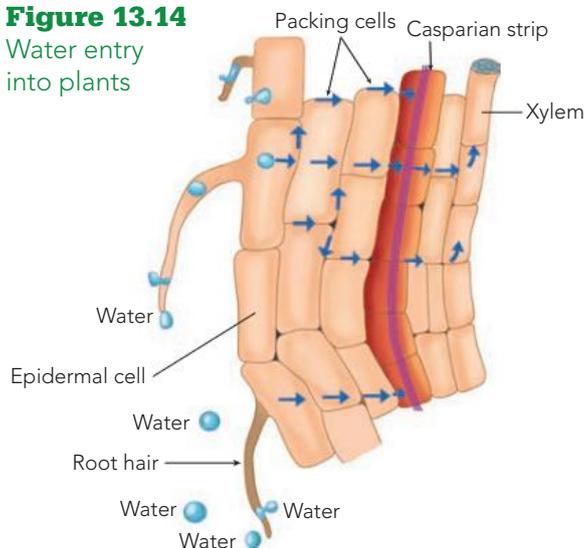


Figure 13.13 Modified stems as roots

Roots are important for the uptake of water and minerals. As shown in Figure 13.14, water enters the plant through root hairs. These are outgrowths of epidermal cells, which form the outer layers of the root. Water entry is a passive process relying on **osmosis**. Once inside the root, water moves through the cells or across the cellulose fibres of the cell walls. The Casparian strip is a thin layer of fatty substance that slows the entry of water into the water transport system of the plant. Mineral ions also enter the plant passively with water. However, most of the plant's mineral needs are supplied by an active process of ion exchange (Fig. 13.15).

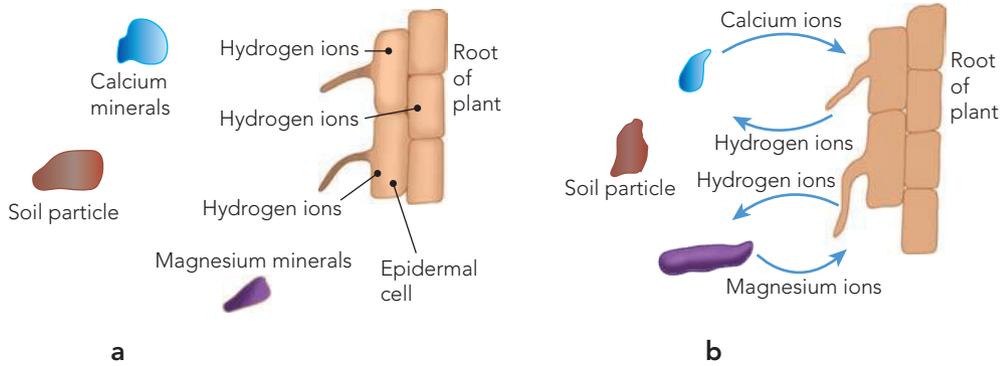


Figure 13.15 Mineral exchange – hydrogen ions are exchanged by the plant for soil minerals.

The stem

The stem has the important functions of holding the leaves and flowers up in the air, transporting materials and storing food. The flowers need to be in the air so that pollination by wind and insects can take place easily. The stem transports water and dissolved minerals from the roots to the leaves. It also transports food material made in the leaves to the roots, flowers and seeds. The food material may also be stored in the stem.

The main components of the stem transport system are the **xylem** and the **phloem** vessels. The xylem vessels transport water from the roots throughout the plant. Water enters this system at a rate dependent on the rate of water loss from the stomata of the leaves. Loss of water from the stomata creates suction, known as transpiration pull, which draws water in fine capillary streams along the hollow, dead xylem vessels, as shown in Figure 13.16.

The phloem tissue is living and controls the flow of dissolved sugars (mainly sucrose) from plant leaves, germinating cotyledons and endosperm to all areas of the plant, such as roots, growing points and developing fruits. The process of food movement is termed **translocation**. Figure 13.17 illustrates the various parts of the phloem.

- 17** Explain how water moves through the plant.
- 18** Explain how sugars move through the plant.

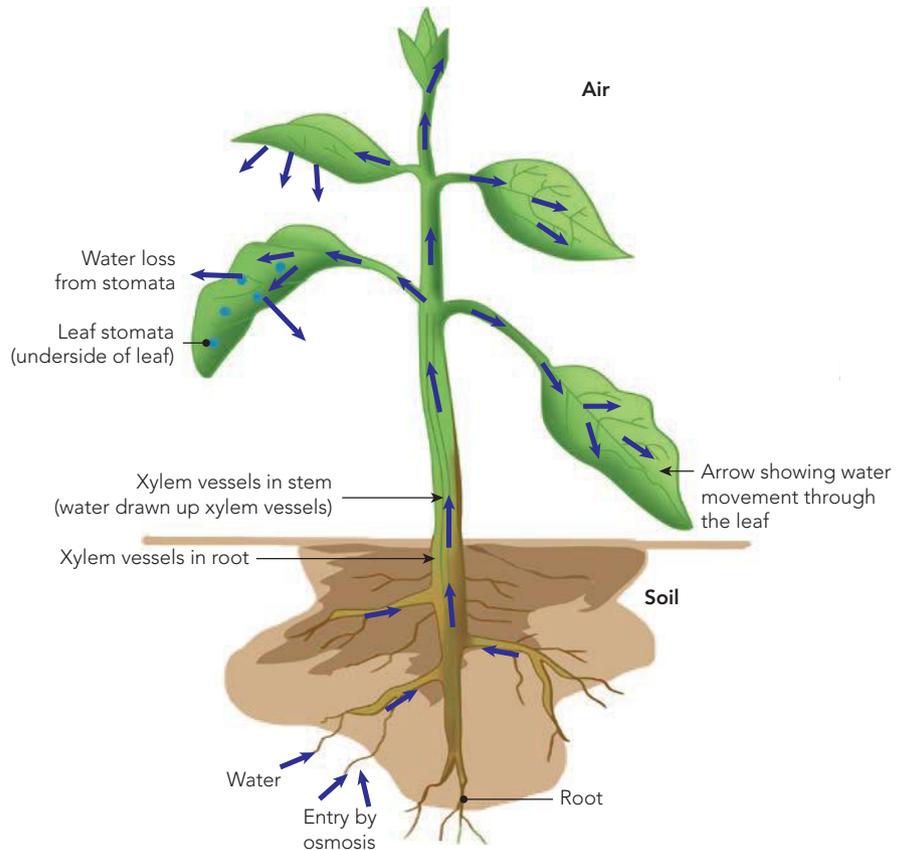


Figure 13.16 Water movement in plants

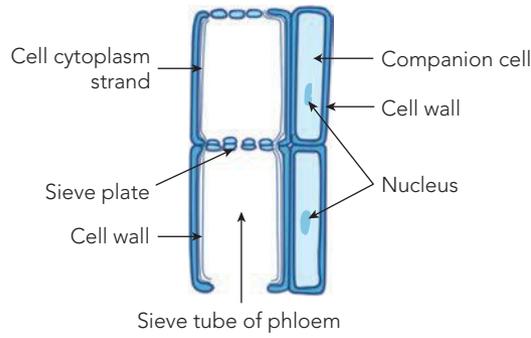


Figure 13.17 Phloem cells

19 Draw and label phloem vessels from Figure 13.17.

Total plant structure

The main components of a plant are shown in Figure 13.18, which reflects the structures discussed in this chapter.

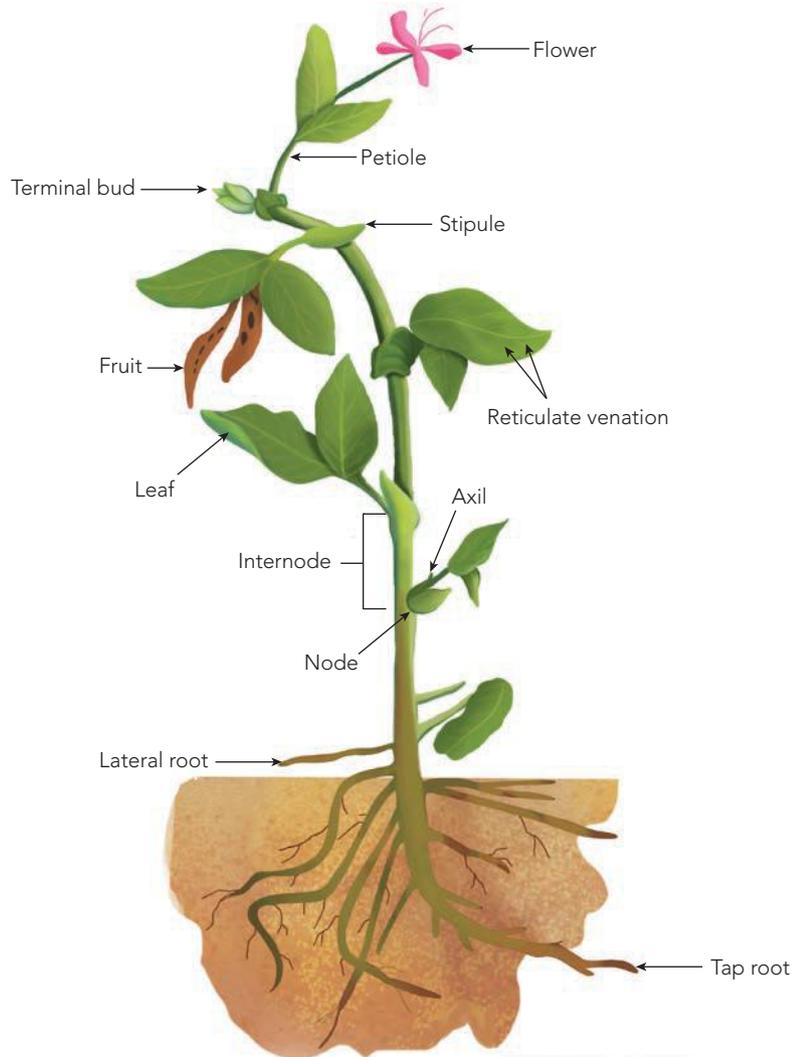


Figure 13.18 Parts of a plant

Chapter review

Things to do

- 1 Find examples of a grass plant and a legume plant and identify the roots, stems, leaves and flowers. Construct a table to compare dicot (legume example) and monocot (grass example) leaf venation, root systems and number of cotyledons on the seed.
- 2 Plant some seeds of a grass (e.g. wheat) and a legume (e.g. beans) and watch them grow. Try to identify the vegetative (before flowering) and reproductive (flowering and after) phases of growth.
- 3 Cut open a bean seed and a wheat seed. This will be easier if you soak the seeds for 24 hours in water first. Draw and label what you find.
- 4 Place some green leaves into a mortar, add a solvent such as methylated spirits and a little sand. Grind, filter and keep the liquid part. Stand strips of filter paper in the solution for 20–40 minutes and then observe the various colour bands. What has occurred?

Things to find out

- 1 Find out in which areas of the world the following crop and pasture plants originated: wheat, oats, barley, rice, potato, sunflower, peas, soybeans, sugarcane, beets, sorghum, cowpeas, field beans, kikuyu grass, paspalum, rye grass, subterranean clover, lucerne, white clover, red clover, triticale.
- 2 What are cover crops, green manure crops, catch crops, silage crops and soiling crops?

Extension activities

- 1 Use the [Virtual plant cell](#) website to examine a virtual plant cell. Draw a diagram of a plant cell on the basis of your observations.
- 2 Organise a class performance of the radio play *A Thorough Investigation Visits A Plant Pty Ltd* (see student worksheet). Have some members of the class take each of the parts and other members do the sound effects.
- 3 Go to the [Plants and increased levels of carbon dioxide](#) website. Develop a concept map of the key ideas.

connect

Virtual plant cell

connect

Plants and increased levels of carbon dioxide

Test yourself

- 1 Copy out the following sentences, and use the correct words for the plant that you have collected.
 - a The type of veins in the leaves of this plant is *reticulate (net)/parallel*.
 - b The type of root system this plant has is *tap/fibrous*.
 - c This plant belongs to the *monocot/dicot* group of plants.
- 2 You will need a plant for this task. Dig one up and wash the soil away from the roots. Make labels on separate pieces of paper for the parts of the plant listed below. Use sticky tape to place the labels on the plant in the correct positions.
Flower, Stem, Leaf, Node, Terminal bud, Fruit, Root, Internode

CHAPTER 14

REPRODUCTION IN PLANTS

Words to know

angiosperm flowering plant with seeds enclosed in an ovary

asexual reproduction reproduction without male and female gametes (reproductive cells); also known as vegetative reproduction

budding a form of grafting, where a dormant bud is transferred from the scion into the bark of the rootstock of another related plant type; the bud forms a shoot if the tissues of the scion and the rootstock grow together

fruit the swollen ovary wall that surrounds some seeds

grafting the union of tissue of two different plants of the same species

ovule the structure in a flower that develops into a seed after fertilisation

pollen the microscopic hard capsule that contains the male reproductive cell

rootstock that part of a graft that contains the lower stem and root system of a plant

scion the part of a graft that contains the upper stem and leaf section of a plant

sexual reproduction fusion of male and female gametes (pollen and ovule) to form a seed containing an embryo

Introduction

Flowering plants or **angiosperms** are the most successful members of the plant kingdom. Their ability to crosspollinate and efficiently produce and disperse seeds has certainly assisted in their success.

Flowering plants supply over 75 per cent of the world's food.

Flowers contain the reproductive organs of flowering plants, but they do not always contain both male and female parts. Some plants, such as maize, have separate flowering parts. The male part, containing the filaments and anthers, is the tassel, and the female part is contained in the cob that forms further down the stem. The parts mature at different times to encourage crosspollination. Plants such as clover or daisies have a compound flower made up of many small flowers forming a flower head or inflorescence. Some plants, such as cucurbits, have separate male and female flowers in the same plant; other plant types, such as the kiwi fruit, have entirely separate male and female plants.

Sexual reproduction

Pollen or male sex cells develop in the anther, which ripens and turns inside out, releasing the pollen. The process of release and movement of pollen to the stigma is termed pollination. If pollen falls to the stigma of the flower that released it, then self-pollination has occurred. The positioning of the anthers by the filaments often determines whether this occurs. In crosspollination, the pollen from one plant falls onto the stigma of another plant. In both cases, pollination represents **sexual reproduction** (Fig. 13.4, on page 155, shows the structure of a typical flower).

Pollen grains have many different shapes and they often cause allergies. Plants are able to identify their own types of pollen. Figure 14.1 shows some common shapes of pollen grain as they appear under a scanning electron microscope.

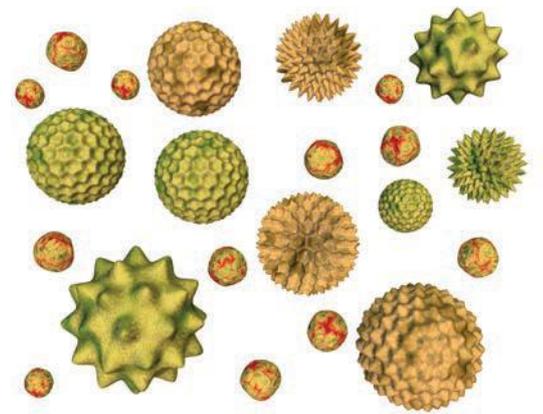
Once on the stigma the pollen grain grows a tube down the style. Grains identified as not belonging to that plant type are soon killed by chemicals produced by the plant; successful pollen grains continue to grow the tube down into the ovary. One nucleus from the pollen fuses with the **ovule** in a process called fertilisation, which starts the development of the seed. Each ovule needs to be fertilised by a separate pollen tube.

The fertilisation process also involves further fusion of pollen nuclei to form seed endosperm. Once formed, the embryo is surrounded by other seed structures and a seed coat, or testa. The ovary wall may also fuse with the seed coat or become fleshy itself and surround the seeds completely. Any seed surrounded by the ovary wall is considered a **fruit**. Technically, wheat grains are fruit. Other common types of fleshy fruit are illustrated in Figure 14.2.

connect

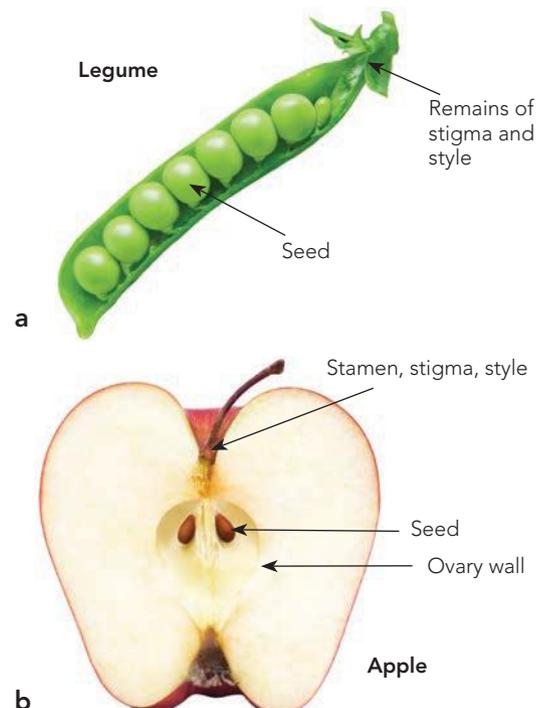
Angiosperms

The many types of angiosperms and other plant types in Australia



Shutterstock/Knorre

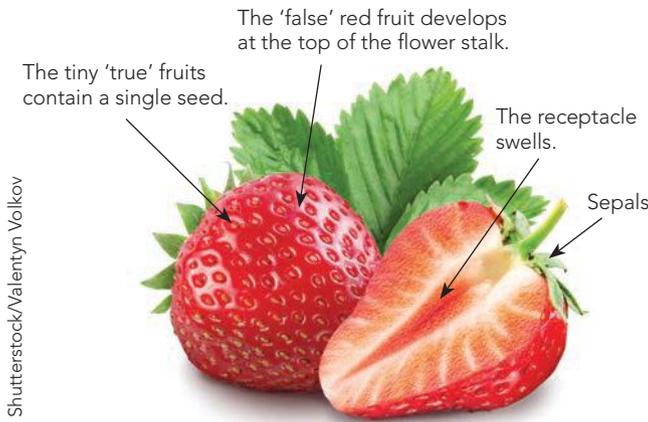
Figure 14.1 Pollen grains under a scanning electron microscope



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Shutterstock/Maks Narodenko

Figure 14.2 Types of fruit **a** legume **b** apple



Shutterstock/Valentyn Volkov

Figure 14.3 The strawberry has both false and true fruits.

Some plants form false fruits; this occurs when the ovary walls remain unchanged and another part of the flower swells. The strawberry is a typical form of this plant, in which the receptacle swells. The pale dots seen on the outside of the strawberry are the true fruits.

Fruits help to distribute seed away from the parent plant, often through the action of birds.

Asexual or vegetative reproduction

Many plants are capable of reproduction without forming seeds.

The parent plant reproduces from outgrowths to form new plants genetically identical to the parent plant. For example, plants such as strawberries produce aerial runners or stolons. Where these touch the ground, they form roots and new plants. Modified stems such as rhizomes, bulbs and corms are also typical structures designed for **asexual reproduction**. Figure 14.4 shows these reproductive forms.

Many plants, such as fruit trees, are vegetatively propagated because most do not grow true to type if grown from seed. For example, a commercial fruit tree consists of two parts, joined by **grafting**, because trees grown from seed take longer to bear fruit and the quality of the fruit is often inferior. Other forms of vegetative propagation include taking cuttings, layering and **budding**.

- 1 What plant structure contains the reproductive organs?
- 2 Define 'pollen'.
- 3 Describe the process of pollination.
- 4 Describe the process of fertilisation.
- 5 Outline the difference between sexual and asexual reproduction.
- 6 Redraw Figure 14.4 to show the various methods of asexual reproduction in plants.
- 7 Describe how fruit trees are propagated commercially.

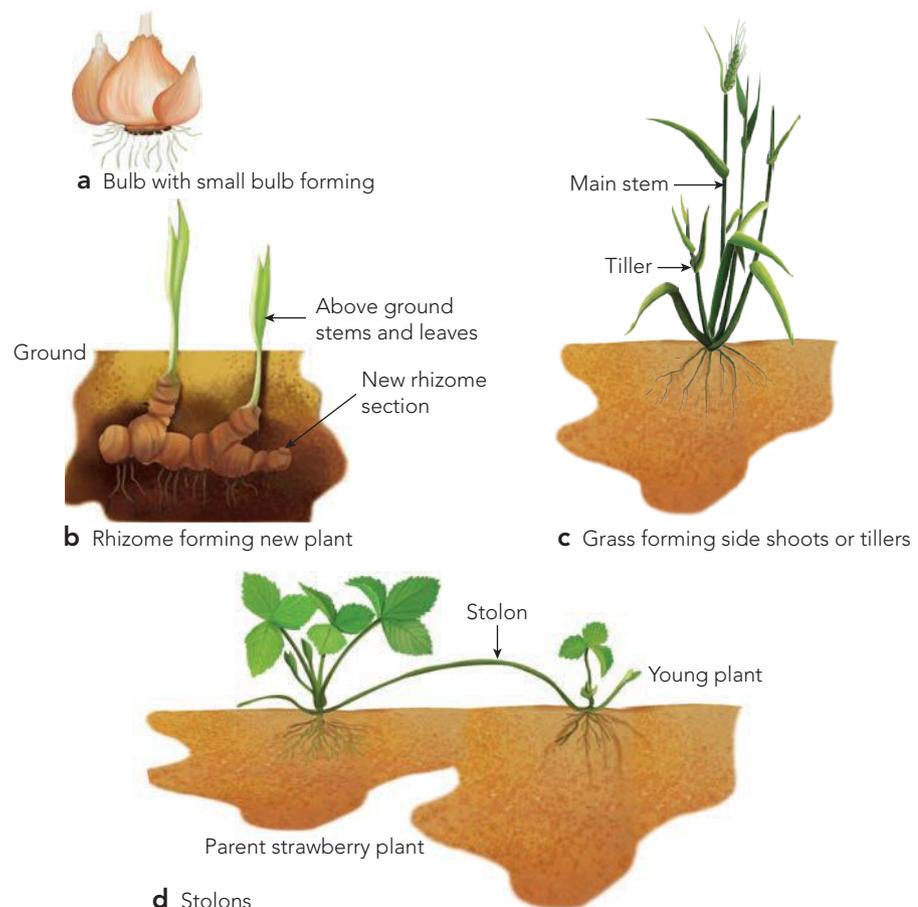


Figure 14.4 Forms of asexual reproduction

Grafting

Grafting is a propagation technique. It is the union of tissue of two different plants of the same species, and involves a method of connecting or joining two pieces of living plant sections together, allowing them to unite and continue to grow as one plant:

- 1 the **rootstock** – the root system plus the lower part of the trunk
- 2 the **scion** – the stem and upper area of a chosen variety.

Grafting is carried out in late winter or early spring, at or soon after bud burst. The scion and rootstock sections should be about the same thickness, so that they fit snugly together, and the union is bound with grafting tape. Figure 14.5 shows different methods of grafting. Matching cambium layers is important. In dicotyledons, a cambium develops between the xylem and phloem vessels. New xylem and phloem are produced from this layer.

Grafting is advantageous because it provides disease resistance, tolerance to poor drainage and better flower colour or type of fruit by combining the desirable characteristics of the two plants. Many citrus varieties are grafted onto rough lemon rootstock, which provides resistance to fungal root diseases.

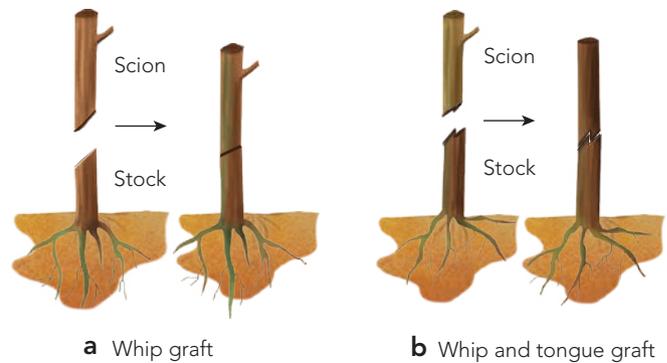


Figure 14.5 Types of graft

- 8 Explain and describe how to graft a plant.

Cuttings

Stem cuttings are of three types: softwood cuttings, taken when the wood is soft in spring and early summer; medium types (semi-hardwood), taken during summer and early autumn; and hardwood cuttings, taken in autumn and winter. Figure 14.6 shows how to propagate some plants using stem cuttings.

Where possible cuttings are taken from established plants using either tip shoots or, in the case of fruit trees, dormant 1-year-old shoots, cut to lengths of 20–40 cm. The base end is coated with rooting powder and often fungicide. The cutting is planted into a coarse medium, which is packed down around the shoot. The aim is to produce a shoot and a strong root system. Quinces, pears, figs, grape vines, kiwi fruit, some plums and some cherries can be propagated by cuttings.

Leaf cuttings are possible for certain plants, especially indoor plants such as begonias or African violets. The main veins are cut and the leaf laid topside uppermost on coarse material. Roots develop from the cut areas.

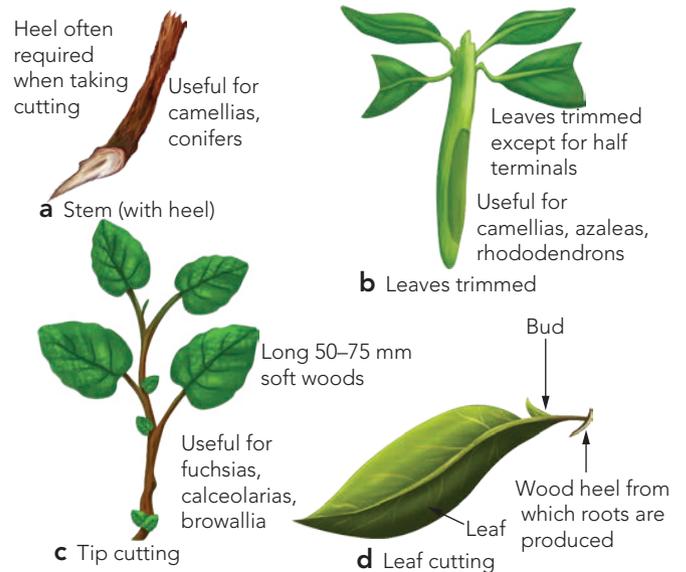


Figure 14.6 Forms of cuttings

- 9 Describe how to make successful stem and leaf cuttings.

Layering

Layering involves bending a shoot parallel to the soil and making a small cut on the lower side of the stem, as shown in Figure 14.7. The stem is then pegged down and soil is mounded over the stem to bury it. This process encourages root development on the stem. Once roots are developed the stem is detached from the parent plant

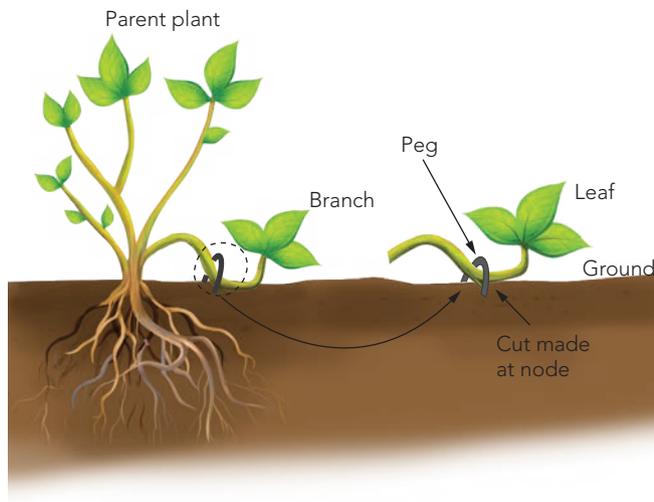


Figure 14.7 Layering



Figure 14.8 Aerial layering

10 Explain how to layer a plant.

and forms a new plant. This is a useful method for propagating apples, plums and cherries. It is also a preferred method for propagating slow growing shrubs and trees such as magnolias and azaleas.

Aerial layering is done as shown in Figure 14.8. It is a useful method for striking plants that prove difficult to strike from cuttings.

Budding

11 Describe the process of budding.

Budding is a form of grafting allowing for the vegetative propagation of plants. A single bud of one variety of plant is inserted into the wood (or rootstock) of another plant of a different variety or species; for example, cherries are budded onto the stock of the wild sweet cherry.

For deciduous plants, budding is carried out in late summer and for citrus it is done in spring or autumn when the sap is flowing. The time is right for budding if the bark comes away easily from the wood. The two species of plant must be compatible and the bud used should be a leaf bud, not a flower bud.

Figure 14.9 shows how to conduct the operation. A ‘T’ cut is made through the bark in one-year-old wood. The cut should be about 3 cm long and 2 cm wide. The bark is then raised to allow the bud to slide firmly into position and tape applied. Do not fully cover the bud with the tape.

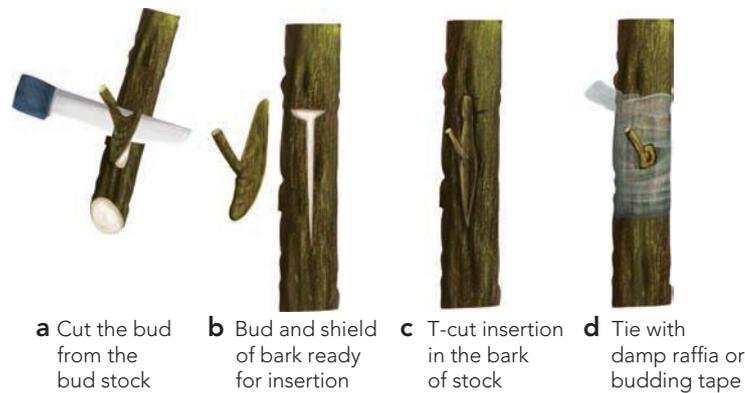


Figure 14.9 Budding

Chapter review

Things to do

- 1** Complete the structure jigsaw in Figure 14.10 to show your understanding of flower structure. Copy the parts of the flower **a** onto a sheet of paper, then cut them out and paste them on **b** the base diagram. Distinguish the male organs from the female organs by using different colours.
- 2** Draw and label the flower structures of the following:
 - a** a garden flower, such as a hibiscus or azalea
 - b** a wheat flower
 - c** a legume flower
 - d** a radish or cabbage flower.
- 3**
 - a** Describe how to make a cutting that can be used for propagation.
 - b** What can be done to cuttings before planting to increase the likelihood of producing a new plant?
 - c** Why do we use cuttings?
 - d** Identify plants (fruit trees) that can be propagated by cuttings.
- 4** Follow the directions in Figure 14.12 to propagate a plant by aerial layering.
- 5** Grow some plants from cuttings as shown in Figure 14.13. February is a good time for camellia cuttings. The best cuttings are the growing ends of the stems, about 10cm long. Cut each close under one of its nodes from a previous year's flowering. Trim the leaves as shown and insert at least half the stem length into the bed. Use rooting powder, which contains plant hormones that promote plant growth, as directed on the container and plant with the bud pointing upward. For best results, leave until spring or for at least 10–12 weeks. You can also take cuttings from azaleas in February but use the current growth. If using rhododendrons, shave one side of the stem at the base.

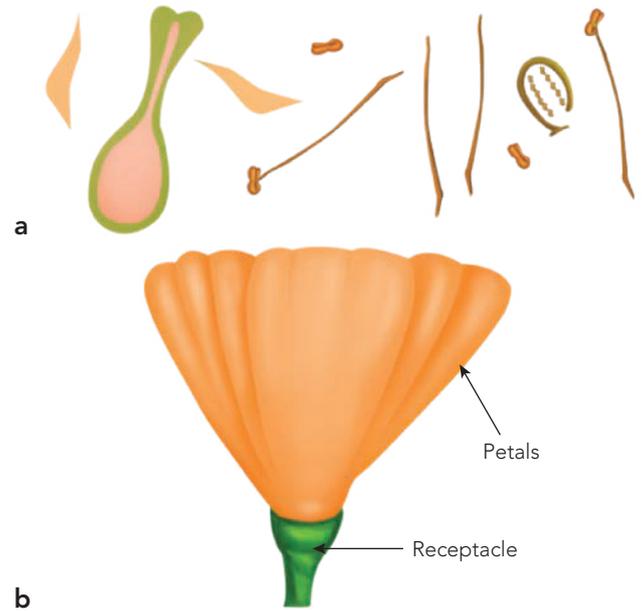


Figure 14.10 Structure jigsaw

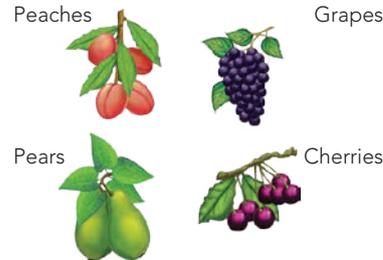


Figure 14.11 Plants that can be propagated by cuttings

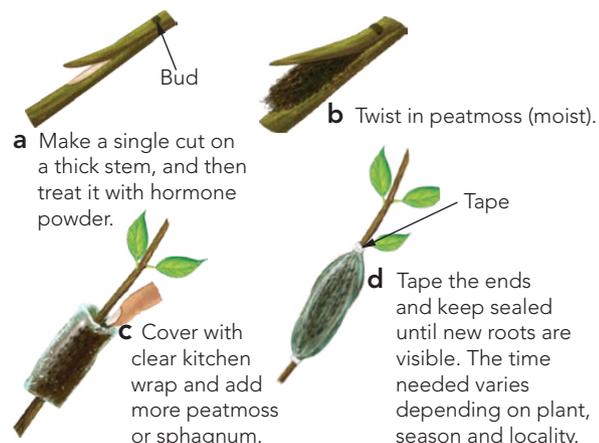


Figure 14.12 Propagating using aerial layering

🔑 Things to find out

- 1 Find out how to press flowers. Collect 10 flowers and press them.
- 2 Find out how to dry flowers to preserve them. Collect five flowers and dry and preserve them.
- 3 Why must strawberries be grown from disease-free stock?
- 4 Describe these methods of grafting.
 - a Whip
 - b Whip and tongue
 - c Cleft



Figure 14.13 Propagating using stem cuttings

+ Extension activities

Use a digital camera to take a photograph of the stem of a fruit tree that has been budded or grafted. Make sure your photograph includes the scion, rootstock and the point of grafting or budding. Load the image onto the computer and label the photograph to show the 'scion', 'rootstock', and the 'point of grafting or budding'.

✓ Test yourself

- 1 Copy this table into your notebook and fill in the blanks.

Propagation technique	Sexual or asexual reproduction?	Description of technique
Sowing seeds		Seed is sown in the soil and, provided sufficient moisture, the right temperature and oxygen is available, the seeds germinate and grow into new plants.
Grafting		
		Cuttings are taken from the shoots or stems of established plants and planted in a coarse medium. Roots develop from the base of the cutting.
Layering		
		A single bud is sliced off the stem of one plant and carefully inserted in a T-shaped cut in the stem of the rootstock plant. The bud is bound in place with plastic tape. The bud develops into the stem of the new plant.

CHAPTER 15

FACTORS INFLUENCING PRODUCTION

Words to know

allelopathy the effect on one plant's growth of another plant by the release of chemicals into the surrounding area

development changes in the composition and proportions of a plant as it ages

growth an irreversible increase in the size of an organism

heterosis increased rates of growth and fertility levels resulting from the production of a hybrid

hormone an organic material, produced in particular areas of the plant, that has specific effects on the plant

hybrid a plant produced by crossing individuals that are genetically different

reproductive phase the part of a plant's life cycle after flowers begin to form

vegetative phase the part of a plant's life cycle in which active growth of stems, leaves and roots occurs

vernalisation the process of exposing some types of plants to a period of cold to induce them to flower

wilt when a plant collapses due to loss of excessive amounts of water

Introduction

Growth irreversibly increases the size of a plant as it ages. The growth curve for a typical plant is shown in Figure 15.1; it is similar to the growth curve for animals. The small dip at germination occurs when a plant uses up food reserves in the seed.

The growth process is distinct from **development**, which refers to the various changes in form that occur as a plant ages and changes from a **vegetative phase** of growth to a **reproductive phase**. For a plant to achieve maximum growth rates and to develop fully, the genetic makeup of the specific plant and environmental factors must interact favourably. Environmental factors include:

- climate
- competition between plants
- the influence of plant pests and diseases
- plant nutritional requirements
- management practices of the producer.

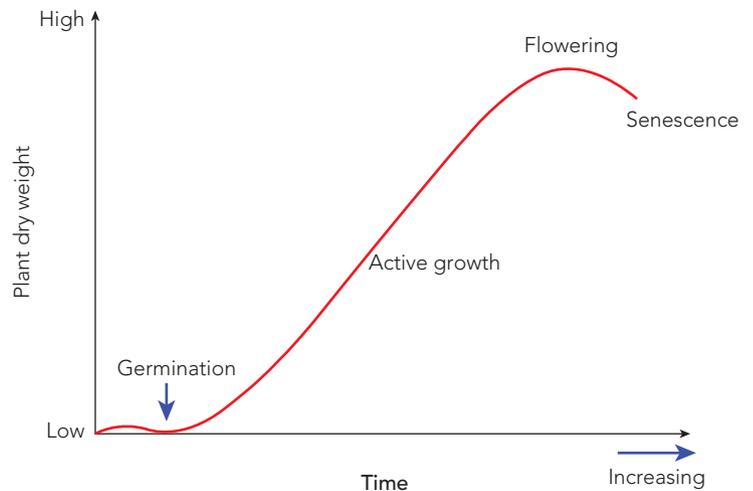


Figure 15.1 Plant growth curve

- 1 Draw the growth curve of a plant.
- 2 What changes occur to a plant as it gets older?
- 3 List the factors that affect the growth and development of a plant.

Plant genetic makeup

The genetic makeup of a plant sets the upper limit to its growth and production. Genetic diversity is important in nature for the survival of a species, but it often leads to unpredictable results in agriculture. Farmers need to have a good idea of the ultimate yield and form of a plant. In commercial situations, to avoid the unexpected results of crosspollination, many plants are grown asexually – by budding, grafting, cuttings or tissue culture – as described in Chapter 14. This ensures that the genetic makeup, and hence the form and yield, of a plant will be identical to that of its parent plant.

Traditionally, breeders have improved varieties of plants by using these methods.

- 1 Collecting the seed from outstanding plants and planting it the following year.
- 2 Collecting the seed from superior plants and planting it in rows the following year. Individual plants in these rows are then selected.
- 3 Crossing two varieties to obtain a new variety that combines the features of both parents. This must be practised over several generations to enable true breeding lines to be formed. The new variety is termed a **hybrid**. It is now possible to cross distantly related species, such as wheat and cereal rye. This particular cross resulted in the hybrid called triticale, which offers high yields coupled with disease resistance.
- 4 Producing a hybrid by a different method. In the case of maize, plants are self-pollinated for several generations to produce small, low yielding, true breeding lines. These are then crossed to produce a hybrid.

All hybrids exhibit a phenomenon called **heterosis**, which refers to the higher than normal yields and more uniform yields that are obtained from hybrids. Hybrid seed is expensive and cannot be replanted because the next generation reverts to the inbred parent type – new seed must be purchased each season. As shown in

- 4 Why is the genetic makeup of a plant important?
- 5 Describe the methods traditionally used by plant breeders to produce improved varieties of plants.

Figure 15.2, it is possible to cross two hybrids to produce a double cross hybrid. This method widens the genetic makeup of the resulting plants and ensures they can be grown in a variety of environments.

Resistance to pests and diseases also improves in hybrid plants. Disease control has been made possible by the ability of plant breeders to introduce one gene, or a complex of genes, into the plant. This is done regularly with wheat to overcome the problem of rust.

In this process of hybridisation, it is important that the original ancestors of modern commercial plants are not lost forever through increased competition from newly created, active growing plants. Genetic banks containing seeds from these primitive plants (now often considered as weeds) and seeds from varieties of crop plants that have been superseded are maintained around the world. In many instances diseases have destroyed modern hybrid crops and if nothing was available to replace these plants, people would starve and economies could be ruined. This occurred in Ireland after 1845, when disease destroyed that country's main source of food – potatoes.

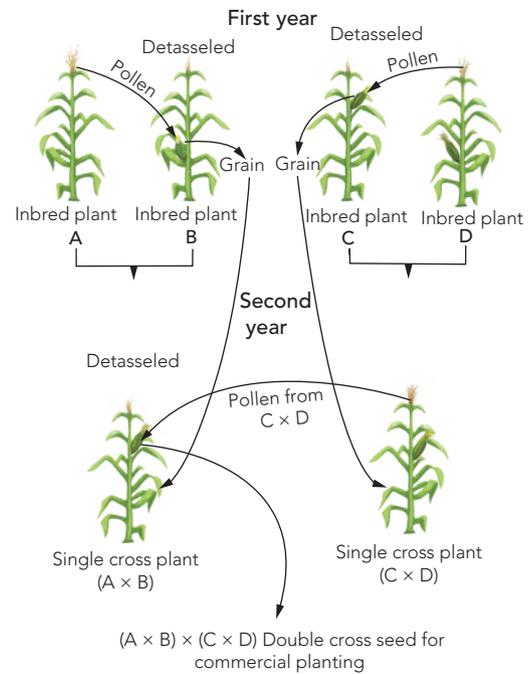


Figure 15.2 Double cross hybrid maize

Genetic engineering

Breeding for disease resistance has traditionally taken a three-pronged approach.

- 1 Vertical resistance.** Breeders use a single gene to develop a plant that has total resistance to the disease. Eventually this plant will fall to a mutant version of the disease and the entire plant variety will have to be replaced with another variety.
- 2 Horizontal resistance.** Breeders select a variety of plant that resists disease by using groups of genes (usually three or more). Plants developed by this method remain resistant to particular diseases for longer periods of time.
- 3 Tolerance.** Breeders develop plant strains that are tolerant of mild-to-reasonable attack by disease-causing organisms such as rust. These varieties of plant continue to yield and the disease-causing organism tends not to change or mutate to a more contagious form.

Genetic engineering involves altering the genetic makeup of a plant to produce a new type of plant or to produce new characteristics in a plant. This is the future direction of plant breeding, provided that adequate safeguards and genetic banks are maintained. Figure 15.3 shows how the process occurs.

By obtaining genes from the close relatives of a plant, yield may be improved or a plant may become resistance to many diseases, chemicals or even insects themselves. Figure 15.4 shows how this is being used in Roundup Ready® cotton.

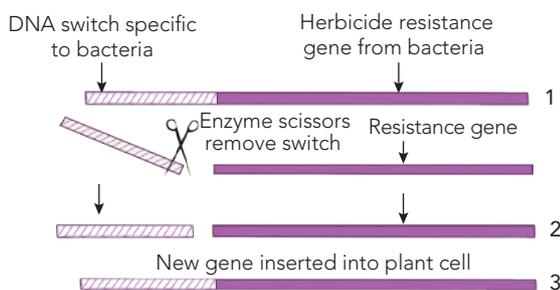


Figure 15.3 Genetic engineering in plants

A farmer sprays a plant with herbicide to kill weeds.

The plant survives the herbicide but non-resistant weeds die.



Figure 15.4 Future directions in plant breeding

- 6** Describe the main methods used to improve the genetic makeup of a plant, in terms of its disease resistance.
- 7** Define 'genetic engineering'.

connect

Humans manipulating genes

Listen to the audio-visual and answer the questions.

connect

Gene technology

Find out more about gene technology.

Tissue culture

Tissue culture is the growth of an entire plant from a culture of cells. The cells are taken from a small section of an adult plant and cultured on a sterile chemical medium, such as agar, with the addition of an array of hormones normally needed by plants for growth. Under controlled conditions a callus grows and, as the hormone levels are changed, new plants are grown. These young plants are now sold from commercial outlets. Sealed in containers, they are ready for planting out under controlled conditions.

Climate

Many aspects of climate can affect the growth of plants. For example, temperature influences the success of germination and the growth rate and flowering of many plants (Table 15.1). Many plants, including winter wheat and bulbs such as hyacinths, need to be exposed to low temperatures as seeds or bulbs in order to flower. This process is termed **vernalisation**.

Plants also need water to:

- maintain shape
- carry out basic processes, such as photosynthesis
- maintain transpiration flow
- be cooled by transpiration
- have material in dissolved form transported around them.

When plants lose too much water, they lose shape and **wilt**. Figure 15.5 shows the effect of water levels on the shape of plant cells.

The ratio of light to dark periods is also an important factor in the development of plants; flowering is often triggered by the length of the dark period or night. Summer plants or long-day plants flower after short periods of dark. Short-day plants flower only after long, uninterrupted dark periods. Some plants, such as tomatoes, seem non-responsive to dark periods.

Table 15.1 Germination requirements

Crop	Optimum germination temperature (°C)
Corn	21–26
Wheat	15–18
Sorghum	21–28

- 8 Explain how temperatures influence plant growth.
- 9 Explain why plants need water.
- 10 Explain how light influences plant growth.

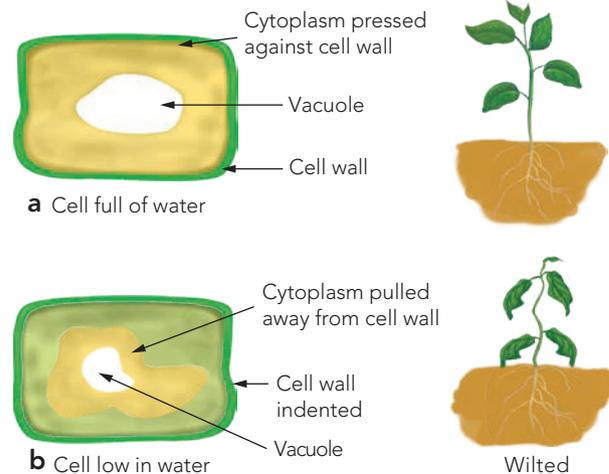


Figure 15.5 Water levels affect the shape of plant cells

Competition between plants

Plants compete with one another for space to obtain soil nutrients, water and sunlight, and to expand without physical damage. Weeds are very competitive – their rapid germination and high initial growth rates mean that they spread rapidly. Weed root systems are efficient and they have effective asexual reproduction

methods. Many weeds also act as hosts for pests and diseases of crop plants and are reservoirs for reinfection of plants from season to season.

Many plants also produce chemicals to limit the growth of surrounding plants. Cabbages and cauliflowers, for instance, have a negative effect on the growth of beans, because of the chemicals they release into the soil around them. This type of active chemical interference is called **allelopathy**.

Plant diseases and pests

Many diseases and pests can limit the growth rate of a plant. Micro-organisms can have quite an effect, even though they cannot be seen by the naked eye. Fungi, such as rust, destroy vital green tissue needed by the plant to photosynthesise. Other types of fungi cause rots, either to the newly germinated plant (e.g. damping off disease) or to developing and mature fruit (e.g. brown rot). Bacteria can multiply in the xylem vessels of plants and cause the plant to wilt and die (e.g. fusarium wilt of carnations). Viral diseases also devastate crops at times; one example is barley yellow dwarf virus, which affects wheat. Figure 15.6 shows some of the effects of plant diseases.

Insects affect plant growth as well. Sap-sucking insects remove food from phloem vessels, usually near the young, actively growing tips of plants. The end result is a wilted and distorted growing region. Sap-sucking insects include aphids, scale, red spider mites and larger insects, such as the bronze orange bug.

Snails and slugs eat plant material, as do caterpillars and beetle grubs. Cutworms remove the stem of young seedlings just above ground level, but they are difficult to detect because they are active only at night. Figure 15.7 shows some examples of insect damage to plants.

- 11** Why are weeds such effective competitors with other plants?
- 12** Define 'allelopathy'.
- 13** List two other ways that a plant can influence the growth of surrounding plants.

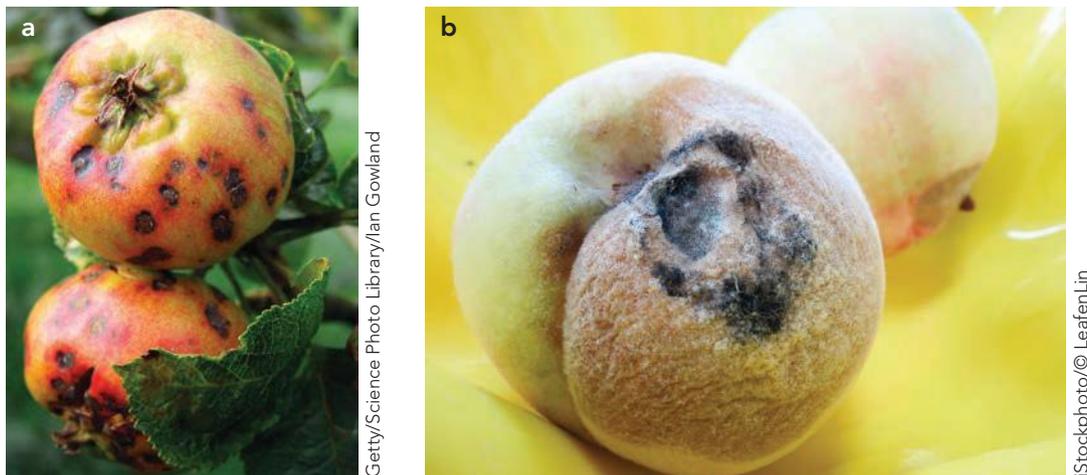


Figure 15.6 Plant diseases **a** apple scab **b** peaches with brown rot

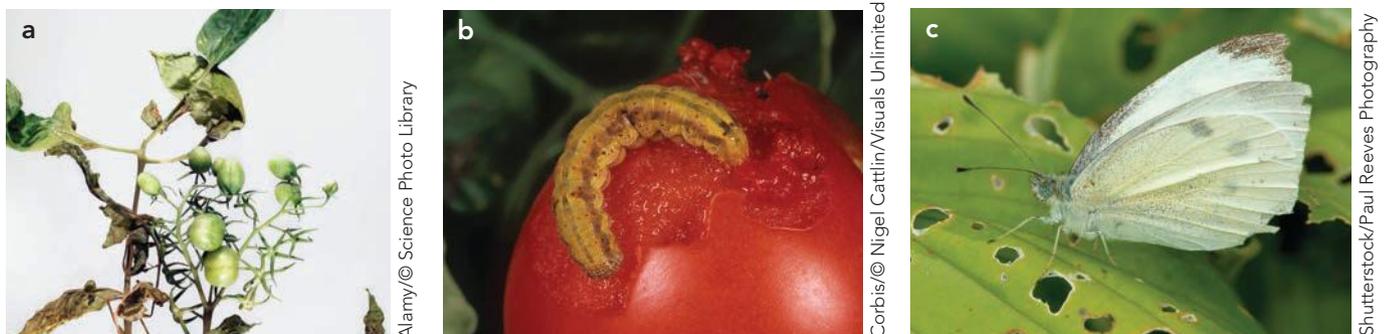


Figure 15.7 Plant pests **a** tomato mite **b** tomato caterpillar **c** cabbage white butterfly

Plant nutrition

Plants require certain nutrients for growth. The air supplies the plant with carbon and oxygen. Hydrogen comes from the water absorbed by the roots. From the soil the plant requires large amounts of the following elements from various mineral sources: phosphorus, sulfur, magnesium, calcium, potassium and nitrogen. These are major elements or macro nutrients because the plant requires so much of them. The plant also requires small amounts of copper, zinc, iron, manganese, boron, molybdenum and chlorine, which are micro nutrients. These are the trace or minor elements, but they are still essential for plant growth. When the soil can no longer supply these elements in the amounts needed by the plant, they must be added to the soil by the use of fertilisers. Fertilisers may be organic in origin, such as blood and bone, compost and decaying mulch, animal manures or green manure crops (crops grown then turned into the soil). These fertilisers break down slowly and have little effect on the pH of the soil. Fertilisers are also manufactured and many are available as mixtures of many elements or as concentrated sources of particular elements. These chemical fertilisers, such as superphosphate, nitrophoska, urea and sulfate of ammonia, are available as crystals or granules and are designed to supply specific minerals (Table 15.2).

Table 15.2 Nutrient content of common fertilisers

Fertiliser	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Superphosphate	0.0	9.0	0.0
Nitrophoska	12.0	5.2	14.1
Sulfate of ammonia	21.0	0.0	0.0

- 14** Distinguish between major and minor elements and list examples of each.
- 15** List three fertilisers that could be used to overcome deficiencies of several nutrients in a soil.
- 16** Identify the factors that should guide farmers in their selection of fertiliser.

The addition of a single mineral nutrient may not overcome a deficiency problem; the deficiency of that mineral may limit the crop's response to others. This exemplifies the limiting factor concept. To overcome this, buy complete and mixed fertilisers. Complete fertilisers are sold commercially by many companies and the label on the bag indicates the nutrients in each, and the form of the nutrient. Mixed fertilisers or high analysis fertilisers are named for their nitrogen (N), phosphorus (P) and potassium (K) content. These fertilisers are often available for specific crops, as you can see in Table 15.3. Table 15.3 shows that the NPK fertiliser for strawberries contains 1 kg nitrogen, 3 kg phosphorus and 1 kg potash (potassium) per 100 kg.

Table 15.3 NPK fertilisers and their use

Fertiliser	Use
5:7:4	Spinach growing
1:3:1	Strawberry growing
8:0:10	Stone fruit growing

Liquid fertilisers are designed for direct spraying onto plant foliage.

Gas fertilisers are injected into soils in irrigation areas.

When buying fertilisers the farmer must consider:

- the nutrients required by the plants
- the nutrients supplied by the fertiliser
- the cost per unit of nutrient (Table 15.4)
- the form of the fertiliser supplied, whether organic or chemical, granulated, bulk blended (a physical mix of different types of fertiliser), liquid or gas.

Table 15.4 demonstrates the cost of fertilisers per bag and per unit. Although urea is the most expensive bag of fertiliser, it is the cheapest in terms of the unit cost of nitrogen.

Table 15.4 Cost of fertiliser

Fertiliser	Nitrogen (%)	Cost (\$/tonne)	Cost (\$/unit of nitrogen)
Sulfate of ammonia	21	792.00	37.71
Nitrophoska	12	1530.00	127.50
Urea	46	1000.00	21.73

Farm management

Planting management

The farmer needs to supply a market with as much quality material as demanded. Excess may be stored or must be marketed irrespective of price unless some alternative use for the product can be found. Agricultural produce often does not keep well once harvested.

The graphs in Figure 15.8 illustrate a common problem for farmers. In Figure 15.8a, the farmer plants more of a particular crop, so production of it increases. The more cabbages planted, the more there are to sell. In Figure 15.8b, the number of plants grown per area of land increases, so the size of the plants, and hence their quality in many instances, declines. Increased competition between the plants for growing space, light, water and minerals from the soil causes the decline. Good farm management is a balance between obtaining maximum possible production and maintaining product quality. In some instances the market may demand small vegetables or fruit; for example, baby sugar carrots or small squash. The farmer must be aware of this before starting production.

Soil management

Where soil pH is a problem and plants are unable to grow because of this or related problems of mineral availability, the farmer may need to use lime to bring an acid soil towards a neutral system. If the soil structure is poor and water and aeration suffer, then the farmer may need to use a chemical rich in calcium, such as gypsum, to improve the structure of the soil.

Pruning management

Pruning is a management technique to remove excess growth of trees and shrubs to increase production and promote new growth, to make picking fruit and spraying trees easier, and to remove dead and diseased material. Figure 15.9 shows some of the equipment used for pruning plants. Before pruning starts the farmer needs

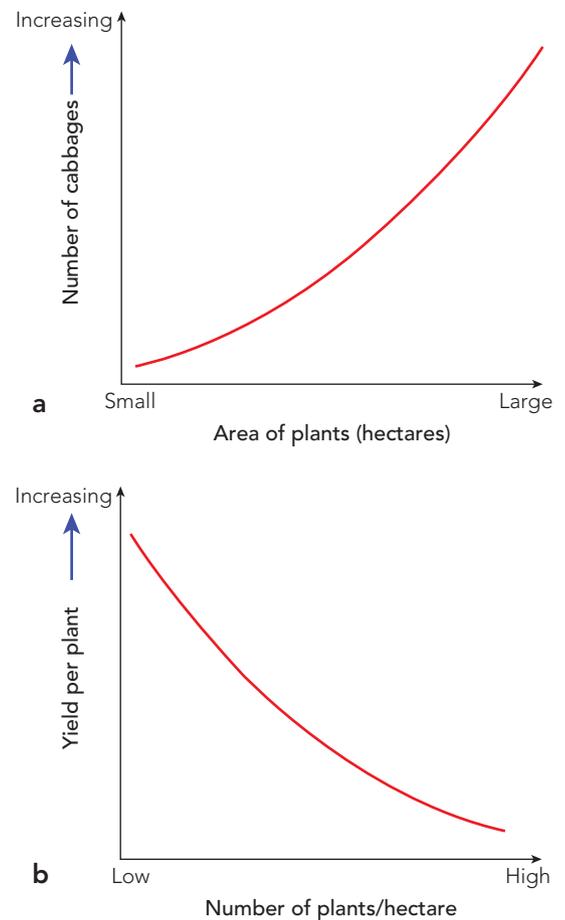


Figure 15.8 Plant density and yield **a** yield per paddock and **b** yield per plant

Shutterstock/Simon Krzic



Fine-toothed saw

Shutterstock/Vadym Zaitsev



Bow saw



Secateurs

Shutterstock/Opas Chotiphantawanon

Shutterstock/ajt



Lever-action lopper

Figure 15.9 Pruning equipment

to know what wood bears the new season's fruit, and where to place the cut to allow buds to develop. Figure 15.10 shows a plant before and after pruning.

In intensive plant growing special chemicals called plant **hormones** may be used. These are chemicals found in living organisms that affect basic processes associated with growth and development. Table 15.5 lists some of the more common hormones and their uses.

Farmers, by creating ideal environments that meet the plants' water, light and temperature needs and that are free from pests and diseases, assist plants to reach their full potential.

17 Examine Figure 15.10 and identify two differences between the plants. Explain what was removed by pruning to achieve those changes.

- 18** Explain how farmers can influence plant production by:
- a** selection of plant varieties.
 - b** varying planting density.
 - c** pruning plants.
 - d** selective use of hormone sprays.

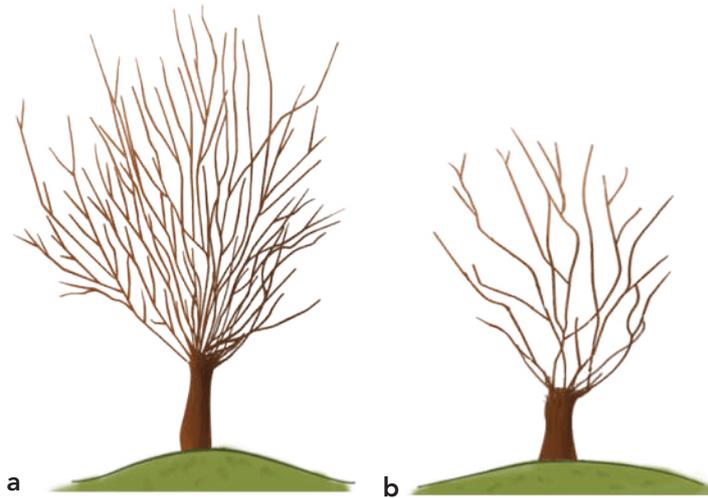


Figure 15.10 Pruning tips: **a** before pruning and **b** after pruning

Table 15.5 Plant hormones

Hormone	Effect	Use
Auxin	Cell elongation; bud and fruit development; plant height and form	Weedicides; flower preservative
Kinin	Active cell division; improvement in effect of auxins	Flower preservative
Gibberellin	Rapid cell elongation; promotion of flowering; breaking of seed dormancy	Growth and maturation
Absciscic acid	Fruit removal	Harvesting
Ethylene	Fruit ripening	Cold store ripening

Chapter review

Things to do

- 1 Select six plots of known area (e.g. 1 m × 1 m). On three of these plots sow the seed of a root crop, such as radish, at the recommended rate. On the other three plots, sow at 10 times the recommended rate. Observe the growth of the crops. Make sure that each plot receives the same amount of fertiliser, water and labour. Using a sample of 10 plants per plot, record the following after 1, 2 and 5 weeks:
 - a time taken for the seeds to germinate
 - b number of leaves per plant
 - c leaf size per plant
 - d radish size
 - e radish weight.
- 2 Selecting three plots of known size, plant beans by themselves (plot 1), cabbages by themselves (plot 2) and a mixture of beans and cabbages planted in alternating rows (plot 3). Record the following, using a sample of 10 plants per plot:
 - a time taken for the seeds to germinate
 - b plant height after 2 and 6 weeks
 - c plant weight after 2 and 6 weeks
 - d final production from each plot (the weights of the various harvests).
- 3
 - a Plot the information in Table 15.6 on a graph.
 - b Which crops grow in summer?
 - c Which crops grow in winter?

Table 15.6 Germination requirements

Crop	Minimum temperature range (°C)	Optimum temperature range (°C)
Corn	8.9–10.0	21.1–26.7
Soybeans	10.0–12.2	18.3–23.9
Wheat	1.1 – 2.2	15.0–18.3
Oats	1.1 – 2.2	15.0–20.0
Sorghum	8.9–10.0	21.1–26.7

- 4 Obtain the following fertilisers: blood and bone, ammonium sulfate, superphosphate, lime, and urea. Construct a table in your notebook to record your results, using the following headings:
Fertiliser, Description, Nutrients supplied, Solubility, Temperature of solution, pH
 - a Describe the appearance of each fertiliser and list the nutrients supplied.
 - b Put a small amount of one fertiliser in a clean test tube and add water. Determine whether the fertiliser dissolves (is soluble) in water.
 - c Use a thermometer to record the temperature of the solution. Does the temperature change over 3 minutes?

- d Measure the pH of the solution using a universal indicator.
- e Repeat steps **b**, **c** and **d** for each fertiliser.

Things to find out

- 1 List six common weeds found in your local area. Draw each of them. Describe how each weed influences crop or animal production.
- 2
 - a What types of hormone sprays have been used on plants in your district?
 - b Describe the action of three of these sprays.
 - c What use may be made of hormone sprays in the future?
- 3 Describe some modern trends in plant breeding.
- 4 For one cereal plant and one legume plant:
 - a draw a diagram of the life cycle of the plant. Show the stages the plant moves through from germination to seed production and death.
 - b identify the features of the vegetative phase
 - c identify the features of the reproductive phase.
- 5 Watch the video on the [GM bananas](#) website. Summarise the similarities and differences between crossbreeding in plants with genetic engineering.

connect

GM bananas

connect

Tissue culture, cloning and seedbanks

connect

GM tomato

connect

Native plant seed bank

+ Extension activities

- 1 Outline the main reasons for cloning plants in production systems
- 2 Use the [Tissue culture, cloning and seedbanks](#) website to find a more precise description of tissue culture. Tissue culture may also be referred to as 'micropropagation'.
Micropropagation is an important alternative to more conventional methods of plant propagation. Plants are produced from very small plant parts (e.g. buds, nodes, leaf segments, root segments), grown aseptically (free from any micro-organism) in a container where the environment and nutrition can be controlled. The resultant plants are genetically identical to the parent plants.
- 3 Discuss critically a list of features that you would like to see developed in different food crops. Watch the video on the [GM tomato](#) website to gain some ideas.
- 4 Based on information contained at the [Native plant seed bank](#) website, critically analyse the role of seed banks in agriculture.

✓ Test yourself

- 1 List the factors that make up the environment of a plant. Discuss how each factor can limit plant production.
- 2 Explain your understanding of the statement 'plant genetic makeup sets the upper limit to production'.
- 3 List the methods plant breeders traditionally use to improve plant genetic makeup.
- 4 Outline the management techniques a carnation grower could employ to improve plant production.
- 5 Discuss the future impact of genetic engineering on plant production systems.

CHAPTER 16

POTATOES

Words to know

axil where the leaf joins the stem

broadcasting a method of applying fertiliser by spreading it over the surface of the soil

crisps thin slices of potato that have been fried in oil until they are crisp (salt and other flavourings are usually added to enhance taste)

early tuber bulking period in tuber development when growth in size is rapid

eye a bud on the tuber

French fries potato chips; long thin pieces of potato that are deep fried or pressure cooked in oil and served hot (a very common fast food)

inter-row cultivation cultivation with machines between the rows of a crop to kill weeds

root zone the soil from the surface to the depth of penetration of the deepest roots of a crop

seed potato tubers or pieces of tubers with eyes that are planted to grow the new crop

set a seed potato

staple food crop a crop that people eat almost every day and that makes up a major part of their diet

stolon an underground stem

tuber swollen underground stem where the potato stores starch

tuber set period of growth when the potato plant starts to initiate and develop tubers

Introduction

Potatoes originated in the Andean region of South America and were first introduced to Europe by Spanish explorers in 1535. In Europe, they became very important as a **staple food crop**. When the Irish potato crop failed in the 1840s because of disease (known as the Irish Potato Famine or Great Famine), the great hardship resulting was a major cause of Irish migration to North America and Australia.

Today the potato is still an important staple food crop and is found in the diet of most Australians. However, there has been a shift in the way it is consumed. Traditional methods of preparation, such as baking and boiling, are being replaced by some form of processing into specific products, such as **French fries** and **crisps**.

In Australia potatoes are grown in all states, generally in cooler regions, as shown in Figure 16.1, with South Australia, Victoria and Tasmania yielding more than 75 per cent. In New South Wales, potatoes are grown in tableland areas of Dorrigo, Comboyne, Robertson, Ebor, Guyra, Orange, Millthorpe, Oberon, Crookwell, Taralga and Batlow, coastal valleys of Grafton, Kempsey, Maitland and Windsor and irrigation areas of the Riverina including Finley and Coleambally.

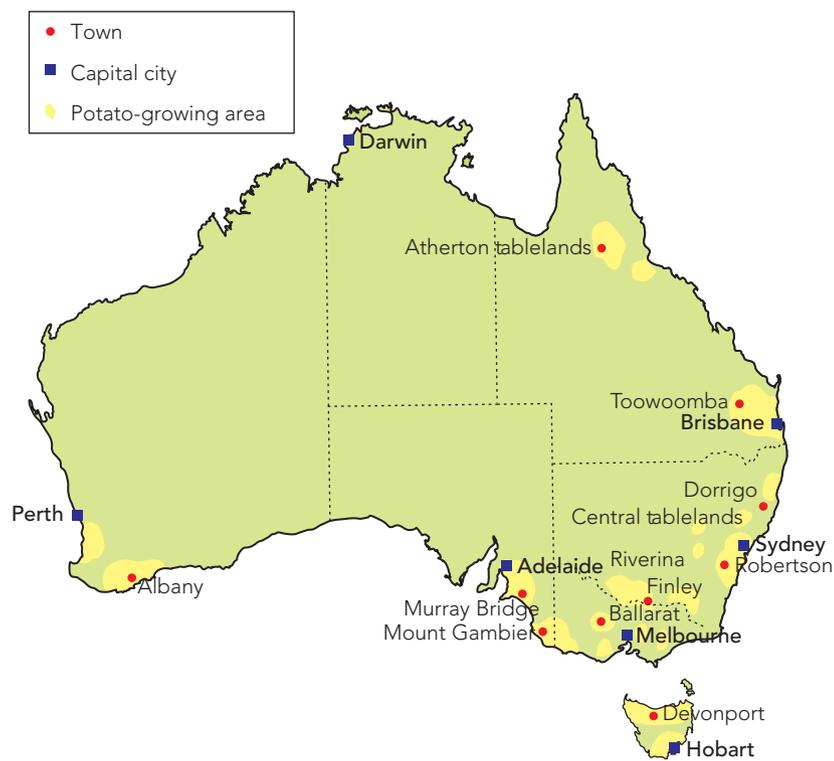


Figure 16.1
Potato-growing areas
in Australia



Shutterstock/Jill Battaglia

Figure 16.2 Fresh potatoes for sale in
a fruit shop

Products from potatoes

The four primary markets for potatoes are determined by their major end-uses by consumers: fresh potatoes, crisps, French fries and seed potatoes.

- Fresh market.** This market requires young **tubers** with bright-looking skin after washing. Their flesh is either white or yellow. The main varieties for the fresh market include the white-skinned Coliban and Sebago, and the red-skinned Pontiac and Desiree. A range of other varieties are produced, with new varieties being tested. Specialty varieties include Kipfler and Pink Fir Apple. Market potential exists for certain gourmet varieties.

- 2 **Crisp processing.** Companies that produce crisps buy uniform, round, white-fleshed tubers, with a high percentage of solids and a very low concentration of reducing sugars. Tubers meeting these specifications produce crisps that are light in colour and appeal to the consumer. Atlantic is the most popular variety used. Research is being conducted to find other varieties suitable for processing into crisps.
- 3 **French-fry processing.** Relatively long tubers with white or cream flesh, a high percentage of solids and low levels of reducing sugars are preferred for French fries. The French fries produced remain light in colour to appeal to the consumer (high levels of reducing sugar result in dark-coloured fries). Shepody is the most popular variety, but Russet Burbank and Kennebec are also used. Research is being conducted to find other varieties suitable for processing into French fries.
- 4 **Seed potatoes.** Seed potatoes are grown under state seed certification schemes and include all varieties.



Shutterstock/bitt24

Figure 16.3 Potato crisps



Shutterstock/ilolab

Figure 16.4 French fries

How the potato plant grows

Unlike most other field crops such as wheat and cotton, the potato plant is not grown from seed. Potatoes are propagated asexually from tubers. Tubers are planted in the soil just as seeds are, and are called **seed potatoes** or **sets**. They are swollen underground stems and are genetically identical to the parent plant. They have buds and leaf scars known as **eyes**. The buds produce stems that make their way to the surface of the soil and continue growing, producing leaves.

A fibrous root system grows from the underground parts of the stem, extending sideways up to 60 cm and to a depth of 30 cm. Approximately 10 days after the stems emerge from the ground, the buds on the underground parts of the stems start to grow, forming underground stems called **stolons**. These grow horizontally in the soil and the ends of the stolons begin to swell with starch produced by photosynthesis in the leaves to form tubers.

The storage of starch continues until the above-ground parts of the plant die off or are killed by the farmer. The tubers can then be harvested by being dug up. Figure 16.5 shows a potato plant approaching maturity. The total growing season for a potato is approximately 18 weeks.

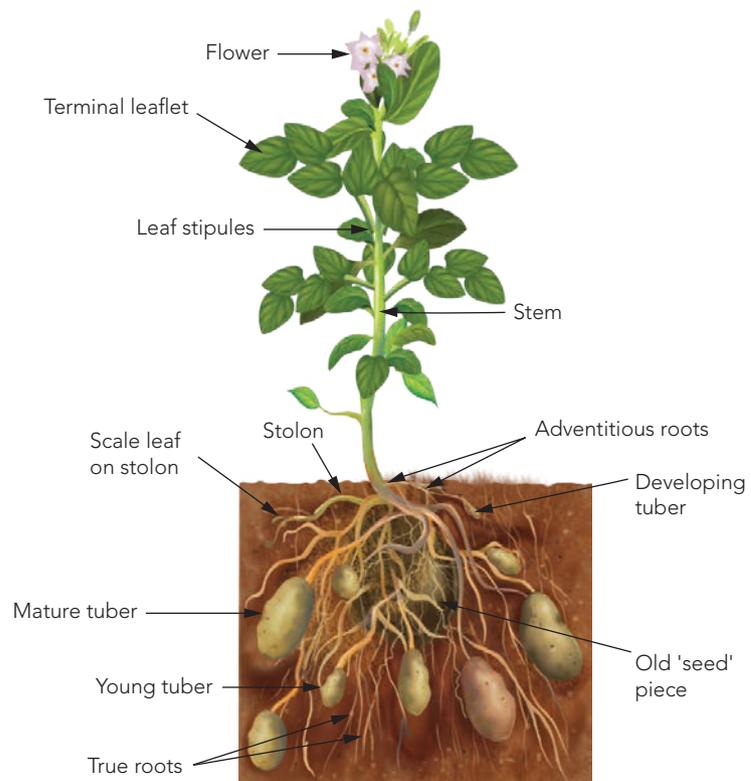


Figure 16.5 A potato plant approaching maturity

- 1 List the four primary markets for potatoes and describe the kind of tubers each prefers.

- 2 To obtain an autumn crop of potatoes, when would you plant, which would you harvest, and where should such a crop be grown?

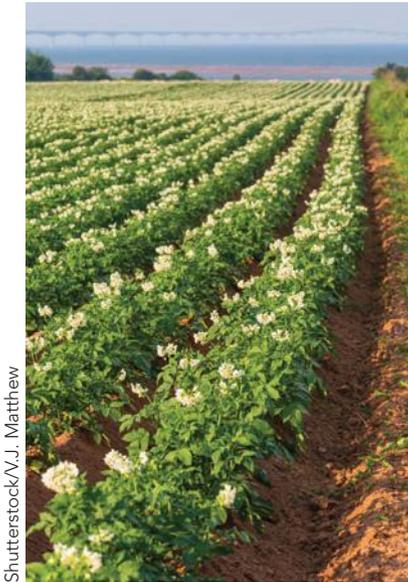
The production cycle

The potato likes cool climates – the best yields are obtained when the temperature range is 15–18°C. However, the crop is only slightly resistant to frost and it is these factors that determine when a crop can be grown in a particular area (Fig. 16.6).

Growing crops in New South Wales

Four main crops are grown in New South Wales to coincide with temperatures favourable to the potato plant.

- 1 *Early crop.* The early crop is planted from June to August and harvested from October to January. It is grown in the coastal valleys and the Riverina irrigation areas.
- 2 *Mid-season crop.* The mid-season crop is planted in August and September and harvested from January to April. It is grown around Dorrigo, Comboyne and Robertson.
- 3 *Late or main crop.* The late crop is planted from October to December and harvested from March to September. It is grown in the tableland areas.
- 4 *Autumn crop.* The autumn crop is planted in February and March and harvested from June to September. It is grown in the coastal valleys.



Shutterstock/V.J. Matthew

Figure 16.6 A potato crop

- 3 Describe two different methods of preparing the land to plant a potato crop.

Preparing the soil

The soil must be cultivated to bury all the existing plant material so that it will rot down before potatoes are planted. Where the crop will not be irrigated, ploughing is carried out 6–8 weeks before planting. This allows moisture to accumulate in the soil for use by the growing crop. Under irrigation, ploughing can be carried out a few days before planting provided there is not too much plant growth. From an erosion-prevention point of view it is best to have the land in a cultivated state for as short a period as possible and herbicides can be used instead of cultivating to reduce plant growth prior to planting.

Planting

Planting is timed to avoid heavy frosts after the plants emerge from the ground because heavy frosts can kill the plants. Planting is carried out by two- and four-row planting machines pulled by tractors. The sets (tubers used for sowing) are planted at a depth of 10–15 cm, with 20–30 cm between sets and 75–100 cm between rows. The ground is not irrigated until the plants have emerged because this may cause the sets to rot.

Fertilising

Artificial fertiliser is required for efficient production of potatoes. Almost all soils where potatoes are grown are deficient in nitrogen and phosphorus and in many cases potassium as well. Nitrogen is applied at rates of 30–220 kg per hectare, phosphorus 35–150 kg per hectare and potassium 0–125 kg per hectare. The rates chosen will depend on the soil type and its history of use. A crop grown on land that has had a legume-based pasture for several years will not require as much nitrogen as land that has been growing other vegetables, such as cabbages.

- 4 Draw a diagram that shows the spacing of sets within and between rows.

Sandy soils tend to require more fertiliser than soils of volcanic origin, such as those developed on basalt.

The best method is to place the fertiliser where it is easily available to the root system – in bands approximately 5 cm to the side and slightly below the sets at the time of planting (Fig. 16.7). Fertiliser can also be placed in the soil in contact with the sets or broadcast before planting. There is a danger of the emerging roots being burnt by the fertiliser when it is placed in contact with the sets, and **broadcasting** before planting results in some of the fertiliser being a long way from the roots of the growing plants and therefore wasted. In sandy soils fertiliser is applied to the growing crop as a side dressing or through the irrigation water as the crop grows.

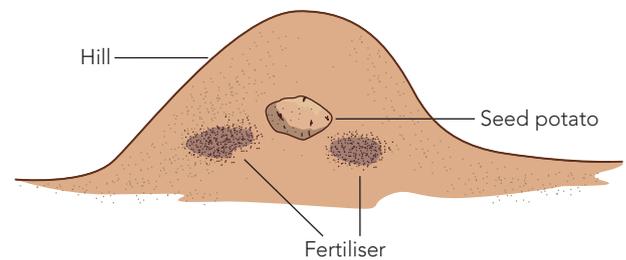


Figure 16.7 Fertiliser placed in bands below and beside the seed potato

Controlling weeds

Weeds compete with the crop plants for space, light, nutrients and moisture. They can also cause difficulties at harvest time. Experiments conducted by students at James Ruse Agricultural High School over a number of years have consistently shown that crops that are not weeded give only half the yield of crops that are weeded. It takes approximately 4 weeks for the potato plants to emerge after planting and during this time weeds will also germinate. These weeds can be controlled by harrowing with spiked harrows when most of the plants have emerged. As the crop grows, **inter-row cultivation** is carried out with a tined implement to control weeds. Once the crop canopy is established – that is, the leaves and stems of neighbouring plants are touching each other – no further cultivation is necessary.

A range of herbicides can be used to control weeds in potato crops. Advice and great care should be taken in applying them. There are advantages in using herbicides rather than cultivation because this practice reduces the risk of soil erosion.

Hilling

Hilling is piling loose soil up round the plants in the row using a special machine. It is first carried out about 4 weeks after the plants emerge, and again at the early flowering stage if necessary. Hilling is carried out for two reasons. First, to ensure the developing tubers have soil to develop in and to keep them covered so that they are not exposed to sunlight (tubers exposed to sunlight go green and can then produce poisonous substances). Second, the soil covering the tubers makes it more difficult for the larvae of the potato moth to get to the tubers. Hilling will also control weeds because it digs them up and buries them.

Irrigating

In most districts potatoes require 380–700 mm of moisture during the growing season to ensure a good yield. Potatoes do best when they have a constant supply of water and, to ensure this, irrigation may be necessary to supplement rainfall. The critical periods of growth – **tuber set** and **early tuber bulking** – are times when irrigation should be used if the supply of irrigation water is limited and not enough water is available to irrigate through all times.



Figure 16.8 Irrigating potatoes

- 5 List the three plant nutrients that are likely to be deficient in potato-growing soils.
- 6 List three methods that could be used for applying fertiliser to a potato crop. Comment on the effectiveness of each method.
- 7 Explain why it is necessary to control weeds in potato crops.
- 8 A farmer has a choice between using cultivation or herbicides to control weeds in the crop. Explain the pros and cons of each approach to weed control.
- 9 Why is hilling carried out on the growing crop?

Irrigation water is applied using some kind of spray equipment such as travelling rotating booms, water cannons, permanent sprinklers and centre pivots. Excessive irrigation may lead to valuable nutrients being leached out of the **root zone** and lost to the crop. Excessive water can also reduce the quality of the tubers and therefore their value. If rain follows irrigation the consequent over-watering can lead to the breakdown of the tubers and the collapse of the plants.

The design of an irrigation schedule for a particular crop has to take into account soil type, crop growth stage, evaporation and root depth. Sandy soils will require more frequent and smaller amounts of irrigation than heavier soils because they do not have as large a water-holding capacity. Early growth stages will require less water than later stages, when the leaf canopy is well developed and transpiration from the leaves will be greater. Evaporation rates will change as the crop grows; for example, in the coastal valleys of New South Wales evaporation will gradually increase from planting time (June–August) to harvest time (October–January) simply because the temperature increases. Irrigation should only wet the soil to the depth of penetration of the crop roots (i.e. the root zone), so as the crop grows and the roots penetrate deeper into the soil more water will be required to wet the root zone.

- 10** Explain why higher yields are achieved with irrigated crops than dry-land crops.
- 11** Why should only sufficient irrigation water to wet the root zone of the crop be applied?

Vine killing

- 12** Identify two methods of vine killing and explain why it is necessary.

The tops of the plants – the stems and leaves – can be a nuisance at harvesting because they interfere with the operation of the mechanical harvesting machines. In some potato-growing areas heavy frosts kill off the plants before harvest. In other areas the farmer must carry out vine killing to clear the way for the harvesting machines. This can be achieved with chemicals or mechanically. The chemicals used are knockdown herbicides that cause the above-ground plant parts to dry up. Slashers and pulverisers are used to mechanically reduce the bulk of the leaves and stems. Care is necessary to make sure the tubers are not damaged as the machines pass over the ground. The potato tubers are then ready for harvest.

Pests and diseases

Many pests and diseases affect potatoes. We will only consider the major ones that are likely to cause sufficient damage to the crop to adversely affect its yield.

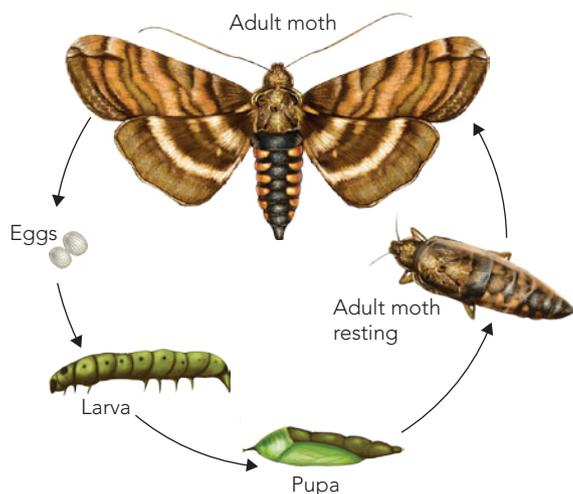


Figure 16.9 Lifecycle of the potato moth

Potato moth

This insect lays its eggs under the leaves, in the **axils** of leaves and in the eyes and cracks of tubers. The eggs hatch into larvae, which feed on the leaves and the tubers. The damage they cause significantly reduces the yield of the crop and the quality of the tubers.

Hilling and irrigation are important in preventing the potato moth from getting to the developing tubers. Hilling keeps the tubers covered with soil, and keeping the soil moist with irrigation prevents cracks through which the potato moth could reach the tubers. Insecticides may have to be used to control outbreaks of this pest.

Aphids

These insects are important pests for two reasons. First, they suck sap out of the plants and thus reduce production. Second, they act as vectors for viral diseases of potatoes such as potato leaf roll virus. That is, the juice they suck in while feeding on an infected plant contains viruses, and when they travel to a new plant and start feeding they inject the virus into the new plant, thus infecting it. Systemic insecticides are the main method of controlling aphids in the crop.

Potato leaf roll virus

This virus is just one that can infect potato plants. The leaves of infected plants roll up towards the central vein in a distinctive way and give the plant the appearance of being water stressed. The leaves cannot function properly to produce food to be stored as starch in the tubers, so yield is reduced. Planting seed that is certified as disease-free is the best way to prevent the disease. Controlling aphids is also important in preventing the spread of the virus in a crop. Genetic engineering has produced a potato variety that is resistant to potato leaf roll virus. A gene from the virus was transferred to the potato plant and this prevents the virus establishing itself within the cells of the plant. Roguing infected plants (removing and destroying them) should be carried out immediately a diseased plant is found.



Figure 16.10 Potato plants affected by potato leaf roll virus

Late blight

This fungus disease was the major cause of the Irish Potato Famine in 1845. It prefers cool and humid conditions and has a devastating effect on the plants as well as the tubers, which it reduces to mush. The best method of control is to grow varieties that are resistant to the fungus, such as Sebago.

Nematodes

These are tiny, long, smooth roundworms, sometimes called eelworms. They feed on the roots of the plant, causing stunted growth and reduced yield. The eggs of the nematodes can last in the soil for up to 20 years, which makes eradication difficult. Crop rotation is an important part of the control program for nematodes. Potatoes should not be grown in the same piece of land without a 5-year break. The pale potato cyst nematode is present in some areas of Victoria and quarantine measures are preventing its spread to New South Wales.

Bacterial wilt

This bacterial disease causes wilting and collapse of the leaves and a creamy-to-brown rot of the tubers. It prefers warm conditions. Control rests on only sowing certified seed and not growing crops on land where previous crops have been infected.

Harvesting and storage

Potato harvesting is carried out by two kinds of machines. The first digs up the tubers and leaves them on the surface of the soil, where they are picked up by workers and put into bags by hand. The other kind digs up the potato tubers and moves them

-
- 13** Select one pest or disease (if a disease, name the organism causing it). Outline the effect of this pest or disease on a crop, and list the methods used to control it.



Figure 16.11 Harvesting potatoes

- 14** Both kinds of potato harvesting machines dig up the tubers. Why is it important for these machines to handle the tubers carefully?
- 15** Use the information in Table 16.1 to complete this question.
 - a** List the states in order of production, from largest to smallest.
 - b** For each state, calculate the production in tonnes per hectare.
 - c** List the states in order of production per hectare, from largest to smallest. Is this list in the same order as the one for total production?

along a conveyer chain system that removes the dirt and passes them on to a sorting and sizing table where they are put into bags, half-tonne bins or large capacity trailers. It is important that the harvesting machines and the people who handle the potato tubers during harvest do so very carefully to reduce injury to the tubers. Damaged tubers are considered lower quality.

Crops sown in early spring and autumn are harvested with immature skins and are called new potatoes. Tubers harvested from other crops have firm and mature skins. The time of harvest is governed by maturity and price.

Yields

One hectare of potato crop will yield from 7 to 40 tonnes. The yields of crops grown without irrigation (dryland crops) average 15–25 tonnes per hectare while irrigated crops yield 17–40 tonnes per hectare. Table 16.1 shows the potato production figures for each of the states in Australia for 2011, with an Australia-wide average of about 35 tonnes per hectare. In 2009–10 potatoes were the largest vegetable crop in Australia in terms of area and levels of production. Since 2009 the area planted to potatoes has fallen 12 per cent.

Table 16.1 Total potato production in Australia in 2011

State	Area (hectares)	Production (tonnes)
South Australia	9 300	356 500
Tasmania	6 000	251 800
Victoria	7 600	236 700
New South Wales	4 100	110 800
Queensland	3 300	87 700
Western Australia	1 900	84 800
Australia	32 200	1 128 300

Australian Bureau of Statistics, *Agricultural Commodities, Australia, 2010–11*, cat. No. 7121.0

Grading and packing

While the potatoes are harvested in the field they are graded by skin maturity, size, damage and dirt coverage. Potatoes for the fresh market are packed in non-rigid sacks of 20 kg, 50 kg or 65 kg, or rigid 20 kg vegetable packages. Details of the grading system and packaging standards can be obtained from the Department of Agriculture or Primary Industries. Processing potatoes are transported in bulk containers.

Storage

Potatoes are stored so that they will be available when they are required for processing or seeding. Storage sheds allow control over temperature, light, humidity and air movement to prevent losses from rot, shrinkage, sprouting, greening and internal disorders.

When potatoes are first stored they are cured at a temperature of 13–16°C with a relative humidity of 90 per cent. This encourages cuts and bruises to heal by suberisation (when a protective layer of corky tissue grows over the cut or bruise, sealing up the damaged tuber and preventing the entry of decomposing micro-organisms). The conditions for storage after curing depend on the end use and are shown in Table 16.2. A constant air flow through the stored potatoes is also necessary. The need to store potatoes has declined in recent years because processors prefer to obtain supplies directly from the field. This can be achieved with the wide range of harvest times for the various crops.

Table 16.2 Storage conditions for different end uses of potatoes

End use	Temperature (°C)	Relative humidity (%)	Sprout inhibitor
Table	3–7	90–95	Yes
Processing	10–11	90–95	Yes
Seed	2–3	90–95	No

Source: *Australian Agriculture*, 6th edn, Morescope Publishing, 1997

16 What is the purpose of storing potatoes in the controlled conditions described?

Marketing

Potatoes are sold from the farm in three ways. They are:

- 1 transported to a central market in a capital city where an agent sells them on behalf of the farmer (e.g. Flemington Markets in Sydney)
- 2 sold to a merchant who then sells them in the central market or directly to retail outlets
- 3 sold by contract to the crisp and French fry processing companies.

The price the farmer receives will depend on the quality of the crop and the supply of potatoes at the time of sale. When there is a lot of production, and therefore a large quantity of potatoes in the market, prices are lower.

17 How are potatoes for the fresh market sold by the farmer?

18 How are potatoes for processing sold by the farmer?

Issues in the potato industry

- 1 *Financial and environmental sustainability.* Soil erosion is a major problem for potato growers, especially in hilly country where run-off after rain can carry away tonnes of valuable topsoil. Techniques such as contour banks and silt trap dams are being used as well as reduced tillage methods that limit the amount of time the soil is in a ploughed state and more susceptible to erosion. New techniques are being sought to reduce the damage to soil structure caused by heavy machinery and by carrying out operations such as cultivation and harvesting when the soil is too wet. In the inland irrigation areas, increasing soil salinity is a problem requiring more efficient use of irrigation water so that salt is not brought to the surface.
- 2 *Market competition.* Potatoes have gradually declined as the main source of carbohydrate in the Australian diet. Consumers have increasingly turned to other carbohydrates such as pasta and rice. The potato industry is working on promoting potatoes and finding new ways to encourage consumers to use more potatoes, such as value adding and specialty potatoes. Value adding processes the potatoes so that they can be sold for a higher price (e.g. turning them into crisps).

Fresh potatoes have not been imported into Australia since 1988. A New Zealand disease, Zebra chip disease, which affects starch and sugar levels in potatoes and in turn both taste and appearance, is spread by an insect called the tomato and potato psyllid. Importing of potato chips has increased rapidly

in the last few years from countries such as Belgium and the Netherlands. In supermarkets consumers are substituting cheaper overseas potatoes for Australian produce and major Australian processing firms are lowering the price they pay to local growers to remain competitive.

- 3 *Pests and disease.* The threat of pests and disease is always present. Strict quarantine laws on the import of plant material into Australia are designed to prevent new pests and diseases arriving. Any potato material that is imported for breeding purposes goes through a strict quarantine process before it can be used.

The cost of controlling existing pests and disease is always increasing so new techniques are being sought that will be cheaper, more effective and environmentally friendly. Pesticide use must come under close scrutiny and practices must be adopted by farmers to make sure chemical residues do not end up in the product or the wider environment where other life can be affected.

- 4 *Breeding.* Potato breeding programs aim to improve the processing quality and pest and disease resistance. Some success has been achieved in controlling potato leaf roll virus, with plant breeders producing genetically engineered potato plants resistant to the virus.

19 List four issues faced by the potato industry.

Chapter review

Things to do

- 1 Grow a row of potatoes about 10m long and every 2 weeks after planting dig up one plant. Draw a labelled sketch of the plant or take a photo showing its development at that time. At the end, you will have a series of sketches or photos that record the development of the potato plant.
- 2 Follow the price and supply of fresh potatoes in the market for a term. Select a grade of potatoes and look up its price every week in a rural or daily newspaper. Take note of any indication in the market reports of the level of supply. Each week record the date, price and supply. Graph the price and supply figures against time. Is there a relationship between supply and price?
- 3 Visit a supermarket and make a list of all the products for sale that are based on potatoes. Write down the price of each and the quantity the packet contains. Calculate the price per gram of product. What processes have been used to change the potato from harvest on the farm to the product in the package?
- 4 Organise a 'Potato products day' for your class. Arrange for each student to bring a different potato product so that on the day everyone gets to taste-test all products. Each student records in a table the information from the food packets and their reactions to each product. Some suggested headings to record information and ratings for the products are listed.

Product

Main use: fast food, regular meal (dinner), snack

Ingredients

Taste rating:

- 1 Excellent
- 2 Yum
- 3 OK
- 4 Not so good
- 5 Yuck

I would eat this product again:

- 1 as soon as I can
- 2 sometime soon
- 3 maybe
- 4 never

Summarise the whole class' reaction to each of the products by collating the number of students who scored the product in each of the 'Taste rating' categories and the 'I would eat this product again' categories.

🔍 Things to find out

- 1 What do the following terms refer to in the seed potato production process?
 - a Pathogen-tested nucleus stock
 - b Minitubers or plantlets
 - c Pre-elite/elite seed
 - d Foundation seed
 - e Mother seed
 - f Certified seed
- 2 Explain how it is possible to produce potatoes for nearly the entire year in New South Wales. The websites listed here may assist you.
- 3 Outline the role of quarantine in protecting Australian potato production from pests and diseases such as the Zebra chip disease.
- 4 Organic potato growing methods are becoming increasingly common. Outline the main features of this form of production.

connect

Agriculture

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DPI

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Australian Bureau of
Statistics

+ Extension activities

- 1 Go to the [Australian Bureau of Statistics](#) website to find out if potatoes are exported from all states. Record your findings for all states.
- 2 Experiment to investigate the effect of changing the planting density on the yield of potatoes. Plant three equal rows of potatoes. Use a different planting density (spacing) in each row, as follows.
 - a Normal density, 30 cm between sets
 - b Double the normal density, 15 cm between sets
 - c Half the normal density, 60 cm between sets.

This experiment could be replicated by planting three rows of each density, or nine rows total. This would improve the validity of the results.

Treat each row in the same way as the crop grows. As far as possible apply the same amounts of fertiliser, irrigation, weeding, pest control and other management practices to all three plots. Keep a careful record of everything that is done during the experiment. When the plants begin to die off carefully harvest the potatoes from each row and weigh them. Record the weight of potatoes produced by each plant density (each row).

Write a report describing how the experiment was conducted and stating what effect, if any, plant density had on potato yield.

✓ Test yourself

- 1 Describe how potatoes are marketed.
- 2 Why is potato farming concentrated on large-scale irrigation farms in areas with sandy soil?
- 3 List and describe the major issues in the potato industry.
- 4 Construct a calendar of management operations for a typical potato farm.

CHAPTER 17

COTTON

Words to know

cotton gin a factory that separates cottonseed from the lint and packs the lint into 227 kg bales

defoliant a chemical applied to cotton plants as they mature, which causes the leaves to drop off

emergence when the germinating seedling breaks through the surface of the soil

economic threshold level of pest numbers that will cause sufficient damage to the crop to make it worthwhile spraying with pesticides

lint the fibres of cotton that grow in the cotton boll and are attached to the seeds

neps small lumps in the lint resulting from tangled cotton fibres

siphon a curved length of plastic pipe used to take irrigation water from the channel to the furrow between the rows of plants

spinner factory that spins the clean cotton lint into thread that can then be woven or knitted into fabric

tail water irrigation water that has passed through the crop and not soaked into the soil, which is collected and used again

trash the remains of the cotton plant: the leaves, stems and bolls

weathering damage to the cotton lint in the open bolls caused by rain while waiting for harvest

connect

Cotton Australia

Select the cotton classroom to find out how to grow the fabric for a pair of jeans.

Shutterstock/Marcia Crayton



Figure 17.1a Cottonseed oil is used in many cosmetic products including shower gels, lip balms, face moisturisers, body lotions, soaps, mascara and lip liners.

Shutterstock/Benchaporn Maiwat



Figure 17.1b Cotton fabrics are cool, soft and comfortable.

Shutterstock/Lovell938



Figure 17.1c Cottonseed oil is a healthy vegetable oil because it is cholesterol free and contains natural antioxidants

- 1 Write the word 'cotton' in the middle of your page and list all the products of cotton around it. Draw arrows from the word 'cotton' to all the products.
- 2 Why are cotton farms situated along rivers and near cotton gins?

Introduction

What are you wearing now? It is highly likely that most of the clothes you wear contain cotton, a natural fibre produced by the cotton plant. Clothing is not the only product of the cotton plant. After the cotton fibres, **lint**, are removed from the seed, the seeds are crushed and cottonseed oil is extracted. Cottonseed oil has a wide range of uses that include cooking and making margarine, soap and plastics. The lint is also used for products that are part of our everyday lives such as bed sheets, towels, paper and canvas for tents. The remaining cotton meal is used as a high-protein stock feed. The remains of the plant itself are used as mulch.

Growing cotton in Australia

In Australia, cotton is grown in New South Wales and Queensland, with a little in the Ord River irrigation area of Western Australia. Queensland grows 36 per cent of the crop; New South Wales, 63 per cent. Figure 17.2 shows where cotton is grown in New South Wales. Cotton growing areas are situated along the inland rivers, which supply the irrigation water for the crops. Overall, 30 per cent of crops are grown under irrigation. The remaining cotton crops, grown without irrigation, are dryland crops. Production from dryland crops is dependent on the weather. Cotton farms tend to be near **cotton gins**, which separate the seed from the lint and pack the lint into bales. The average Australian cotton farm is approximately 362 hectares, and is family owned and operated. Visit the Cotton Australia website for more information.

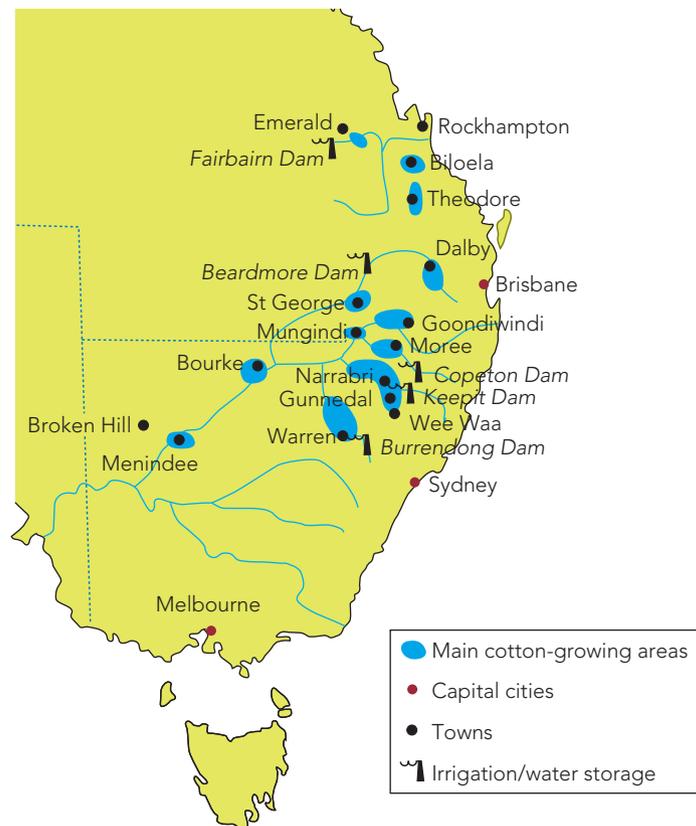


Figure 17.2a Cotton-growing areas of New South Wales and Queensland

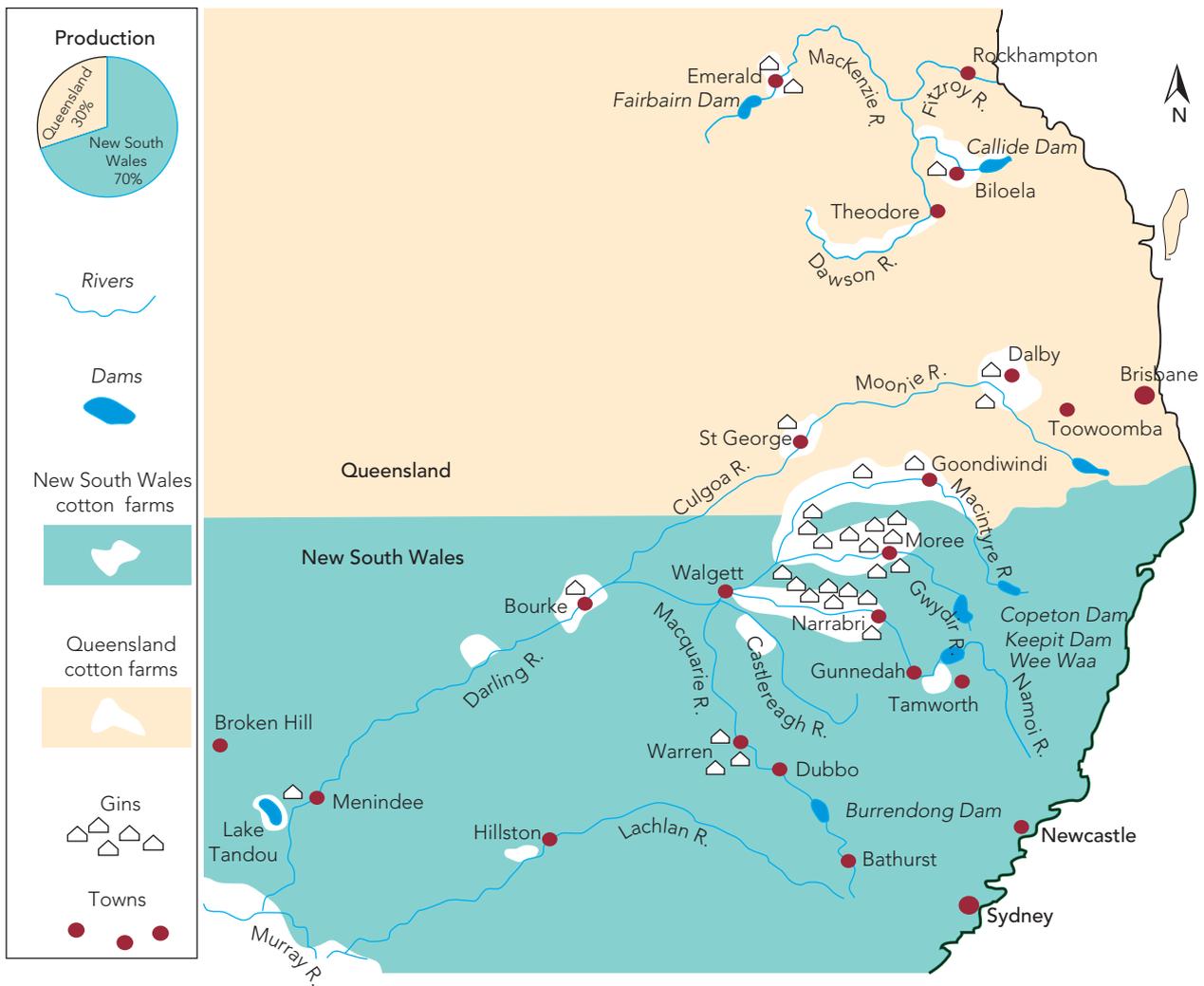


Figure 17.2b Cotton-growing areas of New South Wales and Queensland

Cotton products

The cotton farmer aims to produce lint that will bring the highest price. The price depends on the quality of the lint, described by its grade. Cotton is graded (or classed) by comparing samples with standards for:

- colour
- fibre length
- fineness
- fibre strength
- maturity
- **trash** content.

Today, cotton grading is carried out with special instruments that can test a large number of different samples quickly. Grading was once carried out by specially trained people, some of whom still have some input into the process. The range of cotton grades is shown in Table 17.1.

The characteristics of cotton lint that are of most importance to the **spinners** are length, strength and fineness. Long, fine, strong fibres are highly desirable because they are easier to spin into high-quality yarn: the finer the fibre, the finer the yarn that can be spun from it.

Table 17.1 Cotton grades

Grade	Description
Good middling	High grade, creamy colour, free from trash
Strict middling	Creamy colour, very little trash
Middling	Base grade, white colour, little trash
Strict low middling	Off-white colour with trash
Low middling	Light grey colour with trash
Strict good or ordinary	Grey colour, large amount of trash
Good ordinary	Very trashy grey cotton

- 3 List the characteristics that are used to grade cotton.
- 4 Describe the cotton lint that is preferred by spinners.

The colour of cotton is affected by its age and variety and by the weather conditions before it was harvested. **Weathering** turns the cotton grey. Colour is important because it affects how well the fabric will take up coloured dyes, and bright white or cream is the most favoured.

The less trash in the lint the better, because the trash causes problems in the spinning process. **Neps**, which are small knots of fibres, also cause problems in spinning and do not take dye evenly, which causes pale spots in the final fabric.

Growing cotton plants

- 5 Draw a line from the top to the bottom of a page in your notebook to represent the 180 days it takes from planting the seed to harvesting the cotton. Use an appropriate scale on the line to represent days. Write along the line the stages of development of the cotton plant, beginning with planting and ending with harvesting.

The cotton plant is a large-leaved perennial shrub that is grown as an annual. Cotton prefers hot summers with low humidity and long hours of sunshine. Temperature has the most influence on sowing date, growth rates, fruiting, yield and fibre quality. The best crops are grown where there is a long, hot growing season; the hotter it is, the faster the cotton will grow. After planting the seed, the cotton will be ready for harvesting in 150–180 days (Fig. 17.3).

From planting, the seed takes 5–10 days to germinate and emerge from the soil. The soil must be moist for germination to take place and the temperature at 10 cm depth must be 14°C for at least 3 days.

The young plants grow, producing leaves, a stem and a tap root system. Flower buds, or squares, start to develop about 35 days after **emergence**.

The creamy white flowers appear 25 days later and remain open for only 24 hours. Pollination and fertilisation must occur so that seed is set. If seed is not

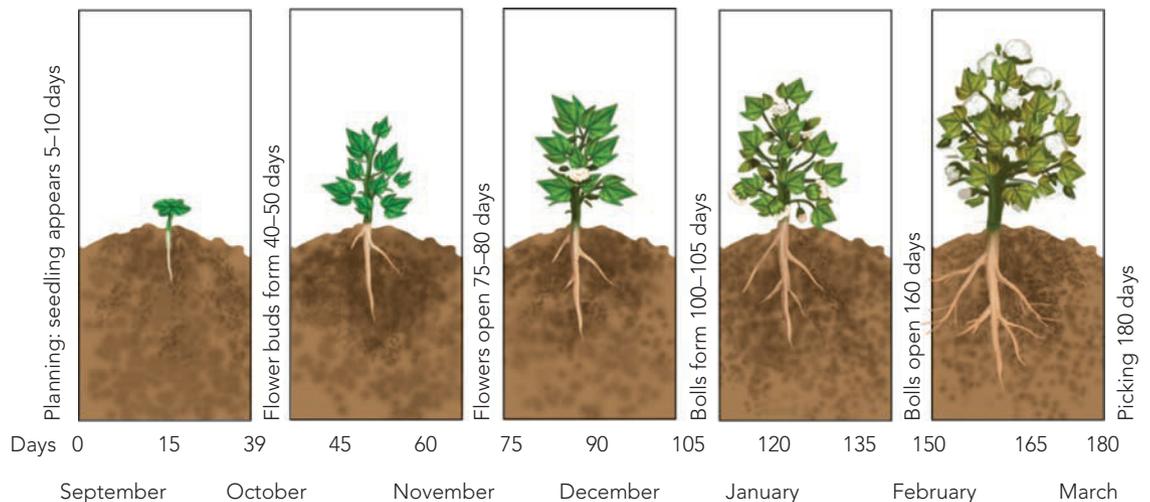


Figure 17.3 How the cotton plant grows

set, then the fruit will not develop. The inside of the fruit is made up of lint, which is attached to the seeds.

The plant continues to produce squares and flowers for approximately half the growing season.

The petals of the flower change colour to pink, red or light purple after they are fertilised. The petals drop off and the cotton boll or fruit develops. It takes 25 days for a cotton boll to reach full size, which is approximately 4 cm in diameter.

Each boll has three to five segments, and 35–55 days after reaching full size it bursts open, revealing the fluffy white cotton lint. Harvesting takes place approximately 180 days after planting, when most of the bolls have split open.

Production cycle

Preparing the land

Considerable effort goes into preparing the land to plant cotton, especially if it is going to be irrigated. Preparation starts in June or July, about 2 months before planting in September. If the crop is to be irrigated the land must be graded to give it a very gentle slope so that the irrigation water will run down the furrows between the rows and water the crop evenly. Machines called laser levellers that are controlled by laser beams very accurately grade the land. The soil is ploughed and cultivated to make a suitable seedbed, and then, using bed shapers, lister rigs and go devil machines, beds or rows are formed. The beds run the length of the field, with a 1-metre space between the top of each bed. The irrigation flows down between the furrows (the low parts between the beds). Farmers tend to leave the beds for subsequent crops once they have been made, to avoid the expense of re-forming them.



Shutterstock/Tooties

Figure 17.4 Preparing land for cotton

Planting

Cotton seed is planted in the top of the beds at a depth of 4 cm, with 6 cm between seeds in the row, or 16 seeds per metre. Not all seeds will germinate, and not all of the seeds that germinate will survive. The aim is to end up with 10 cotton-producing plants per metre. Precision row crop planters plant the cotton seed, sowing 6–12 rows at a time. The machines cut a furrow, deposit the seed at the correct depth and then firm the soil down around the seed. This ensures good contact between the seed and the soil so the seed can absorb moisture and start the germination process quickly.

Irrigating

There are three major sources of irrigation water: underground water, water from rivers, and rainwater caught and stored on the farm. River water is stored in huge dams near the river sources, and they supply most of the irrigation water. The water is pumped to the paddocks or fields in channels. In the paddocks or fields **siphons** transport the water from the channel into the furrows between the rows of cotton. Excess water, called **tail water**, is gathered at the bottom of the paddock or field and recycled so that none of it is wasted. The amount of irrigation water used is carefully measured and the farmer is charged accordingly.

-
- 6 What is the result of preparing the land for planting cotton?
 - 7 The aim is to plant 16 seeds in each metre of the row. How is this achieved?

-
- 8 What is the main source of irrigation water for cotton crops?
 - 9 How is the irrigation water applied to the crop?

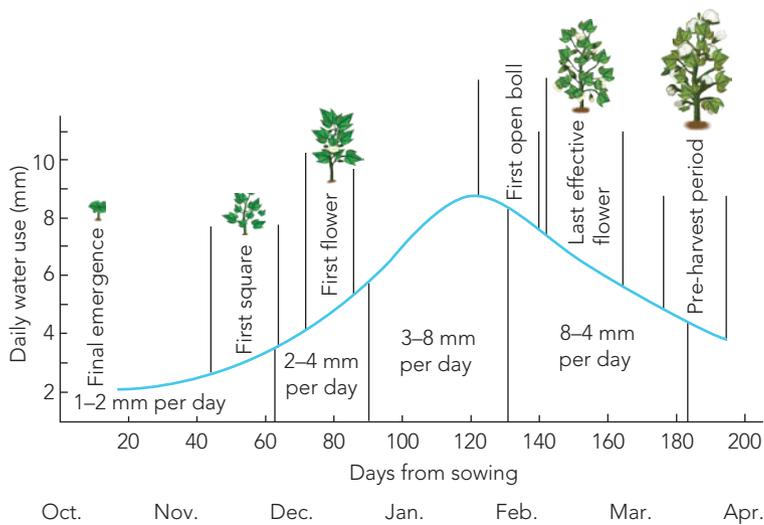


Figure 17.5 A cotton crop's daily water usage

- 10** What happens to the excess irrigation water?
- 11** Why is most irrigation carried out in January–February?

Water monitoring, irrigation scheduling, evaporation control and improved irrigation practices have doubled the water efficiency of cotton growers in the last 10 years.

Fertilising

Soil sample testing, conducted months before planting, determines the type and amount of fertiliser required for the cotton crop, so that any nutrients lacking can be added to the soil. As the crop grows, leaves can also be analysed, deficiencies detected and appropriate fertilisers applied. Nitrogen is often lacking and can be applied in several ways.

- *Gaseous anhydrous ammonia.* A tined implement injects ammonia gas into the soil, up to 6 months before planting (Fig. 17.7). The gas dissolves in soil moisture and is taken up by the roots of the cotton plant.
- *Dry fertiliser.* A dry fertiliser such as urea can be applied at planting, while the crop is growing, or even be dissolved in the irrigation water.
- *Growing a legume crop before the cotton crop.* A legume crop, such as faba beans or chick peas, when correctly inoculated with nitrogen-fixing *Rhizobium* bacteria, supplies nitrogen to the cotton crop as they are broken down by micro-organisms in the soil.

Phosphorus is another nutrient often in short supply. Fertilisers containing phosphorus, such as monoammonium phosphate (MAP) or diammonium phosphate (DAP), are used to correct the deficiency. Potassium, sulfur and zinc can also be deficient.

- 12** Explain how soil sample testing helps to determine fertiliser use.



Shutterstock/Paul B. Moore

Figure 17.6 Irrigating a cotton crop



iStockphoto/© TheBusman

Figure 17.7 Applying anhydrous ammonia to correct a soil nitrogen deficiency

Controlling weeds

Weeds reduce the yield and quality of cotton by:

- competing for light, water and plant nutrients
- contaminating the cotton (weed leaves and seeds get into the lint)
- harbouring pests and disease that can move from the weeds to the cotton plants (such as the native budworm and cotton bollworm, genus *Helicoverpa*).

Controlling weeds may involve:

- cultivating the land to prepare it for planting, which reduces weeds
- treating the land with a pre-emergence herbicide before planting
- inter-row cultivating in the early stages of growth
- hand weeding, which involves teams of people moving through the crop, chipping out the weeds with hoes
- using herbicides in the growing crop so that contact is made with the weeds but not the cotton plants, using spot spraying, ropewick applicators and shielded sprayers
- growing Roundup Ready Flex® Cotton that can be sprayed up to the four-leaf stage without damaging the cotton plants.

Controlling pests

Table 17.2 lists the major cotton pests. These pests, along with others such as thrips, damage the crops and spoil the quality of the cotton lint.

Table 17.2 The major pests of cotton

Common name	Scientific name
Native budworm	<i>Helicoverpa punctigera</i>
Cotton bollworm	<i>Helicoverpa armigera</i>
Green mired	<i>Creontiades dilutes</i>
Two-spotted mite	<i>Tetranychus urticae</i>
Cotton aphid	<i>Aphis gossypii</i>

The native budworm and cotton bollworm insects (known as *Heliothis*, but now belong to the genus *Helicoverpa*) have the most devastating effect. Their larvae eat the flower buds and burrow into the bolls, destroying the lint so cotton cannot be produced (Fig. 17.8). Once the larvae become moths, they are carried by wind currents over large distances and are attracted to green lush cotton crops.

In the pupal stage of the *Helicoverpa* lifecycle, the larva transforms into the adult moth. The fully fed larva burrows 10 cm into the soil and makes a chamber, where it pupates. Native budworm and cotton bollworm survive over winter in the pupal stage. Cultivating destroys the pupae and helps reduce the numbers of moths emerging to infest next season's crop.

Monitoring pests

Controlling cotton pests is challenging, and the farmer must seek the advice and input of experts such as agronomists and entomologists. A pest control program begins with close monitoring of the types and numbers of pests present in the crop. Every 3 days, in four different square-metre areas in a cotton paddock or field, the number of insects and their eggs are counted. From this, the pest numbers are estimated. If pest numbers have reached the **economic threshold** – a level likely to cause significant damage to the crop and where loss of income from this damage is

- 13 Identify three ways weeds affect the yield and quality of cotton.
- 14 List the weed control techniques available to the cotton farmer.



Figure 17.8 A
Helicoverpa larva attacking a cotton boll

- 15 List five major pests of cotton.
- 16 Describe the role of monitoring pest numbers in control programs.
- 17 How can *Heliothis* numbers be reduced when the cotton crop is not growing?

higher than the cost of treatment – control with pesticide is necessary. When the numbers are below the threshold, nothing is done except continued monitoring. Spraying is only carried out when necessary.



Figure 17.9 Applying pesticide to a cotton crop

Choosing pesticides

The pesticides used on cotton crops at a particular time are specially selected from seven groups to best cater to a particular pest problem. Two main types of pesticide exist: those that kill a narrow range of insects (preferably only the target species) and broad-spectrum pesticides that kill a wide range of pests and other insects. The pesticide chosen will depend on what pest monitoring shows. The pesticides are applied by aircraft (Fig. 17.9) or by a row crop sprayer, up to eight times in a growing season. Caution must be exercised when using pesticides to avoid the pests developing resistance to the chemicals. One way of doing this is to switch insecticide groups.

It is important to ensure that neither the environment nor humans are affected by the pesticides used on the cotton crops.

Beneficial insects also help by attacking the pests; beneficial insects include ladybird beetles, wasps, spiders and ants. Encourage beneficial insects by spraying the crop with Envirofeast, a food developed by scientists that attracts beneficial insects. When beneficial insects arrive, they feed on the pest eggs and larvae, reducing pest numbers.

When several different pest control techniques are used together against pests, this is called integrated pest management or IPM.

One development in the war against the Heliiothis insects has been the production of Bt cotton, a variety of cotton that produces its own insecticide. When the Heliiothis larvae eat these cotton plants they eat a toxic protein that destroys their stomach walls and kills them. This toxic protein is normally produced by the bacterium *Bacillus thuringiensis*. Scientists have transferred the gene that produces the toxin from the bacteria to the cotton plant, giving the cotton plant the ability to produce the toxin. The first Bt cotton is known commercially as Ingard®. Farmers growing Bt cottons must follow a strict set of guidelines to minimise the risk of Heliiothis becoming resistant to the toxin. This includes planting other varieties of cotton adjacent to the Bt cotton to allow survivors of Bt to mate with insects that have not been in contact with it. Bt cotton is expensive and has produced mixed results where it has been grown. The efficacy of Bt cotton seems to be reduced by low temperatures and waterlogging of the crop.

Cotton plant breeders have also developed cotton varieties that have leaves with fewer hairs than usual. Heliiothis insects lay their eggs on the hairs, so fewer hairs on the leaves means fewer eggs laid, resulting in less damage to the cotton.

The war against pests goes on, with researchers trying to find new management strategies, pesticides and genes that will help control them.

Over the last 10 years, use of biotechnology and IPM systems has contributed to a 90 per cent decrease in use of pesticide.

-
- 18** Identify two problems arising from the use of pesticides.
 - 19** How can beneficial organisms be encouraged in the cotton crop?
 - 20** How can Bt cotton help to control Heliiothis insects?
 - 21** Explain why an IPM system is desirable for cotton growing.

Controlling disease

Diseases of cotton include bacterial blight, *Rhizoctonia* and Fusarium wilt. Crops affected by disease produce less cotton and the quality is reduced. Farmers usually use a combination of the following techniques to control disease.

- 1 Plant disease-resistant cotton.** Some farmers plant varieties of cotton that are resistant to certain diseases. Unless the disease-causing organisms change, they are unable to attack the resistant plants and the bad effects they have are reduced.
- 2 Rotate crops.** By rotating crops, the same crop is not grown on the same field year after year. Instead, a completely different crop is grown after a cotton crop so that the cotton disease organisms have no cotton plants to attack, and therefore will die out. When cotton is planted again on that field there are fewer disease organisms. Crop rotation over a six-year period is shown in Table 17.3.
- 3 Control weeds.** Controlling weeds in the cotton crop helps to prevent disease spreading from the weeds to the cotton crop.

22 List three techniques used to control disease in the cotton crop.

23 Explain how crop rotation helps control disease.

Table 17.3 A crop rotation for a cotton field

Year	Crop
1	Cotton
2	Cotton
3	Wheat
4	Cotton
5	Cotton
6	Faba beans or fallow

Harvesting and processing

Picking is a term used to describe the harvesting of cotton. A **defoliant** spray is applied to help the plants drop their leaves before the picking machines move in. This reduces the possibility of trash being included with the picked cotton, which reduces its value. The bolls are left on the stems ready for picking. The farmer decides the best time to apply the defoliant spray by cutting open some bolls and examining the seeds. If the seeds are fully formed, the crop is ready to be treated. If the lint in the youngest bolls is mature then a boll opener can be used. At this stage some bolls will not have opened and most farmers add a boll-opener treatment to the defoliant spray to encourage the bolls to open.

Once the cotton is ready it should be picked as quickly as possible because if it rains the quality of the cotton will be affected (rain discolours the cotton). The cotton must be dry, with a moisture content of less than 12 per cent. Damp cotton that is harvested and stored can begin to decay through the action of micro-organisms and the heat generated can cause a fire.

The harvesting machines move through the crop picking four rows at a time (Fig. 17.10). The cotton lint attached to the seed (seed cotton) is removed from the open bolls and blown into a basket on the back of the machine. This basket can hold up to four bales of cotton when full. When the basket is full the cotton is tipped into a boll buggy, which is a bin pulled by a tractor. The boll buggy takes the cotton to a module builder (Fig. 17.11), which uses hydraulics to compress the cotton into a block 11 m long × 2.5 m wide × 2.5 m high. A module stores 13 tonnes of cotton. The module is covered with a tarpaulin to protect the cotton until it can be transported to the cotton gin.



Shutterstock/Alaettin Yildirim

Figure 17.10 Cotton-picking machines at work



Shutterstock/Lindasj22

Figure 17.11 A cotton module

24 What is the result of cotton being ginned?

The module of seed cotton is lifted onto a semi-trailer truck with an infield loader machine. At the cotton gin (Fig. 17.12), the modules are stored in rows with each farm's cotton all in the one place. In the gin the lint is separated from the cotton seed, then pressed into 227 kg bales and stored in a warehouse. The cotton is then ready for transport to spinning mills for processing.



Alamy© Tony Hertz

Figure 17.12 A cotton gin

Marketing

25 Where does most of Australia's cotton crop go?

26 What is the major influence on the price the farmer receives for cotton?

Australia is one of the world's largest exporters of cotton. Cotton is exported to Japan, Indonesia, China, Thailand, Bangladesh, South Korea, Hong Kong, the Philippines, Malaysia, Taiwan, India, Italy and Belgium.

Merchants operate on behalf of farmers to sell their cotton to the processing mills or spinners (Fig. 17.13). Merchants acquire cotton of a similar grade from several farmers to make up enough to meet the requirements of the spinners to whom they sell the cotton. There is often a contract for ginning and selling the cotton between a farmer and the merchant or ginning organisation.

Farmers have a number of options available to them when selling their cotton.

- In the *cash market* farmers sell their cotton for a daily price.
- In a *forward contract*, the farmer and buyer agree to a fixed price for cotton to be delivered in the future, up to 3 years in advance.
- A *seasonal pool* gives an average price from the total sales of cotton delivered to that pool during the season, with a third party marketing for the farmer.
- A *minimum price pool* guarantees at least the pool price but a better price is available if prices improve.
- In a *call pool*, the farmer promises a quantity of cotton to the pool but is free to trade the cotton using futures and options, which are a paper sale of something that will be delivered in the future.
- In a *balance crop*, any unsold bales are sold at an agreed price.

The price the farmer receives largely depends on what happens in the international market. If the cotton crop fails in one of the major cotton-producing countries, supply is short and the price goes up. If all the major cotton-producing countries have good crops, there is oversupply and the price goes down.



Shutterstock/junrong

Figure 17.13a Carded cotton is a process where rollers make a thick rope of loose fibres.



Shutterstock/Alaettin Yildirim

Figure 17.13b Spinning cotton

Issues in the cotton industry

Cotton growing is closely scrutinised in Australia. There are two major areas of concern, pesticides and water usage, which the cotton industry endeavours to manage.

Pesticides

Concerns arise because of the possible effects of pesticides on human and environmental health. What effects do the chemicals sprayed on cotton have on humans that are exposed to them? It seems that, as long as the recommended precautions are taken when using the pesticides, humans are reasonably safe.

Pesticide residue is also of concern when it finds its way into other agricultural products such as beef. In drought conditions cattle can be fed on cotton trash. Along with the cotton plant material they eat pesticide residue, which ends up in the meat. Pesticide residue in meat is not acceptable to Australian consumers or to the countries that import it. In 1999, residues of the pesticide Endosulfan were found in beef exported to Korea. The cotton industry has put strategies in place to prevent recurrence, such as strict rules about when and how often Endosulfan can be sprayed on the cotton. However, the cattle affected may also have absorbed Endosulfan as a result of spray drift (when the pesticide being sprayed on the cotton crop is blown onto surrounding areas such as pastures, which are then grazed by cattle). It is possible that chemicals from spray drift can end up in water supplies for stock and humans, and even in rivers and streams, thus affecting wildlife in unintended ways.

27 Explain why pesticide residues are of such concern to the community.

28 What is spray drift and why is it a problem?

Water usage

Towns (people and facilities) and livestock use water. Water is needed to maintain the flow of rivers and wetlands. Irrigation farming needs water. Yet there is a limited amount of water available and in times of water shortage, irrigation farmers have last priority. Cotton farmers who irrigate recycle excess water by building tail-water drains that take it to storage dams where it can be used again. Irrigation water is expensive so it pays not to waste it.

29 Why do cotton farmers go to such lengths to manage the tail water from irrigation?

Best management practices

The cotton industry is developing a system of best management practices that will enable farmers to produce high-quality cotton safely, with minimal risk to humans or the environment, and with efficient water usage.

connect

Cotton Australia

Use the information to develop a series of summaries.

Chapter review

Things to do

- 1 List all the pieces of clothing that you are wearing. Look at the labels of each and record the percentage of cotton and other materials (such as polyester, nylon, lycra and wool) that it contains. Calculate the average percentage of each of the materials. Does cotton have the highest average percentage?
- 2 Plant some cotton seed when the soil temperature is above 14°C. Keep a record of the planting date and record when the first squares are seen, the first flowers are seen, the first bolls appear and the first boll opens. Count the number of days from planting to each of the events recorded. Do your results tally with the figures shown in Figure 17.3? Do you think your area is suitable for growing cotton?
- 3 Design and conduct a survey of the families of your class to find out what they like and dislike about cotton.

Things to find out

- 1 Why would a legume crop such as faba beans be included in the crop rotation shown in Table 17.3?
- 2 Find some market reports for cotton and see what the current price of cotton is. Market reports can be found in rural newspapers and on the internet.
- 3 What happens to cotton during the spinning process? Draw up a flowchart that shows the steps involved in spinning.
- 4 How is cotton that has been spun into thread processed into knitted and woven cloth? Draw up a flowchart that shows the steps involved, including the dyeing and/or printing of the cloth.

+ Extension activities

- 1 Go to the [Cotton Australia](#) website and use the information to explain the principles underlying best management practice (BMP).
- 2 Using examples, discuss the impact of gene modification technology on the growth and management of the cotton plant.
- 3 Discuss the issues relating to the long-term sustainability of cotton production in the current cotton-growing areas of Australia.

Test yourself

- 1 Outline the yearly management calendar for a cotton crop.
- 2
 - a List the main insect pests of cotton.
 - b Describe the methods available to farmers to control insect pests.
 - c List the main diseases of cotton.
 - d Describe the methods available to farmers to control diseases of cotton.
 - e Outline the safety precautions farmers need to meet workplace health and safety, or WHS, requirements for pest control (parts **b** and **d**).
- 3 Define 'IPM'. Outline examples of this concept in relation to growing cotton.
- 4 Discuss and evaluate marketing options available to cotton farmers.

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WHS

CHAPTER 18

WHEAT

Words to know

bran a carbohydrate food obtained from the outer covering of the wheat seed

cereals large-seeded grasses used for food

fallowing resting of a paddock, usually in a ploughed state

Gramineae botanical name for the grass family of plants

lodge crop plants that fall or are blown over by wind

nodes points on the stem where leaves arise

pollard a carbohydrate food also obtained from the outer covering of the wheat seed

pustules clusters of fungal spores bursting through the surface of the plant

shot grain grain that has started to germinate and the first root has started to emerge

sprung grain grain that has started to germinate and has a noticeable bump where the embryo is

tillering refers to the branching pattern of growth of the wheat stem



Figure 18.1 Members of the grass family, Gramineae

Introduction

Wheat belongs to a family of annual grasses called **cereals** that are grown for their grain. These plants all belong to the family **Gramineae** (grass family) and provide carbohydrate foods for energy to livestock and humans. Figure 18.1 shows some important members of the Gramineae family. The important part of the cereal plant is the grain and some of the main foods obtained from the grain are illustrated in Figure 18.2.

Wheat varieties used today are totally dependent on humans for the dispersal of seed because the breeding programs that led to the formation of heavier grain also limited the plants' natural ability to disperse seed. On average, Australian wheat farmers produce 27 million tonnes of wheat grain per year and, of this, the majority of the product is exported. Wheat remains one of the leading primary export industries in Australia and Australia exports the fourth largest quantity of wheat in the world. The main export destinations for our wheat are Asia, the Middle East and the Pacific countries.

The distribution of wheat in Australia

The area planted to wheat in any particular period varies as a result of three factors:

- the frequency and severity of droughts
- the comparative economic advantage offered to farmers through planting alternative crops such as oilseeds
- prevailing world market prices for wheat.

Varying soil and climatic conditions around Australia allow a diverse range of wheat varieties to be sown. Higher protein hard wheat is grown in northern New South Wales and Queensland, while lower protein soft wheats are grown in southern regions.



Figure 18.2 Commercial products from cereal grain

- 1 List four important cereal crops that belong to the grass family.
- 2 List three products made from cereals.
- 3 In what rainfall range is wheat grown?
- 4 Why can a diverse range of varieties of wheat be grown in Australia?

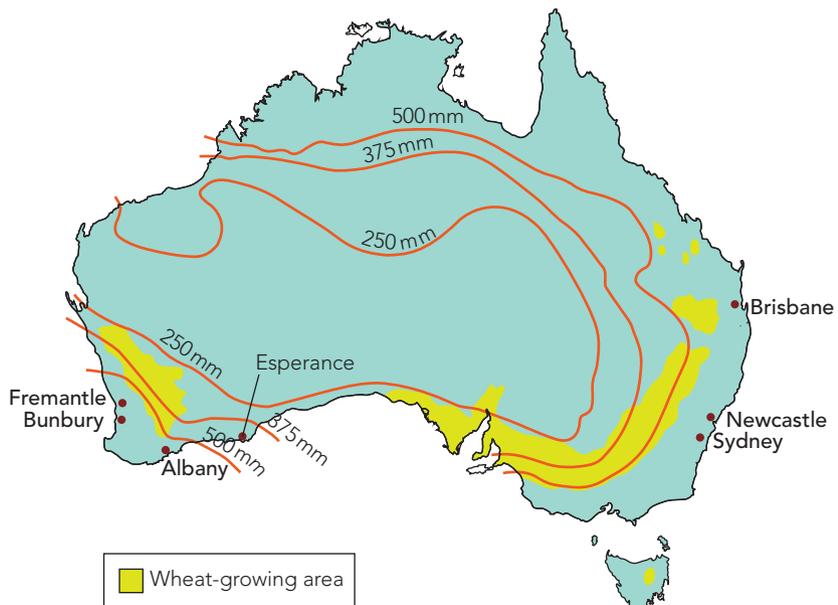


Figure 18.3 Distribution of wheat-growing areas in relation to annual rainfall

The structure and growth of a wheat plant

Wheat grows for 5–7 months, flowering in spring and ripening as the weather becomes hotter. Figure 18.4 illustrates the stages of growth of a wheat plant. Up to the flowering stage, the wheat plant produces a number of stems in a process called **tillering**. When the stem is mature a number of bumps or joints can be seen along the stem where **nodes** have formed. From these nodes, leaves or roots may form. This is the vegetative stage of growth in the wheat plant.

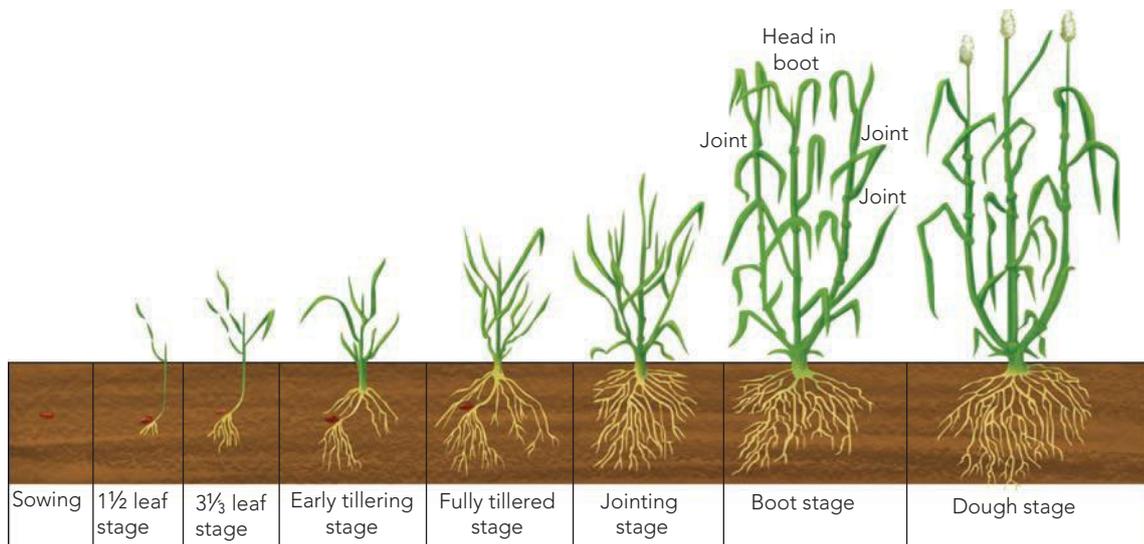


Figure 18.4 Stages of growth for a wheat plant

About 6 weeks after tillering commences, the end of each stem forms a small swelling that will develop into a seed head or inflorescence. This structure is also called a head or an ear. At the end of winter, the stems grow and the wheat crop becomes visibly taller. During this period the plant needs adequate moisture and nutrients to sustain growth. By the middle of September the small ears of wheat grow up through the leaf sheaths, eventually emerging as a swelling of the topmost leaf. This emergence of the seed head surrounded by a green cover of leaf is the boot stage of growth. Next, the wheat plant flowers.

The period from flowering onwards is the reproductive stage of growth. The whole head of the wheat plant is called a spike and the flowers occur in bunches called spikelets. Once fertilised, the seeds develop in the spike and swell as starch is produced.

The dough stage is a stage in the formation of the wheat grain. The starch in the seed is very soft, and as it dries out the seed hardens to form the common wheat seed. Food is moved from the stems and leaves of the plants into the grain as it forms. The stems and leaves dry out and turn to straw. Finally the whole plant turns a yellow colour and is ready for harvesting.

Wheat is an annual grass. After sowing, the wheat grain absorbs moisture from the soil and swells. The small wheat plant or embryo inside the seed begins to grow and forms a lump in the seed, called a **sprung grain**. The roots are the first to emerge from the grain, which at this point is known as a **shot grain**. The shoot system emerges from the grain after the roots, called seminal roots, are established. The shoot is protected by a structure called a coleoptyle while it grows towards the soil surface. Once the coleoptyle emerges above the ground the grain has

- 5 Describe the vegetative phase in the lifecycle of the wheat plant.
- 6 Describe the reproductive phase in the lifecycle of the wheat plant.
- 7 Draw a diagram of a mature wheat plant in your notebook. Label all the parts of a wheat plant.

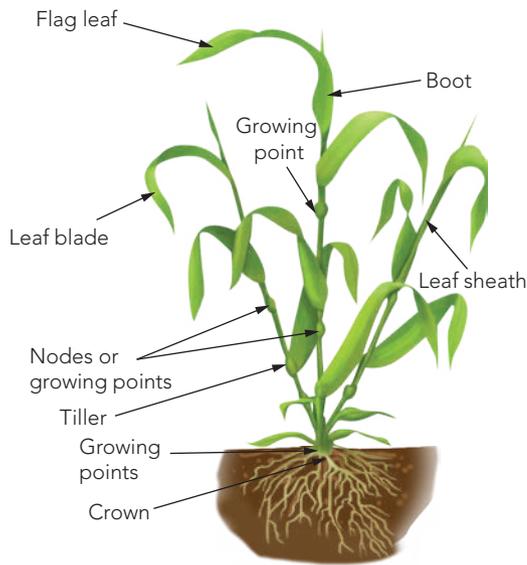


Figure 18.5 Parts of the wheat plant

germinated. The leaves emerge from the coleoptyle and the earliest stages of growth of the plant are described in terms of the number of visible leaves. Figure 18.5 shows the main parts of a wheat plant.

The seed

The wheat grain is commonly called a seed. In botanical terms, it is a fruit because the seed is still enclosed by a mature ovary. The seed coat and ovary wall are fused together. Figure 18.6 shows the main parts of the wheat grain.

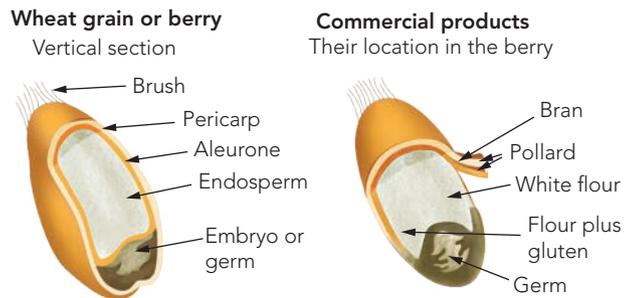


Figure 18.6 The wheat grain

- 8 Draw and label the parts of the wheat seed in your notebook.
- 9 What commercial products are obtained from the wheat seed?

The protective coats of the grain (pericarp, or ovary wall, and testa, or seed coat) amount to 5–6 per cent of the grain and during milling are removed and used as **bran** and **pollard** for livestock feed. The endosperm consists of starch grains and some proteins and this makes up around 86 per cent of the grain. This is extracted to form flour. The embryo or young plant makes up 2 per cent of the grain and is used in foods such as wheat germ.

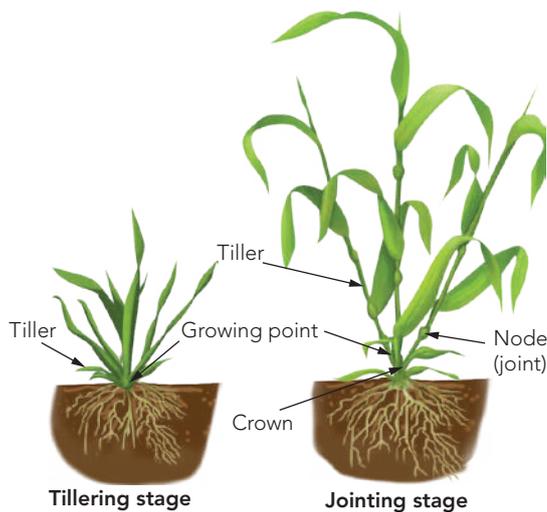


Figure 18.7 Tillering in wheat

Tillering

As shown in Figure 18.4, the early stages of growth are referred to as tillering. Buds from the base of leaves develop to form new stems, thickening the wheat plant (Fig. 18.7). Mature wheat plants may have 15–20 tillers. Roots can develop from these tillers and form a secondary root system that helps the plant extract moisture and minerals from the soil.

The leaves are the most obvious features in the early growth of wheat. Leaves help the plant to make food and to direct rainwater down the stem on to the root area. Wheat leaves have several features in common with all grasses.

- They are in a set arrangement occurring at 180° intervals on the stem.
- The leaf consists of a sheath, which wraps around the stem, and a leaf blade (lamina).
- The leaf blade is long and narrow, with all the veins parallel to each other.
- The largest leaf on the wheat plant is the top leaf, called the flag leaf.
- The growth region of the leaf is at the base of the leaf blade.

Flowering

Wheat, like all grasses, relies on wind for pollination and the flower is not obvious or attractive for insects to visit. Figure 18.8 shows the seed head of wheat and the wheat flower, which is protected by outer husks that must be removed to reveal the grain. Hulling is the term used to describe the removal of these outer protective parts of the flower.

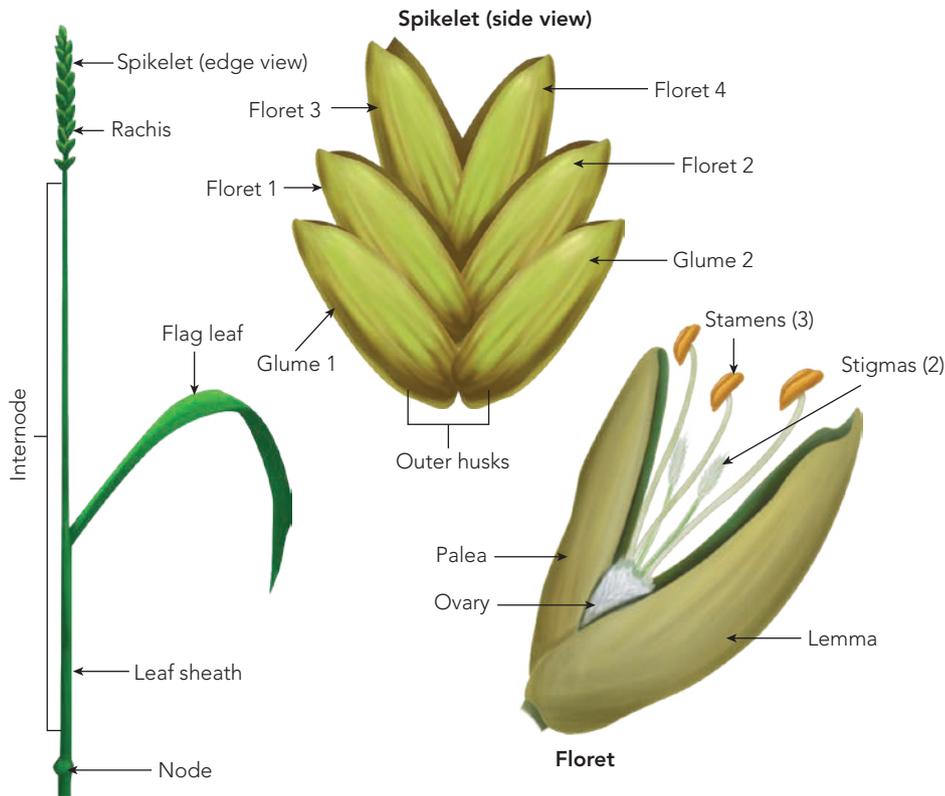


Figure 18.8 The wheat flower

Factors affecting the production cycle

Environment

Rainfall is the main factor affecting where wheat can be grown. Wheat needs to grow in areas that receive 250 mm or more rainfall in the May–October growing season. Wheat needs very significant soil moisture during the active growth period. However, a hot dry summer period is necessary to allow the grain to ripen and dry.

Wheat is a winter-growing annual that can survive under a variety of conditions and a wide range of temperatures, but in warmer weather wheat plants produce small seed heads quickly. Frosts assist production by causing plants to tiller during the vegetative stage of growth, but late frost can cause damage once the seed head has emerged.

10 Draw the flower of the wheat plant.

11 Explain why the wheat flower is wind pollinated.

12 Define 'hulling'.

13 Which environmental conditions favour the growth of wheat?

Because wheat seed heads are heavy, wind can cause the plants to fall over or **lodge**, which makes harvesting very difficult.

Wheat requires fertile soil with adequate lime to prevent acidity. It is very sensitive to nutrient shortages in the early stages of growth. In general, depending on rainfall, wheat requires 200–400 kg of superphosphate per hectare and 100–200 kg per hectare of nitrogen-based fertiliser.

Controlling pests

Australian plague locust

Locusts cause widespread damage to pastures, cereal crops and forage crops. Locust eggs are laid in the soil and start hatching in September. After 5–6 weeks of growth, the young locusts are able to fly during November and December. These adults lay eggs, which result in a second generation in February and March that attacks autumn-sown wheat. The plague locust becomes a major problem when climatic conditions are favourable for their breeding. In the Western Plains when large numbers hatch they migrate eastward and southward into the main wheat–sheep zones. Constant surveillance of breeding areas is essential. Areas where eggs are laid can be ploughed to prevent hatching. Timed spraying requires precise applications to reduce insect numbers.

14 Construct a table in your notebook with the following headings: pest, damage caused, control methods. Use the information in the textbook to complete this table for three insect pests of wheat.

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Armyworm (*Pseudaletia unipuncta*)

Visit the Department of Entomology, University of Nebraska-Lincoln website for more information on armyworms.

Armyworms

There are two types of armyworms that attack cereal crops: the common armyworm and the southern armyworm. Armyworms get their name from the way that late-stage caterpillars, when present in large numbers, advance like long columns of soldiers. Both pests severely defoliate or destroy young winter cereal crops and pastures, but most damage occurs during spring and summer when they feed on the heads and leaves of maturing cereal and grass crops. The worms live for 2–4 weeks, with each female laying up to several hundred eggs that hatch in 1–2 weeks. The caterpillars feed in the evening and at night and hide during the day under debris on the surface of the soil. Severe outbreaks of caterpillars often occur after heavy rains in spring and summer.

Armyworms can be controlled by natural predators such as birds, especially magpies. Insects also prey on the worms. Species of predatory shield bugs will actively attack the armyworms. Various wasps and flies are also parasites of the caterpillars, their larval stages feeding on the live caterpillars.

Careful checking of the crop to detect infestation early is essential. Boom sprays may be used to spray insecticide strategically over the crop at critical times.

Cutworms

Cutworms are soil-inhabiting pests that mainly attack young plants. They are general feeders on young weeds, field crops and vegetables. The young cutworms climb plants and eat holes in the leaves. Older cutworms also cut leaves off the plant and, as the caterpillars become larger, they start to eat the stems of plants at ground level, causing the plant to fall over, and then they feed on the top growth of the plant. Cutworms usually feed at night and hide in the soil under vegetation by day.

The cutworm is a pest during autumn and winter although attacks on plants may extend into spring. Birds, weather conditions, parasitic insects and strategic spraying with insecticide control the numbers of cutworms. Cutworm infestations can be drastically reduced by removing weeds at least three weeks before planting or sowing.

Grain pests

During storage periods special care must be taken to maintain grain quality. There are a number of species of beetle that damage wheat seed after it is harvested.

Common pests include the lesser grain borer (*Rhizopertha dominica*), the granary weevil (*Sitophilus granarius*), the rust-red flour beetle (*Tribolium castaneum*), the indian meal moth (*Plodia interpunctella*), and mice. More information about these pests is available from the [Stored grain insects](#) website.

Controlling disease

Many types of fungi cause damage to wheat plants. Common examples include rust, which can be further distinguished into stem rust, leaf rust and stripe rust. Other common fungal diseases include bunt and take-all, a root-rotting fungus.

Rusts obtain their name from the yellow-to-brown colour of the spores that the fungus produces in order to reproduce itself. Stem rust is the most damaging disease of wheat. This fungus forms red-brown spore **pustules** on the leaves, stems and husks of wheat. It likes warm temperatures and a moist environment and becomes a serious problem later in the growth season. It affects the grain-filling ability of the plant because nutrients are diverted to the fungus rather than to the developing grain. Total grain loss can occur. Spores being blown along in the wind infect wheat plants that grow wild in the countryside, as well as barley and related grasses. This way, the fungus can survive from one wheat crop to the next.

The best way to control rust diseases is to use rust-resistant varieties of wheat. Good farm management in the form of allowing animals to graze wheat stubble reduces the risk of infection from wheat left to grow at random.

Take-all is a root- and crown-rotting fungus found in the wheat-growing areas of New South Wales, particularly on light and poorly compacted soils. It is also a serious problem in irrigated areas growing wheat or barley. Host plants include wheat, barley, rye, oats and related grasses. This disease devastates after a few years, especially after periods of wet weather.

The typical sign of take-all is premature death of the plants after heading and before the grain matures. Take-all occurs in patches. Infected plants appear stunted, with few tillers, and produce little grain. The empty ears are called 'whiteheads' because of their appearance. These signs become very visible after hot dry winds where the root systems are unable to supply the water needs of the plant. Management is a key to the control of take-all. In serious situations the farmer may need to grow immune crops such as rapeseed, lupins, sunflower or sorghum. Weed-free fallow periods of up to 8 months can also be used to deprive the fungus of a host.

Controlling weeds

Weeds are one of the major problems a wheat farmer must overcome. They damage crop production through their competition for water, nutrients and sunlight. Weeds can also block or clog the operation of machinery. The harvested grain, if mixed with weed seeds, will be worthless in the marketplace.

Common weeds include cape weed, skeleton weed, bindweed, wild turnip, wild oats and annual ryegrass. If weed growth is very active then spraying with herbicides may be necessary. Boom sprays or aerial spraying may be used after the wheat plants have reached the four-leaf stage and, if necessary, during the dough stage. Farmers may also control weed growth through cultivation, strategic grazing, slashing and pasture rotation.

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Stored grain insects



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Figure 18.9 a Fungal-affected wheat rachis
b Wheat leaf affected by rust

15 Outline the cause, type of damage to the wheat plant and the method of control for one disease of wheat.

16 List three common weeds that affect wheat.

17 Why are weeds a problem in wheat farming?

Managing the crop

It is important for the wheat farmer to decide which variety of wheat is best suited to their local area. Agriculture departments assist by making recommendations each year as to which varieties are best suited to each area. Wheat varieties differ in various features such as:

- size, colour and hardness of the grain
- length of stalk
- shape and appearance of the wheat head
- drought resistance
- maturity rate
- baking quality of the flour
- resistance to disease.

Preparing the soil

Soil water levels and nutrient availability are crucial to the development of a good wheat crop. Soil preparation methods need to take this into account. **Fallowing** of the soil allows water infiltration and removal of weeds reduces water loss.

Tillage is the mechanical manipulation of the soil to achieve a particular purpose. Wheat farmers must consider various tillage options to:

- 1 develop a suitable seedbed to allow seed contact with moist soil, which is essential for seed germination and early root development
- 2 control weeds
- 3 manage plant residue by chopping up plant matter to provide a protective organic layer over the surface of the soil
- 4 provide adequate oxygen and water levels without creating large clods of soil that allow water to move rapidly through the soil; alternatively, the method of cultivation should not shatter the soil, producing a cement-like layer of surface soil that hinders air and water movement in the soil (soil compaction)
- 5 control erosion; the method of tillage employed should not contribute to the risk of erosion by shattering the surface soil or shifting the soil down a slope. Such sustainable management practices include direct drilling and stubble retention.

No till and minimum tillage land management models are also popular. In these situations the extent and number of tillage operations are reduced. This lowers the risk of soil deterioration from over-cultivation and lessens the possibility of soil erosion. These methods of cultivation involve the use of chemical herbicides in some instances to remove weeds and prevent regrowth. Strategic grazing of stubble also thins out the plant matter on the surface of the soil to allow replanting of the next crop. In all cases the new crop is planted in the remains of the stubble from the previous crop. Seeding machines fitted with discs are often used for this operation. There is minimal disturbance to the soil surface.

Rotating crops

The process of growing wheat for a few years, and then fallowing or resting the land as a pasture allows nutrient build-up, improves soil structure and breaks disease cycles. Figure 18.10 shows a typical rotation pattern for a wheat farm. Another management strategy is to grow a legume crop to replenish nitrogen levels in the soil. This is called ley farming.

18 Why are rotations important in wheat farming?

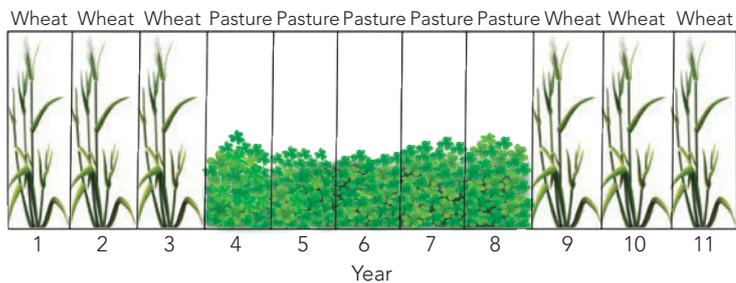


Figure 18.10 Wheat rotations

Sowing

Sowing takes place between April and July, depending on where the farm is located. Late sowing of wheat causes poor yields. A special machine called a combine can be used to plant the wheat. A combine cultivates the field, plants the wheat and adds fertiliser. Wheat is sown to a depth of 7 cm in rows 18 cm apart. The wheat seed used for sowing should be weed free, with no broken, germinating or rotten seed.

Harvesting

Wheat is cut for hay when the base of the stalk starts to turn yellow. The grain is still soft to the touch at this stage. The harvesting of wheat for grain involves collecting ripe, hard grain from the plant, when moisture content is about 12 per cent. It is then threshed to remove the husk surrounding the wheat seed. A process called winnowing then removes the grain from the rest of the plant, leaving straw. These processes were once separate but header harvesters now complete them all and then load grain directly into waiting trucks for transport to silos.

At the silos wheat is inspected and classified according to quality. Sticks, stones and other foreign material are removed. Over half of all wheat produced is sent from silos to terminals for shipment overseas as grain. The remaining grain goes to mills for making flour. Once cleaned of debris, the grain to be used in flour manufacture is washed to remove dust, and conditioned (water is added to toughen the bran coating to allow easier removal of the bran layer). The grain is then broken by rollers and sifted to remove the bran fraction. Products removed at this step include bran, pollard and wheat germ. The remaining material is used for flour. This material may be coloured or vitamins added to make various types of bread. Figure 18.11 illustrates the steps involved in the manufacture of flour.

19 Outline how wheat grain is harvested on the farm.

Marketing

The marketing of wheat is carried out by companies both local and international. Payments to growers are made over several years and depend on the quality of the wheat produced, which in turn depends on protein levels. The grades of wheat are briefly described as follows.

- *Australian premium white*. This wheat product is a blend of white, hard and ground wheats, produced first in 1995–6. It has a guaranteed minimum protein level of 10 per cent, and is excellent for making noodles, tandoori bread and various Middle Eastern baking materials.
- *Australian prime hard*. This wheat has a minimum protein level of 13 per cent and is used for the manufacture of bread.

- 20** How is wheat marketing conducted?
- 21** Explain the steps in the manufacture of flour.

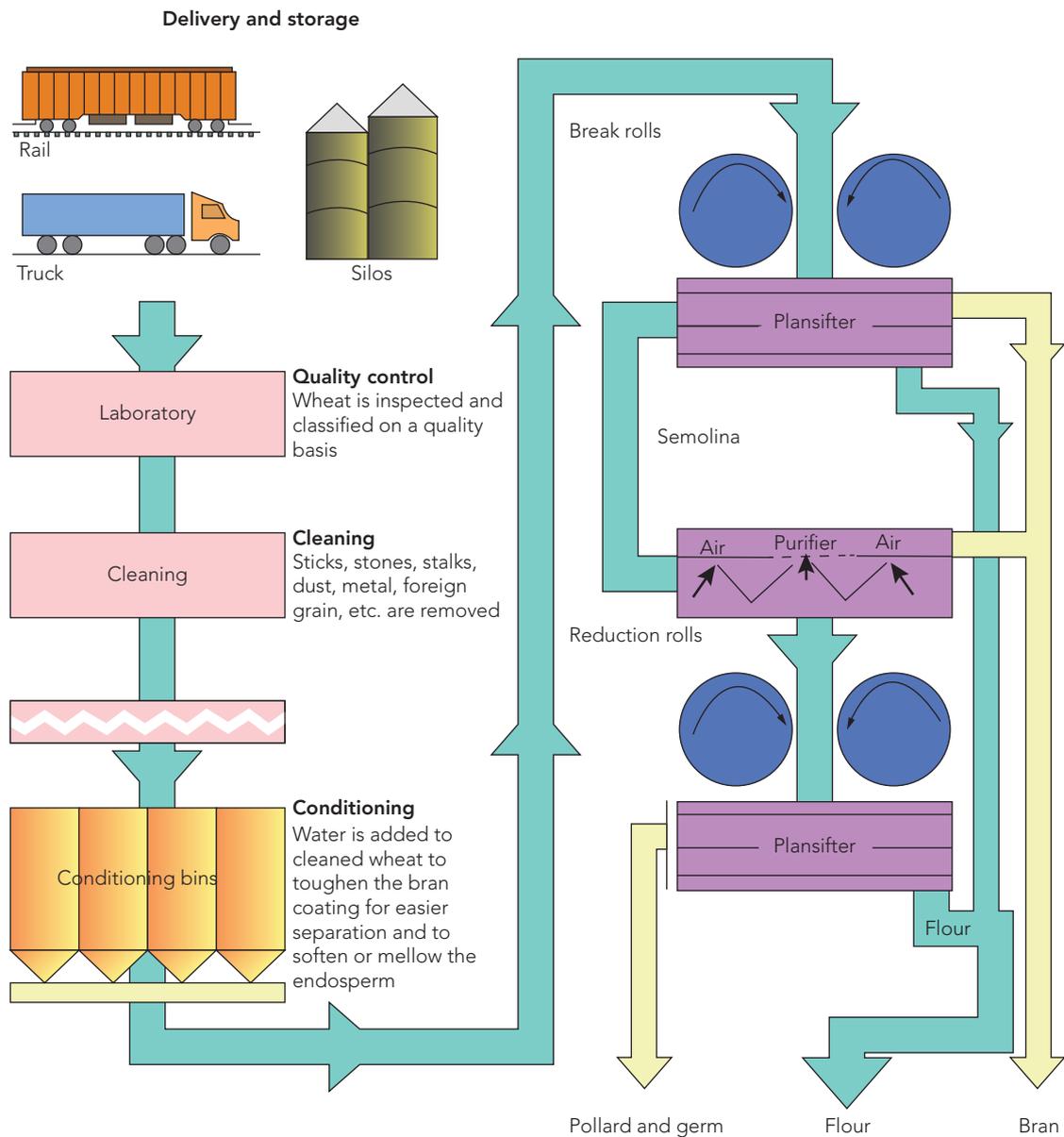


Figure 18.11 Flour manufacture

- *Australian hard*. This wheat has a minimum protein level of 11.5 per cent and is used for the manufacture of bread.
- *Australian standard white*. This covers wheat varieties with a protein level of 10 per cent, a general-purpose wheat product with many uses. Over 70 per cent of all wheat produced falls into this category.
- *Noodle wheat*. Most of the wheat varieties in this category are grown in Western Australia, but there are few. They have a protein content of 9.5–11.5 per cent, and are used in the production of white, salted noodles for the Asian market.
- *Australian soft*. This type of wheat has a protein level of 8–9 per cent and is used in the manufacture of flour to be used in cakes and biscuits.

Marketing patterns for Australian wheat closely reflect the demands of the various world markets. Marketing companies assist in identifying the exact requirements of overseas markets and in developing wheat varieties that reflect these needs. The domestic market was deregulated in 1989, so any operator can trade wheat domestically.

The main features of Australian wheat on the export market are that it is white-grained, insect free, clean and undamaged. In the need to encourage and exploit niche markets around the world, companies categorise wheat received by variety, composition, the location of production and premium classification. Payment is made accordingly.

The marketing companies accept wheat for delivery into a number of marketing pools according to the wheat's quality characteristics. The return to the grower is the average price received for wheat sold in all the different markets.

Through the use of wheat futures markets, forward contracting and stock exchange futures markets, some protection can be offered to the value of wheat delivered to these pools.

Uses of wheat and wheat products

The majority of Australia's wheat export is used by various countries to produce breads and noodles (Fig. 18.12). Within the Asian countries there is now a growing demand for feed grain because of an increase in intensive animal production systems within these countries. Japan is a consistent importer of Australian wheat, especially high protein, milling wheat suitable for the noodle industry.

About one-third of wheat used in the domestic market is made into flour, which is made from hard wheat or blended hard wheat and soft wheat. Many products can be made from wheat flour, including biscuits and cakes (made from soft wheat), bread, pastry, pasta goods such as semolina (made from high protein Durum wheat) and noodles. Further processing of the flour produces starch, gluten, glucose and fructose. Wheat starch or gluten is used as a food additive in bread and for glue.

Australia's flour exports are mainly in the form of bread dough, premixed flour, noodle, cake and biscuit premixes. Gluten and starch are Australia's major processed wheat exports.

Issues in the wheat industry

On a historical basis the domestic milling and production market is fragmented. The processing plants are also small, so economies of scale cannot be realised. The factories are highly mechanised and technically efficient. It is difficult for this type of factory to quickly change the manufacturing process to cater for changing levels of demand by overseas buyers because of the high level of capital investment in specialised technology and machinery.



Figure 18.12 Wheat products: **a** bread **b** noodles

Chapter review

Things to do

- 1 Grow a selection of cereal crops in 1 m × 1 m plots of ground. Note the ones that germinate most successfully and measure the various rates of growth by observing both plant heights and levels of tillering. What is the most successful cereal crop for your locality?
- 2 Grow several varieties of wheat in 1 m × 1 m plots of ground. Harvest some plants for hay and weigh the output from these plots. Which variety was most successful?
- 3 Look at samples of wheat, oats and barley plants in head. How can you tell these plants apart?
- 4 Examine common weed pests of wheat such as black oats, skeleton weed or cape weed. What features of these weeds make them such a pest for wheat farmers?

Things to find out

- 1 Why is rust such a devastating disease of wheat and how can it be controlled?
- 2 Find out how either starch, gluten or semolina is manufactured.
- 3 Research three types of cultivation equipment used to prepare the soil for planting wheat. Explain how the machines work and the effect these machines have on the soil.
- 4 Research three issues facing the wheat industry. Examples are sustainability, marketing structures and value adding to enhance product market potential.

+ Extension activities

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Collecting ancient seeds

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Where does bread come from?

- 1 Find out how value adding occurs in the marketing of wheat products.
- 2 Visit the [Collecting ancient seeds](#) website. Listen to the audio-visual and answer the questions
- 3 Visit the [Where does bread come from?](#) website. Listen to the audio-visual and answer the questions.

Test yourself

- 1 Describe the vegetative and reproductive growth and development phases of a wheat plant.
- 2 Describe the yearly management calendar for wheat.
- 3 Discuss the marketing chain for wheat from the time it leaves the farm until sold as bread in a supermarket.
- 4 In table form prepare a summary of the limiting factors and their influence on wheat productivity.
- 5 Research Durum wheats to find out what they are and why they are important in Australia.

CHAPTER 19

VEGETABLE CROPS

Words to know

bacteria single-celled microscopic organisms; some cause organic material to decay or cause disease; others are important in the formation of cultured dairy products and fixing nitrogen both in the soil and in the roots of legumes

fertiliser any manure or chemical substance used to make soil more fertile by replacing plant nutrients removed by crops or leached from the soil

fungi plant-like organisms including rots, mildews and moulds that lack chlorophyll and possess threads (hyphae); can be parasitic and cause disease in plants and animals or feed on organic matter

fungicide a chemical substance used to control or prevent fungal growth

irrigation the application of water to a crop to provide moisture not directly provided by rain

nematodes roundworms that are parasitic on plants, or free living in water and soil

nursery bed a special seedbed where seedlings are raised for transplanting; often a more protected environment than the field where the crop is grown

organic matter material that originally came from living things – dead and decaying plants, animals and manures; important in holding water and plant nutrients in the soil as well as improving the structure of the soil

pesticide any chemical substance (usually dust or spray) used for the destruction of any pest; usually an insecticide

processing the various stages of treatment, from harvesting to packaging or canning (e.g. tomatoes are washed and peeled before canning)

seedling a young plant that has just established itself after germination

Introduction

A visit to a greengrocer's (fruit and vegetable) shop or a large supermarket reveals a huge variety of vegetables available for sale. Vegetables are crucial to the human diet, because they supply:

- vitamins and minerals for good health; for example, tomatoes are rich in vitamin C and spinach is rich in iron
- large amounts of energy food; for example, potatoes are rich in starch
- fibre, which is necessary for healthy functioning of the digestive system.



Shutterstock/Ana Blazic Pavlovic

Figure 19.1 A huge variety of vegetables is available in Australia.

The vegetable industry annually produces approximately 3.2 million tonnes of vegetables valued at \$2.2 billion. Of this, 15 per cent is grown in New South Wales, where it supplies to both the **processing** and fresh markets. The majority of the vegetables grown in Australia are grown for the fresh market (60 per cent) and sold domestically.

On average, in one year each Australian eats 55 kg potatoes, 15 kg tomatoes, 17 kg root vegetables, 25 kg leafy green vegetables and 21 kg of other vegetables.

A fascinating variety of plant parts are eaten as vegetables. For example, the roots of carrot, the stem (tuber) of potato, the leaves of lettuce, the developing flowers of cauliflower, the seed pods of beans and the fruits of tomatoes. Table 19.1 lists the various vegetables and the part of each plant that is used for food.

As well as being eaten fresh, vegetables can be frozen, dried and canned, so they can be transported across distances and eaten at times in the year when they cannot be grown.

Table 19.1 Vegetable crops and the parts of each plant that are used for food

Vegetable crop	Part(s) used for food
Tomato, pumpkin, zucchini, cucumber, squash, marrow, gramma, bean, eggplant, pea, broad bean, capsicum, snow pea	Fruit
Lettuce, cabbage, onion, leek, spinach, silver beet	Leaf (includes bulbs)
Rhubarb, celery	Leaf (celery), stalk (celery, rhubarb)
Brussels sprouts	Bud
Carrot, radish, turnip, parsnip, beetroot	Root
Cauliflower, broccoli, artichoke	Flower
Sweet corn	Seed

Growing vegetable crops

Vegetables are grown mainly on small farms or market gardens (an example of intensive agriculture). Such farms tend to be situated near large cities to be close to the markets, but refrigerated transport has allowed vegetables to be grown and delivered to markets from farms distant from cities. Irrigation areas are also popular locations for growing vegetables. Growing vegetable crops involves similar processes to those used to grow field crops.

Preparing the soil

The aim is to prepare a seedbed in which to sow the seed or transplant **seedlings**. Disc or chisel ploughs are commonly used first to break up the soil, though mouldboard ploughs are sometimes used. A disc harrow, tined cultivator or rotary hoe is then used to further break down the soil until it is fine enough for the desired type of vegetable crop to be grown. Those crops with small seeds (such as carrots) need a much finer seedbed than a large-seeded crop (such as sweet corn). The final operation for some crops is to use a hilling or bed-forming machine that lifts the soil up into raised beds just before planting.

Seeding and transplanting

The spacing of vegetable plants is very important to obtain a good uniform crop and some vegetables need more space than others. Cauliflowers are planted in rows 1–1.5 m apart, with 60–90 cm between plants in the row. Carrots are grown in rows 15–90 cm apart, with 1–2 cm between plants in the row.

The depth of sowing is also important: the general rule is that small seeds should be sown much shallower than larger seeds. For example, carrots have small seeds and are sown at a depth of just 0.5–1 cm, while broad beans have large seeds and are sown at a depth of at least 5 cm.

Some vegetable crops, such as cabbage and cauliflower, are raised as seedlings and then transplanted. Transplanting must be carried out carefully (Fig. 19.2).

- 1 Dig a hole in the soil using a trowel.
- 2 Hold the seed in the hole so that it is 1 cm deeper in the soil than it was in its **nursery bed**.
- 3 Put the soil back in the hole around the roots and firm it down.
- 4 Give the newly transplanted seedling a watering as soon as possible because the roots will have been damaged and it will take the plant time to recover.

Transplanting ensures that plants have sufficient space to grow and are developed enough before planting to protect them from frosts. On some large vegetable farms special machines do the transplanting.

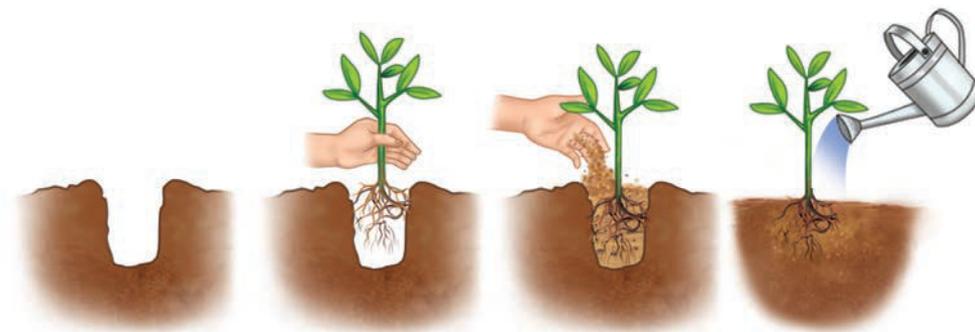


Figure 19.2 Transplanting

- 1 What is the aim of seedbed preparation?
- 2 Why is it important to have plants evenly spaced?
- 3 Onion seed is the same size as carrot seed. How deep would you sow onion seed?
- 4 Why is transplanting used in the establishment of some crops?

Fertilising

- 5 Identify two kinds of fertiliser used on vegetable crops.

Fertilisers are almost always used when growing vegetable crops. Wherever possible, vegetable growers use animal manures (such as poultry manure), spent or old mushroom compost, and spent deep-litter material from poultry as fertilisers. These materials add necessary plant nutrients and build up the **organic matter** in the soil, which makes it more suitable for growing vegetables. Complete fertilisers that supply nitrogen, phosphorus and potassium (NPK) are the chemical fertilisers most often used.

Fertilisers are applied to the soil close to the seeds or seedlings at planting. They may also be placed next to the growing plants once they are well established. Fertiliser applied to a growing crop in this way is known as a 'side dressing' (Fig. 19.3).



Figure 19.3 Applying a side dressing of fertiliser

Controlling pests

- 6 Identify two ways of controlling insect pests.

Each type of vegetable plant has its own pests. For example, the cabbage and related vegetables are attacked by the cabbage white butterfly, the potato by the potato moth and the pumpkin by the pumpkin beetle. Some pests attack a wide range of vegetables, such as aphids and cutworms.

Pests are usually controlled by spraying the crops with **pesticides**. The law now requires that only those pesticides designed specifically for the pest to be controlled are to be used. Great care is necessary when using pesticides and the manufacturer's instructions on the container should be followed strictly, especially in relation to waiting periods between applying the chemical and harvesting the plant produce for human consumption. Some pests have been controlled by using their natural enemies; this is called biological control. For example, the green vegetable bug has been controlled by a parasite that attacks its eggs and the cabbage white butterfly can be controlled by using a spray that contains a bacteria that causes a lethal disease of the larvae, such as Dipel.

Controlling disease

- 7 How can a farmer control disease in crops?

All vegetables can be attacked by diseases, which are most commonly caused by fungi, viruses and **bacteria**. **Nematodes** are also responsible for causing disease in some crops. Actions farmers can take to control disease in their crops include:

- *Sowing only certified seed.* Certified seed is produced under strict supervision by the Department of Agriculture and is guaranteed to be disease-free.
- *Treating the seed with a fungicide dust before planting.* Using a fungicide before planting reduces the chance of the germinating seedling being attacked by disease.

- *Rotating crops.* Each crop is followed by a completely different crop, so disease does not build up in the soil.
- *Spraying the crop in the field while it is growing.* Using a recommended chemical for a particular disease in a crop as it grows reduces the chance of the crop being attacked.
- *Growing disease-resistant crops.* Some varieties of vegetable crops that can be planted are resistant to the disease that is likely to be a problem.
- *Using biological control agents such as predatory mites and lady beetles.*
- *Using cultural methods such as mechanical barriers, sticky traps and water traps.*
- *Quarantining the farm.*

Integrated pest and disease management (IPDM) uses all available methods to control diseases, pests and weeds effectively while minimising environmental hazards such as the accumulation of chemicals in the soil, enhancing water and air quality and preserving the habitat.

Irrigating

Vegetable crops require a lot of water to grow well and produce high yields. **Irrigation** must be used because natural rainfall seldom provides sufficient water (Fig. 19.4). Many kinds of irrigation system are used, including spray, furrow and trickle.



Shutterstock/Kosin Sukhum

Figure 19.4 Spray irrigation

Harvesting

Most vegetables are harvested by hand, but some machines have been developed for harvesting particular crops. For example, potatoes are harvested with a potato digger and tomatoes for processing are picked with a special machine. Vegetable crops can yield up to 30 tonnes per hectare with crops such as carrots or potatoes reaching as high as 70 tonnes per hectare.

8 Why is irrigation used on vegetable crops?

9 How are most vegetables harvested?

10 Why is the timing of harvest important in some crops?



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Figure 19.5 Harvesting vegetables

After harvesting, most vegetables are sorted or graded based on size, colour and quality. In some instances products that are leafy can be trimmed, but root crops need to be washed. Once these processes have occurred the vegetables are packed into cartons or other containers.

Produce must be stored in cool conditions after harvest to prevent spoilage. Many growers have cool rooms while refrigerated transport is used to carry produce to the wholesaler or market.

Growers also produce vegetables for processing (canning, bottling or freezing) in factories. These vegetables are grown under contract and are usually harvested by machine.

The timing of harvesting is very important. Many crops left even 1–2 days too long suffer a marked reduction in quality (for example,

in sweet corn the sugar in the kernels turns to starch so the corn does not taste as sweet, and zucchinis will be far too large and often taste bitter).

Marketing

connect

Marketfresh

Most vegetables are sold as ‘fresh vegetables’. Visit the [Marketfresh](#) website for market information on produce. Vegetables are transported from the farm to the produce markets in the capital cities. Here they are sold by wholesalers to retailers who in turn transport them to their shops for sale to consumers. To make sure the vegetables the consumer buys are as fresh as possible, cold storage facilities are increasingly used on the farm, at the markets and in the retail shops. Refrigerated transport also contributes to the consumer being able to buy fresher vegetables.

Some vegetables are processed and frozen before being sold; for example, beans and peas. Vegetables may also be processed and canned; for example, sweet corn and asparagus. Drying is another way vegetables are processed; for example, peas and potatoes are sold in this form.

Alternative marketing strategies for vegetables include:

- direct sale to the public from the farm
- sale through a farmer co-operative
- contract sales to a major retailer.

Because marketing is direct, the farmer needs to develop an effective marketing plan and a working relationship with the selling agent.

To learn who specialises in marketing a particular product, farmers can get advice from the local growers association, make a direct approach to major retail outlets or visit websites such as [Freshmarkets](#).

In any marketing arrangement farmers need to be sure that transport is efficient and that there are no delays in unloading or loading product for market. Delays can result in considerable loss due to spoilage. Farmers also need to understand the quality standards required by the retailer and what happens if the produce is spoilt or rejected.

connect

Freshmarkets

Information on the marketing of fresh vegetables

- 11** Draw a flowchart that shows what happens to vegetables after they are harvested. Include the following: vegetable farm, produce market, processing factory, retail shop and consumer.

Chapter review

Things to do

- 1 a Visit the [Edible gardens](#) website. Look at the troubleshooting fact sheets and outline solutions to the problems presented.
 - b List some advantages of growing your own vegetables.
 - c Visit the [Veggie guide](#) website. List the vegetables you can plant for your current season.
- 2 Grow a vegetable crop. (Try the one to be researched in 'Things to find out'.) Keep careful records of all the processes you carry out growing your crop. If you have never grown vegetables before, perhaps try radish because they are very easy to grow and can be harvested in less than 6 weeks. Keep a digital record of the growing crop.
- 3 Go to a greengrocer's shop or the vegetable section of a supermarket and make a list of all the vegetables on sale. Go to the section where canned vegetables are on sale and compile a list of them. Then go to the freezer section of the supermarket and list all the vegetables that are sold frozen.
- 4 Design a market slogan to increase vegetable consumption in Australian diets.

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Edible gardens

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Veggie guide

Things to find out

- 1 Select a vegetable crop and research:
 - the varieties that are most commonly used
 - planting time
 - harvest time
 - spacing of the plants
 - sowing depth
 - fertiliser used
 - an important disease affecting the crop and how it is controlled
 - an important pest affecting the crop and how it is controlled
 - how the crop is harvested and marketed.

+ Extension activities

- 1 For a nominated vegetable crop outline the market requirements in terms of quality. Discuss why these characteristics are used as a measure of product quality.
- 2 Tissue culture is a means of increasing the productivity and range of vegetable crops. Outline an example of current research being done with this technology and vegetable growing.

Test yourself

- 1 Explain the main management steps in the production of a named vegetable crop.
- 2 Outline in table form the main pests and diseases for a named vegetable crop.
- 3 Discuss the methods available to a farmer to market vegetables.
- 4 Explain the concept of integrated pest and disease management (IPDM).

CHAPTER 20

HORTICULTURE

Words to know

disbud to remove excess buds, thus allowing only a few buds per stem to develop fully

germinate form roots and shoots from a seed under favourable conditions (i.e. sufficient moisture, oxygen and suitable temperature)

growers people who raise plants to sell from seed, tubes or pots

hydroponics growing plants without the use of soil in carefully balanced nutrient solutions

retailers people who sell plants to consumers through shops and nurseries

transplant move rooted seedlings from one location to another, generally from a punnet or seed tray to a garden bed

wholesalers people who specialise in supplying certain types of plant to nurseries, landscapers or retail outlets

Introduction

The cut flower industry has an estimated gross value of \$1.32 billion per year. The industry is located around cities, which provides for direct transport links to markets.

Commercial flower growing is labour intensive and reliant on technology. Farm management may involve:

- the growing of annual crops in rows or beds, irrigated by overhead low pressure irrigation systems
- using slow release fertilisers
- controlling pests by a combination of cultivation methods, strategic use of chemicals and biological agents
- using alternative management systems such as **hydroponics**, which grows plants without soil in a watery medium to which a balanced nutrient mixture is applied.

Greenhouse horticulture is the growing of plants within, under or sheltered by structures such as greenhouses and glasshouses, shade houses, screen houses and crop top structures, which can provide specific growing conditions and/or protection from pests, diseases and adverse weather.

Controlled environment horticulture (CEH) is the most modern and sophisticated form of greenhouse horticulture. This form of greenhouse management combines high-technology greenhouses with hydroponic (soil free) growing systems.

Greenhouse systems allow a greater value of production per given area, so small areas of land can be economically viable. The greenhouse or floriculture industry is an important part of agriculture. It is concerned with the growing of plants under glass or similar protective structures. There are several stages in this complex system. Floriculture includes growing flowering plants to be sold in pots; growing plants for their cut flowers or colourful leaves; and the production of seedling plants. Some of the more common plants grown for their flowers are carnations, roses and chrysanthemums. Plants grown for their leaves include poinsettias, philodendrons and many types of peperomias.

Traditionally, this industry also grows seedlings for sale to nurseries and **retailers**. Potted plants are also supplied nationwide to sellers in the industry; such plants are competitively priced and attractively presented, allowing for a rapid turnover of stock.



Shutterstock/Graeme Dawes

Figure 20.1 A commercial nursery

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Nursery and garden industry Australia

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Agriculture NSW

Horticulture and the greenhouse industry

Growers produce various crops under special environmental conditions. These producers often specialise in one or two types of plant because it is expensive to cater to the exact needs of the plants to allow them to grow rapidly, remain healthy and sell quickly. Some growers may even limit themselves to the production of plant bulbs or seedlings, rather than grow full adult plants.

Farms that specialise in producing plants for sale are usually very well laid out, to avoid high labour costs. A typical structure of a large production system is shown in Figure 20.2. A farmer may have to adopt several of the roles shown in this

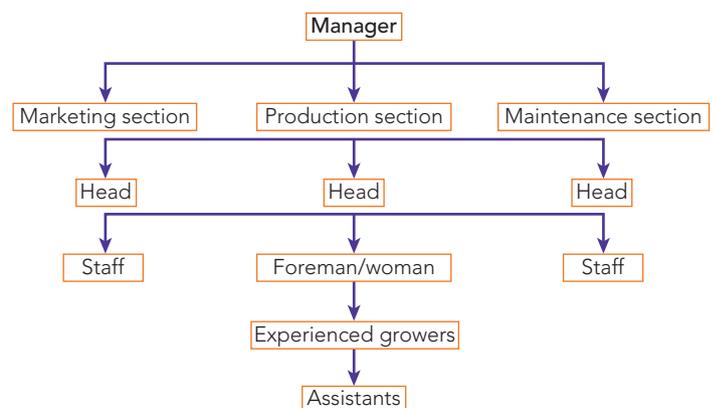


Figure 20.2 Greenhouse production management

- 1 List three outputs from the greenhouse industry.
- 2 Distinguish between a grower, a wholesaler and a retailer.
- 3 Why is it important to maintain a high turnover of plants?

diagram, depending on the scale of their operation. The manager is often the owner, who coordinates all aspects of the operation. The other more specialised sections of the business are run by experienced staff, who are involved in repotting, cutting, packaging and the striking of new plants. Casual and untrained workers perform the many basic operations that keep plants healthy, such as weeding, watering, pruning, spraying and harvesting.

Types of glasshouses

The main feature of these horticulture farms is the glasshouse – a building designed to allow the farmer to control the environment in which the plants are grown. The glasshouse provides flexibility. In this environment the farmer can grow many plants to any stage of their lifecycle at any time of the year.

Glasshouses can be the traditional glass-framed structure, plastic-covered polyhouses or fibreglass structures. Many have highly developed systems to control watering, heating, humidity, light and ventilation. Figure 20.3 shows some of the structural features of a glasshouse.

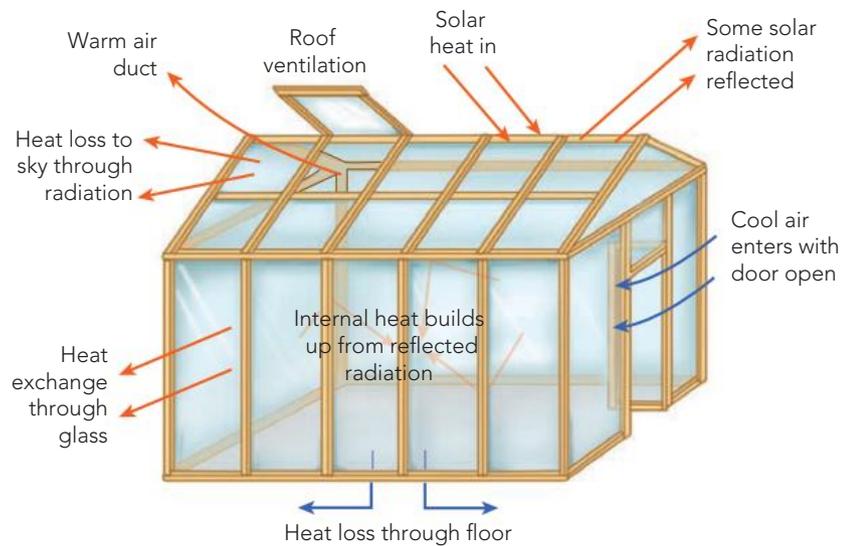


Figure 20.3 Features of a glasshouse



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Figure 20.4 Suspended benches

Growing plants in a glasshouse

Plants in glasshouses can be grown in a variety of different ways.

- Containers may be placed on suspended benches, as shown in Figure 20.4.
- Large plants may be planted directly in the soil, as shown in Figure 20.5.
- Seedling plants may be placed in large containers, as shown in Figure 20.6.



Shutterstock/Diana Taliun

Figure 20.5 Direct planting



Shutterstock/Daniel Alvarez

Figure 20.6 Container planting

To encourage root growth, especially with seedlings, some benches that store the pots are heated using electric cables or pipes containing hot water. These are called ‘hot frames’.

Planting and monitoring

In a glasshouse system, in many situations plants are grown from seeds or cuttings. Plants are usually started and seeds **germinated** in coarse, well-drained material made up of a mixture of sand and potting mix; other material can include vermiculite or perlite – two inert materials. When plants become established the potting mix is often changed to one that allows some water to remain, so that the plant does not dry out rapidly. Plants need a lot of water, and sphagnum peat moss or ordinary peat moss may be used in the mix.

Rapid changes in temperature may cause slow growth in the early stages of plant growth; later, disease becomes the main problem. Because of the high-moisture environment in a glasshouse, fungal diseases often cause large losses. To control this, a fungicide spray is used. Invertebrates such as snails and slugs may need to be controlled by the use of other chemicals.

Plants that have been established in a glasshouse often need to be ‘hardened off’ so that they can be successfully grown outdoors. The most common way of doing this is to transfer the established plants into a shadehouse. Shadehouses are covered with special shade cloth designed to produce various levels of shade ranging from relatively dark conditions to almost full sun. By gradually moving plants through such shadehouses they become hardier and can eventually be easily planted outside.

There are a number of common causes of seedling loss in glasshouses. These include planting too close or too deeply, forgetting about the plants, under- or over-watering, disease problems, rapid temperature changes and poor ventilation.

Using a hydroponics system

Some growers periodically soak young plants in nutrients. The seedlings or cuttings are supported in fibre wool and jiffy or peat pots. Growing plants without soil in this manner is called hydroponics. Figures 20.7a and b show the main features of a glasshouse hydroponic system.

- 4 List three possible building structures in which plants can be grown.
- 5 List three ways plants can be grown inside glasshouses.
- 6 Refer to Figure 20.3 and draw a diagram showing the features of a glasshouse.

- 7 Why do plants need to be hardened off?
- 8 List the main reasons for plant death in glasshouses.
- 9 Describe two main features of a hydroponic system.

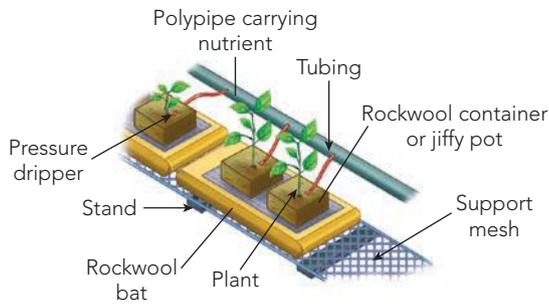


Figure 20.7a A glasshouse hydroponic system



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Figure 20.7b Growing lettuce hydroponically in an experimental glasshouse



Shutterstock/pan_kung

Figure 20.7c The hydroponic setup

Seedlings

Growing seedlings is a major part of the floriculture industry. Seedlings are usually annuals, grown to a size that can be easily transplanted. They are sold in containers that may or may not have internal compartments, although the trend today is towards putting individual seedlings in their own cells (Fig. 20.8). Plants produced this way are more advanced and transplant well. Other common containers consist of a few individual moulds, which allow the seedlings to be pricked out for easy transplanting.

Both flower and vegetable seedlings are produced and they require careful watering and fertilising. Because so many plants are grown close together, if a disease develops losses are significant. Careful application of chemicals is needed to prevent excessive loss.

Transplanting seedlings

It is necessary to **transplant** seedlings when they become too big for their container, or when they are to be placed into a garden. Transplanting must be carried out carefully because damage to the plant root system could kill the plant. Figure 20.9 illustrates the steps involved.

Take care when easing the plant out of its container. Remove excess roots and gently spread them, trying to leave as much of the original material around the roots as you can. Gently place the plant into the new container or hole in the ground, and cover the roots with soil. Firm down the soil, so that no air pockets remain around the root system. Lightly water, and in a week or two fertilise the soil with a complete liquid fertiliser



Shutterstock/Tanawat Pontichour

Figure 20.8 Large seedling containers

at half-strength concentration. If the transplanted seedling is very leafy or if the conditions are hot and dry or windy, remove some of the leaves (Fig. 20.10). This prevents excessive water loss from the plant.

Potted plants

The main types of potted plants grown are the flowering forms or those with attractive leaves. There is also a recent trend towards growing native plants. Plants are produced for their colour, form and the traditional consumer demand. Most potted plants are grown from cuttings. Growers buy cuttings from propagation specialists because they guarantee plant quality, uniformity of sample and, most importantly, freedom from disease and insect damage.

The plants are grown in a range of media and all have special light and temperature requirements. This is most important when the plant is to be sold to the public in flower. To guarantee large, quality flowers, growers **disbud** many plants – only one bud is allowed to develop per stem and all other buds are removed. This is sometimes termed ‘pinching’. It allows the plant to then channel all of its nutrients into the development of these single buds.

When growing potted plants it is important to have sufficient shelf space to prevent overcrowding (Fig. 20.11). All plants need to obtain enough light and water, otherwise the shape of the plant may suffer and this could make it unsuitable for sale.

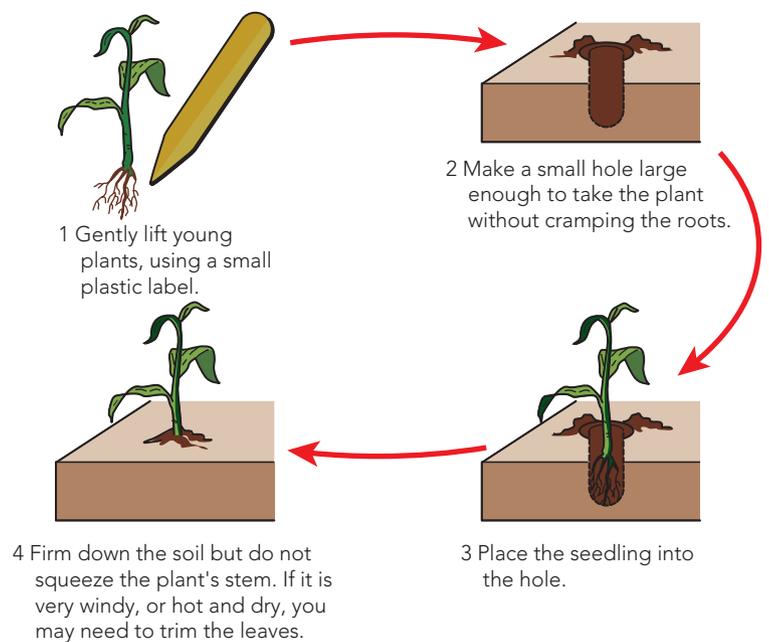


Figure 20.9 Transplanting seedlings

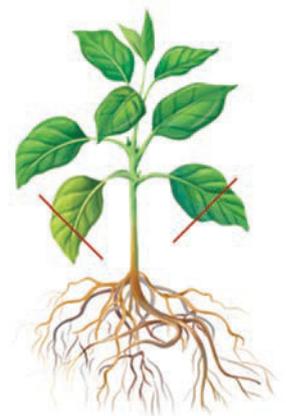


Figure 20.10
Deleafing

- 10 Describe the correct way to transplant seedlings.
- 11 Define ‘disbudding’.



Shutterstock/lakov Filimonov

Figure 20.11 Pot plants need sufficient space to grow to prevent overcrowding.

Cut flowers

Growing flowering plants to supply the cut-flower market is another profitable aspect of the horticulture industry.

Cut-flower production systems require careful monitoring for disease problems and to meet the nutrient requirements of the plant. To maintain a suitable growing environment for the plant, many producers use a range of special instruments to monitor such things as soil water levels, glasshouse temperatures and soil acidity levels (Fig. 20.12).

Flowers are usually cut with long stems, early in the morning. Flower buds that are just starting to open are selected, and flowers are graded for quality and stem length. They are then bunched (e.g. with carnations each bunch contains 10 flowers). Once bunched, the flowers can be stored in containers of water and other chemicals to encourage the slow opening of the flowers and to increase shelf life. Flowers are then taken to retail outlets or local markets and sold through agents. When too many plants are available on the market, some growers attempt to cold store the buds. Carnations can be stored for up to 6 months in this way. When taken from cold storage the buds are persuaded to slowly open up, and are then sold while the market price is more attractive. This technique is also used to ensure supply for times when there is a high demand for cut flowers, such as Mother's Day or Valentine's Day.

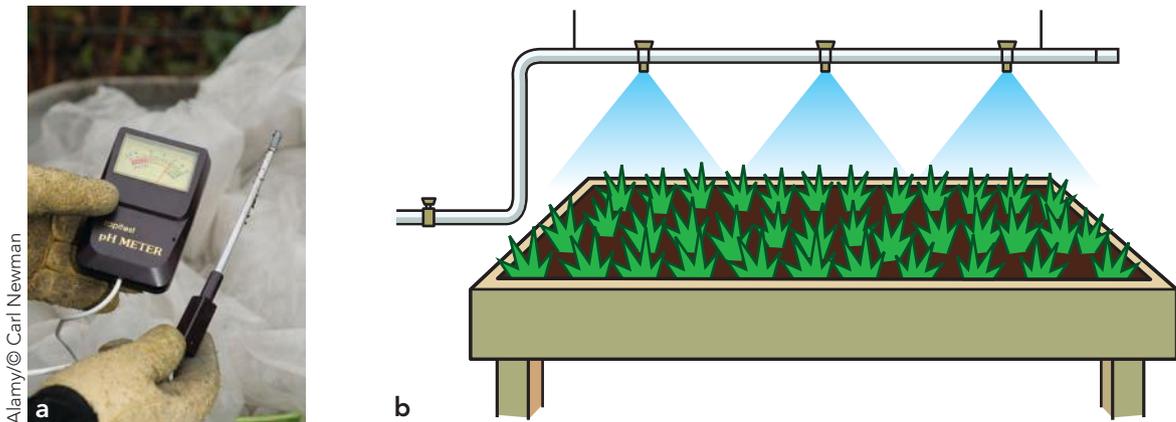


Figure 20.12 Glasshouse equipment **a** pH meter and **b** misting system for plant propagation

Marketing flowers

connect

Exporting cut flowers

12 List and describe the steps involved in marketing flowers.

The **traditional flower industry** is based mainly in the Sydney region, which extends from the Central Coast just north of Sydney, down to the South Coast, and west to the Blue Mountains, where the climate allows year-round production of a wide range of flowers. Flower growers are also located elsewhere in the state, including the North Coast, Southern Tablelands, and several centres further inland.

Most of the flowers produced are sold on the domestic market, mostly through the Sydney Flower Market at Flemington, Sydney. Growing flowers for commercial purposes close to metropolitan Sydney has a number of advantages:

- Consumers and florists have the opportunity to buy a wide variety of fresh flowers direct from the grower.
- Flowers can be transported in water, which can enhance vase life and reduce damage associated with packaging.
- Local marketing reduces the need for packaging (and its recycling) associated with transporting flowers over long distances.

- The industry can recycle urban and industrial waste products in the production cycle. This helps reduce the amount of waste products sent to landfills and treatment works.
- The industry is part of a large horticultural/agricultural industry that enhances the scenic/aesthetic aspects, as well as the amenity value and cultural diversity, of Sydney's rural fringe, and provides green space.
- The metropolitan location of farms also allows efficient handling and transport of flowers destined for other domestic and export markets.

There are major flower exporters located in and around Sydney who target key markets in Japan, South-East Asia, Europe and North America.

With potted plants the growers usually sell to a wholesaler. **Wholesalers** often develop a specialised range of products for sale to the retail industry. The main outlets for wholesalers include landscapers, nurseries, florists and retail stores. These outlets market the plants to the public and must clear their stock rapidly because plants age and become pot bound. The maintenance required on older plants also becomes more involved and costly.

Retailers attempt to attract the public through effective advertising, attractive packaging and other dynamic marketing techniques. Certain types of plant are also marketed at particular times of the year (e.g. chrysanthemums are always available on Mother's Day and roses on Valentine's Day).

Chapter review

Things to do

- 1 Study the process of germination.
Find a container about 8cm deep and fill it to within 1 cm of the top with a coarse medium such as a sand–soil mix. Even this out, and firm it down. Sow in some seeds thinly and evenly. With small seeds you may need to mix them with sand so that an even spread is obtained. Store any remaining seed in a sealed container in a cool, dry place. Once the seed is sown, lightly cover with sand, or a medium such as perlite. Very small seeds may not need to be covered, just lightly mixed with the top soil. Do not bury the seeds, because they may then germinate without ever reaching the surface. Generally plant a seed to a depth of 2–3 times the diameter of the seed. Moisten the seed but do not over-water. Cover the container with a piece of glass or clear plastic and place it in a dark area if possible. The plastic or glass helps to maintain the moisture levels and the darkness encourages germination.

Leave the container for a few days, but be ready to move it as soon as you notice young shoots. If the plants are left to grow in areas that have a low light intensity they form long thin stems and fall over easily when transplanted.

Once the plants have formed 3–4 leaves, they need to be lifted or pricked out. This requires care and patience, with each seedling being placed into individual containers or punnets. The new medium should be a heavier mix designed to retain water. Make a small depression in the medium and place the plant in it. Gently firm down the soil, taking care not to squash the stem. Keep these newly established seedlings in the shade for a few days to prevent them from drying out.

Things to find out

- 1 Discover what the following potted plants look like, and draw them.
 - a Pilea
 - b Mimosa
 - c Piggyback plant
- 2 Find out what a bonsai is and how they are grown. Write a short description in your notebook.
- 3 Discover how to dry flowers. Try to dry some, such as paper daisies or statice.
- 4 Find out what a terrarium is, and draw the plans for one in your notebook. Describe how it works.

Extension activities

- 1 Explain the way a greenhouse works to enhance plant growth. Describe any design modifications you could make to improve the effectiveness of a traditional glasshouse/greenhouse.
- 2 Explain the reasons a producer may choose to use a hydroponic system.

- 3 Research the impact Australian wildflowers may have on European cut-flower markets. Is this a future viable option for horticulturalists? Explain your reasons.

✓ Test yourself

- 1 Describe the main aspects of the horticultural industry.
- 2 Outline how a glasshouse-based production system is managed.
- 3 Compare the management system for growing cut flowers with that for growing potted plants.

CHAPTER 21

ORCHARD CROPS

Words to know

budding a form of grafting, where a dormant bud is transferred from the scion into the bark of the rootstock of another related plant type; the bud forms a shoot if the tissues of the scion and the rootstock grow together

crosspollination pollination between flowers of different plants of the same species; in fruit trees from one variety to another

grafting the union of tissue of two different plants of the same species

set when, as the result of pollination, the fruit in the flower starts to develop and does not fall off the tree when flowering is over (fruit that is not pollinated usually falls and is lost)

variety a plant within the same species that differs genetically and therefore has different characteristics such as disease resistance. Other examples include fruit tree varieties such as Pink Lady, Granny Smith, Delicious and Jonathan apples

Introduction

Orchard crops grow as trees, and they include all the fruit crops we are familiar with, such as apple, peach and orange. During planting the trees are set out in an orderly way so that the farmer can easily carry out all the husbandry operations on them to ensure good production. The fruit produced by orchard crops is considered to be a very important part of a healthy diet, providing vitamins, minerals, fibre, carbohydrates and some proteins. (Fruit is very tasty and enjoyable to eat, too!) Table 21.1 lists the fruit crops grown in large quantities in Australia, but many other fruit crops are also grown.

Some fruit produced by farmers is sold as fresh fruit; some is processed before it is marketed. A considerable amount is exported to markets as far away as Europe.



Dilibrary



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Figure 21.2
Processed fruits

- 1 Why is fruit considered an important part of a healthy diet?
- 2 List three ways in which the fruit from a farm may be used.



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Figure 21.1 Fruits commonly available in Australia

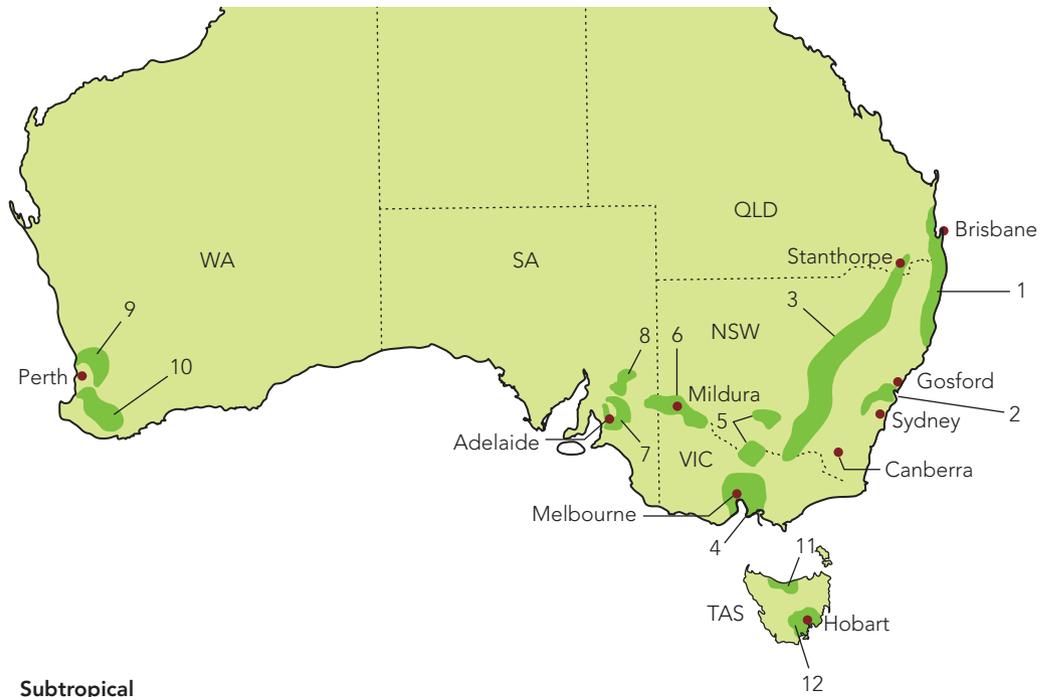
Examples of types of fruit processing (Fig. 21.2) include:

- juicing
- canning (peaches, apricots, pears, cherries, passionfruit)
- drying (grapes, apricot, pear, peach, apple)
- fermenting (grape and apple juice to produce wine and cider).

The major fruit production regions in Australia are restricted to certain areas (Fig. 21.3). The reason for this is that, for optimal production, fruit crops have climatic requirements. Some of the fruit-producing regions are in irrigation areas.

Table 21.1 Important Australian fruit crops

Pome fruit	Apple, pear
Citrus fruit	Orange, mandarin, lemon, grapefruit
Stone fruit	Peach, apricot, nectarine, plum, cherry
Tropical fruit	Avocado, banana, mango, pawpaw
Vine fruit	Grape, passionfruit
Olives	



Subtropical

Region 1 Coastal fringe, southern Queensland to mid-New South Wales – bananas, pineapples, avocados, pawpaws, passionfruits

Temperate

- Region 2 Gosford – Sydney, coastal fringe – citrus, deciduous fruits, grapes
- Region 3 Tablelands, southern Queensland to Victoria – all deciduous fruit, grapes – apples and pears principal crops
- Region 4 Melbourne – deciduous tree fruits, lemons, passionfruit
- Region 5 Murrumbidgee Irrigation Area and Goulburn Valley – apricots, peaches, pears, apples, grapes, citrus, prunes
- Region 6 Lower Murray River Valley – grapes, citrus, stone fruits
- Region 7 Adelaide – apples, pears, cherries, deciduous fruit, citrus
- Region 8 Barossa Valley – wine grapes
- Region 9 Perth – grapes, citrus, stone fruits, apples, pears
- Region 10 South-west Western Australia – apples and pears
- Region 11 Northern Tasmania – apples, pears, plums
- Region 12 Southern Tasmania – apples, pears, plums, apricots

Figure 21.3 The main fruit-growing areas of Australia

Growing orchard crops

3 Explain why fruit trees are produced by budding and grafting.

Fruit trees required for planting in orchards are grown in nurseries by **budding** or **grafting**. The kind or **variety** of fruit tree required is grafted onto a plant that has grown from a seed or cutting. The plant that is grafted or budded onto the other plant is known as the scion. The plant that receives the graft or bud is known as the rootstock (Fig. 21.4). Fruit trees are produced in this way for two reasons, to ensure that:

- the fruit tree produces the variety of fruit wanted
- the root system is vigorous and resistant to disease.

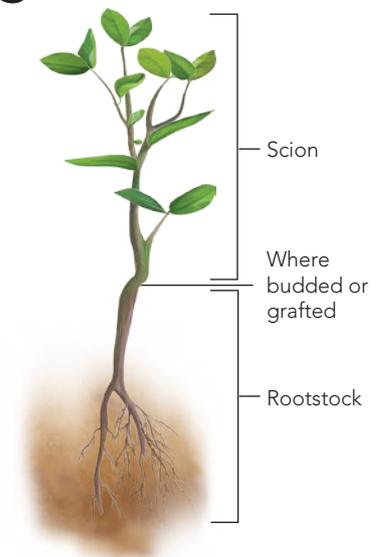


Figure 21.4 Parts of a young fruit tree

Planting

The spacing of trees in an orchard is very important. There has to be enough room between the trees for them to grow and produce good fruit. There also has to be sufficient space for the farmer to carry out all the husbandry operations and to harvest the fruit when it is ready.

The spacing between rows of trees is 6–9 m while the space between trees in the row is 3–7 m. The trees can be planted in a number of different systems, as shown in Figure 21.5.

When planting the tree it is important to have the point where the scion and rootstock meet placed well above the ground and the roots well spread out. A planting board helps position the tree exactly where you want it. Figure 21.6 shows how the planting board works.

Some fruit crops will not produce fruit unless two varieties are being grown very near each other. This is because **crosspollination** is required before the flowers will **set** fruit. (For example, Granny Smith apples will not produce fruit unless another variety of apple, such as Delicious, is grown with it.)

- 4 Why is it important to space fruit trees carefully when planting them in an orchard?
- 5 Why are two varieties of fruit tree grown in separate rows next to each other?

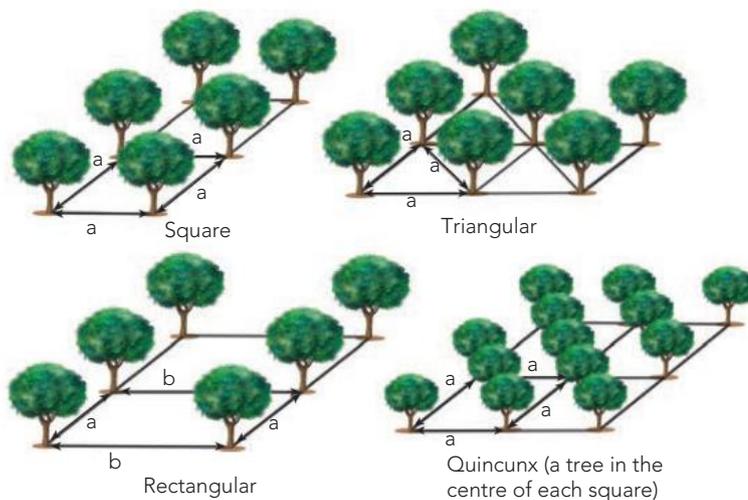


Figure 21.5 Four systems for tree planting



Figure 21.6 Planting a tree with a planting board

Fertilising

6 What nutrients do fruit trees most need?

Fruit trees require a good supply of plant nutrients, most commonly nitrogen, phosphorus and potassium. Farmers use a complete fertiliser combining these three (NPK) to provide these nutrients. This fertiliser is applied in autumn and spring. Organic fertilisers such as blood and bone, poultry manure and Dynamic Lifter may be used to supply not only nutrients but also organic matter, which is beneficial to the physical fertility of the soil. Zinc is a nutrient required in very small amounts and is often applied to fruit trees as a spray, with the zinc being absorbed through the leaves.

The amount of fertiliser applied depends on the type of soil, the age of the trees and what nutrients have been applied in the past. For citrus trees a general rule of thumb is to apply 500 g of NPK fertiliser for each year of age up until 10 years for each tree. For example, a 6-year-old tree would receive 3000 g of fertiliser.

Controlling pests

Every type of orchard crop is affected by some pest: insects such as aphids, bugs, flies, moths and scale insects; arachnids such as mites; and molluscs such as snails.

Queensland fruit fly

One very important insect pest is the Queensland fruit fly, which attacks many different kinds of fruit. After mating the female lays eggs in the flesh of the fruit, just under the skin. The eggs hatch into larvae (maggots) that burrow through the flesh as they feed, making the fruit unmarketable. The fully fed maggots drop to the ground and burrow into the soil where they pupate; after some time the adults hatch and search for a mate to continue the cycle. Controlling this pest is difficult; in the areas where it occurs, fruit crops have to be sprayed regularly with systemic insecticides as the fruit forms and harvesting approaches. Care must be taken to allow for sufficient time between the last application of insecticide and harvesting for the withholding period of the chemical to pass. All fallen and unharvested fruit must be collected, placed in plastic bags and left in the sun for 3 days to kill the fly.

In areas of southern Australia not inhabited by the fruit fly, fruit from infected areas is prohibited. This area, known as the Fruit Fly Exclusion Zone, spans three states: New South Wales, Victoria and South Australia, comprising the fruit-growing areas of the lower Murray–Darling basin, including the Goulburn Valley.

Citrus leaf miner

Another insect pest is the citrus leaf miner. The larvae of this moth tunnel their way between the upper and lower surfaces of the young leaves of citrus trees – hence their name. An integrated control program has been developed that involves the timing of fertiliser application and using a low impact spray. Fertiliser that stimulates new growth is only applied at a time in spring when moths are few, so infestation is low. Citrus make another flush of new growth in late summer and autumn when there are likely to be more moths about, laying eggs. If fertiliser is not used then this growth is reduced and so is the likelihood of infestation. During this time the trees are sprayed every 2 weeks with light mineral oil, which makes the leaves unattractive to the egg-laying moths. This has to be done every 2 weeks to ensure any new leaves are protected.

Controlling disease

Every type of fruit crop is affected by at least one disease and quite often by more than one. These diseases are caused by fungi, viruses, nematodes and bacteria, but the fungal diseases are the most important.

Brown rot

Brown rot is a fungal disease of stone fruits. It attacks ripening fruit, starting as small brown spots that spread rapidly and cause the fruit to go mushy and brown. The infected fruit soon produces masses of brown spores that spread the fungus. The infected fruit finally shrivels up and becomes mummified. Control involves a fungicide-spraying program that starts at bud swell (when the buds begin to expand in late winter and spring), continues at full bloom, petal fall (when petals fall off flowers) and shuck fall (when the remains of the flower above the fruit drop off). The last spraying is carried out 1 week before harvest. All infected fruit, mummified fruit and prunings should be removed and destroyed, because they are the source of infection for the next year.

Collar rot

Collar rot is a fungal disease of citrus. It attacks the trunk at ground level and kills the bark, effectively ringbarking the tree and causing it to die. The main way to control this disease is to plant trees that have a rootstock resistant to collar rot. One such rootstock is *Trifoliata*. Preventing the build-up of organic matter such as grass and weeds round the trunk will reduce the probability of attack because the moist conditions that favour the fungus will not occur.

Dealing with outbreaks

When pest or disease outbreaks occur, it is important that control action is taken quickly. To help with this Property Identification Codes (PICs) are being introduced in Victoria, first for grapes and then other crops. These codes will assist the Department of Environment and Primary Industries to respond to pest and disease outbreaks. This is so that property owners are informed earlier about disease outbreaks and any treatment that must be carried out so disruption to trade is minimised.

-
- 7 Identify three pests or diseases of fruit trees and outline a method of control for each.

Irrigation

For best results, fruit crops require abundant water, so it is very common for orchards to be irrigated. Furrows are often used to apply irrigation water to crops, because they allow water to flow down between the rows of trees. However, interest has been growing in recent years in less wasteful irrigation methods. Newer irrigation systems use drippers and micro-jets at each tree, rather than simply spreading water everywhere – the water is applied where it is needed, at the plant roots.

-
- 8 Why are drippers and micro-jets being increasingly used for irrigating fruit trees?

Pruning

Almost all fruit crop trees are pruned. This involves cutting stems and branches out of the tree. Fruit trees need to be pruned for two reasons:

- 1 to remove dead, damaged and diseased wood from the tree, because diseased wood can spread disease, and dead and damaged wood could also injure the developing fruit
- 2 to shape the tree and encourage both the production of blossom and the maturing of a reasonable amount of good-sized fruit.

-
- 9 Why are fruit trees pruned?

Secateurs and pruning saws are the basic tools used in pruning. The job has been made much easier with the introduction of machines, such as pruning shears driven by compressed air, and motorised hydraulic pruning platforms, which do away with awkward ladders.

Harvesting

Most orchard crops are still harvested by hand. The fruit is picked into canvas bags carried by the picker and then emptied into bins or boxes. Labour is expensive, so considerable attention has been given to developing machines to do the job. In the packing shed the fruit is graded for size and quality and packed into boxes ready for transport to market. Laser technology can be used to grade fruit for size and quality. Many fruit farms have installed cold rooms to store fruit, allowing it to reach the markets and consumer as fresh as possible.



iStockphoto/© 1001nights

Figure 21.7 A fruit stall in a supermarket

Marketing

Farmers sell their fresh fruit through selling agents in the produce markets in the capital cities. It is purchased by greengrocers, suppliers to restaurants and hotels, and supermarket chains. The consumers purchase their fruit from these outlets. Some large supermarket chains purchase directly from farms, bypassing the produce markets by arranging contracts with producers.

Fruit production is seasonal. The first fruit of a particular type to reach the market usually brings the farmer a very high price. As the season progresses, more and more of that type of fruit comes onto the market and the price goes down considerably. For this reason, researchers are developing techniques that allow fruit to be stored for long periods of time so the supply can be spread out and the price to the producer is better. One of

the first methods tried was storage at low temperatures using refrigeration. Work is now being done on controlled-atmosphere storage. As well as keeping the fruit cold, the level of carbon dioxide or nitrogen in the atmosphere is increased in the storage area, slowing down the chemical reactions in the fruit and making it last longer. Apples and pears have been successfully stored in this way.

Improvement in road, rail and air transport has meant that fruit can be transported to markets over large distances very quickly; for example, fruit grown in Queensland can be marketed in New South Wales, Victoria and South Australia. Each state has different growing seasons, so various types of fruit can be on the market for longer periods of time.

Fruit is also grown and sold directly to processors such as canneries and juice manufacturers. Processed fruit and juice keeps for a long time and is available all year round.



Shutterstock/Sally Scott

Figure 21.8 A truck transporting fruit

- 10 How are most fruit crops harvested?
- 11 Describe three different ways that fruit can pass from the orchard to the consumer.

Chapter review

Things to do

- 1 Examine fruit trees on the school farm and identify the point where the scion was grafted or budded onto the rootstock.
- 2 Look for signs of pests and disease on the school fruit trees. Try to identify any that you find.
- 3 Have a fruit tasting in your class. Each person should bring a different type of fruit or fruit product (some bring fresh fruit, others fruit that has been processed in some way; e.g. juice or canned or dried fruit).
- 4 Plant some fruit trees in the school farm and care for them.
- 5 Visit a fruit shop or supermarket and make a list of all the different types of fruit that are on sale. Make a note of the season.
- 6 Design and conduct a simple survey to find out where people buy their fruit – the supermarket or the fruit shop – and why they buy it there.

Things to find out

- 1 What orchard crops could be grown in your area? Would the crop have special requirements (e.g. irrigation)?
- 2 Visit the [Horticulture](#) website. Select one orchard crop such as apples or citrus as an example and prepare a report on what varieties are available and how combinations of varieties enable production periods to be extended throughout the year.

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Horticulture

Extension activities

- 1 You are now able to buy a single citrus tree that bears lemons, oranges and grapefruit. You can also buy a stone fruit tree that has plums, peaches and nectarines on it. Explain the management and genetic principles behind the development of such plants.
- 2 Research an emerging orchard crop such as olives. Why is there interest in the development of this crop? What marketing options are available to farmers for this crop?
- 3 Visit the [Horticulture](#) website. For a nominated orchard crop, research:
 - a three common diseases for the crop.
 - b the effect of each disease on the plants.
 - c the control methods used for the disease.

Test yourself

- 1 Describe the steps involved in planting and managing an orchard.
- 2 Explain the difference between the processes of budding and grafting.
- 3 Discuss the marketing of a named orchard crop.

CHAPTER 22

CANOLA

Words to know

- aluminium toxicity** a toxic effect on crop plants caused by the aluminium that is available in the soil
- broadleaf weeds** weeds that belong to the dicotyledonous group of plants
- canopy** the leaves and stems of a plant
- crusher** the business that purchases the crop and extracts the oil from the grain
- early maturing** varieties that have a short growing period and reach maturity in fewer days than other varieties
- emergence** when the germinating seedling breaks through the surface of the soil
- establishment** when a seedling has emerged and starts to photosynthesise, thus becoming self-sufficient
- exchangeable aluminium** aluminium ions in the soil that are available and can be taken up by the plant roots
- fatty acids** organic acids made of chains of carbon atoms with an acid group attached
- friable** soil that has a good structure and easily crumbles; it is well aerated and drained
- herbicide tolerant** varieties of the crop that are not affected to any extent by the herbicide
- irrigate up** process of germinating and establishing a crop using irrigation, not relying on rainfall
- late maturing** varieties that have the longest growing period; taking longer to reach maturity than other varieties
- meal** the protein-rich remains after the oil from the seed has been removed by crushing
- post-emergent** a herbicide that is applied to the crop after it has emerged from the soil
- pre-emergent** a herbicide that is applied before or at sowing, before the sown crop emerges from the soil
- sodic clay** a clay soil that contains a lot of sodium ions and disperses easily when it becomes wet
- stubble** the stems that remain after the crop has been harvested
- subsoil moisture** moisture stored deep in the soil that can be accessed by crop plant roots (e.g. 80 cm of subsoil moisture means the soil has moisture available to the plant to a depth of 80 cm)
- variety** a plant within the same species that differs genetically and therefore has different characteristics such as disease resistance. Other examples include fruit tree varieties such as Pink Lady, Granny Smith, Delicious and Jonathan apples
- windrowing** cutting the top parts of the canola plants that have the seedpods on them and placing them into rows on top of the cut stubble

Introduction

Canola is a winter-growing oilseed crop. It is a relatively new crop for the southern farming areas of Australia, first grown in 1969. Australian canola crops are used for vegetable oil and as a source for biofuel. After initial success, problems with the fungal disease blackleg caused canola to fall out of favour. Now, with the breeding of disease-resistant varieties and its usefulness in crop rotations with pastures, legumes and cereals such as wheat, canola has become a significant crop. Australia no longer imports canola, instead exporting 75 per cent of the annual production of approximately 1.6 million tonnes. Canola is the largest oilseed crop in Australia (Fig. 22.1), producing 57 per cent of the oilseed crop, followed by cotton. Western Australia has the largest area under canola. Table 22.1 shows the production and area harvested for each state.

Table 22.1 Canola: area and production by state 2013–14

State	Area planted ('000 ha)	Production ('000 tonnes)
New South Wales	550	880
Victoria	390	624
South Australia	250	350
Western Australia	1 100	1 430
Total	2 290	3 284

Used with permission of Australian Oilseeds Federation Inc.

Canola is used for oil and protein (Fig. 22.2). Approximately 40 per cent of the seed is oil, although the amount varies with the conditions under which the crop grows. The oil that is removed from the seed by crushing is used in cooking, salad oils, shortenings and margarine. Canola oil, like any vegetable oil, is made up of **fatty acids**. The predominant fatty acid in canola oil is oleic, which is monounsaturated. Plant breeders have virtually eliminated the unhealthy erucic acid from Australian varieties and have increased the level of linoleic and oleic fatty acids. These unsaturated fatty acids are recognised as being useful in healthy human diets. Canola oil has the lowest level of undesirable saturated fats (6 per cent) of any of the vegetable oils.

The remains of the canola seed after crushing is called **meal** and it contains 36–39 per cent protein. It also contains carbohydrates, minerals and fibre. It is used as an ingredient in stock feeds, mostly as a source of protein.

Australian production of canola has increased dramatically over the past 5 years.



Shutterstock/Phillip Minnis

Figure 22.1 A canola crop in the wheat belt of New South Wales

- 1 Use the information in Table 22.1 to calculate the average yield per hectare for each state and for Australia overall.
- 2 Identify the two uses of canola.
- 3 Describe how plant breeders have changed canola since it was first grown in Australia.
- 4 List the percentage of the seed that is oil and the percentage of protein in the meal that is left after crushing.

Climatic requirements

Canola is grown mainly in the winter–spring season, similar to cereals such as wheat, barley and oats. In regions above 800 m, some crops are grown in spring. Canola is not as drought tolerant as cereals and therefore requires a high and reliable rainfall. Good winter rainfall or stored **subsoil moisture** (80 cm–1 m) is required for the crop to grow without restriction until the end of flowering. Further rainfall in spring is needed to achieve the maximum yield. Seedlings can be damaged by frost but this is rare. As the crop grows it becomes more frost tolerant. Major losses can be caused by a late frost when the crop has finished flowering – the seeds shrivel in the pods.

Canola is grown in the higher rainfall areas of the wheat belt and in irrigation areas with yields in the range of 2.0–2.5 tonnes per hectare. It is grown in the lower rainfall or marginal cropping areas provided there is good subsoil moisture and it is planted before May, with average yields of 1.3–1.5 tonnes per hectare.



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Figure 22.2 Products that contain canola oil

Lifecycle of the canola plant

Canola is an **annual plant** and two species are grown in Australia: *Brassica napus* and *Brassica campestris*. The majority of crops are *Brassica napus*. There are seven stages in the lifecycle of the plant.

- 1 Germination and emergence
- 2 Leaf production
- 3 Stem extension
- 4 Flower bud development
- 5 Flowering
- 6 Pod development
- 7 Seed development

It is important for canola growers to recognise the beginning of each stage because critical management decisions have to be made at these times. Remember that the stages overlap and the beginning of each stage from budding is determined by what is happening on the terminal or main stem.

Germination and emergence

Germination and **emergence** occurs when the seed absorbs moisture from the soil and swells (Fig. 22.3). The root (radicle) emerges, splitting the seed coat. The shoot (hypocotyl) pushes the cotyledons to the soil surface and as it does the seed coat drops off. Once in the light the cotyledons spread out and become green.

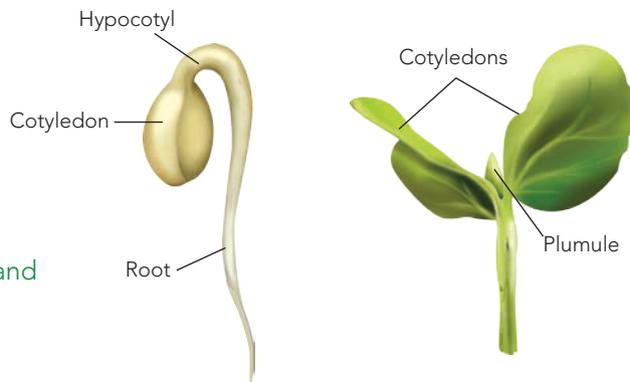


Figure 22.3 Germination and emergence

- 5 At what times in the growing of a crop is rainfall needed to ensure the success of the crop?
- 6 When can frost cause the most loss of production?

Leaf production

The plant produces 10–15 leaves (Fig. 22.4), and some of the older leaves may drop off. The number of leaves produced is an indicator used to determine when certain management practices should be carried out, such as spraying pests and weeds. A leaf is counted when the majority of its surface is exposed to light.

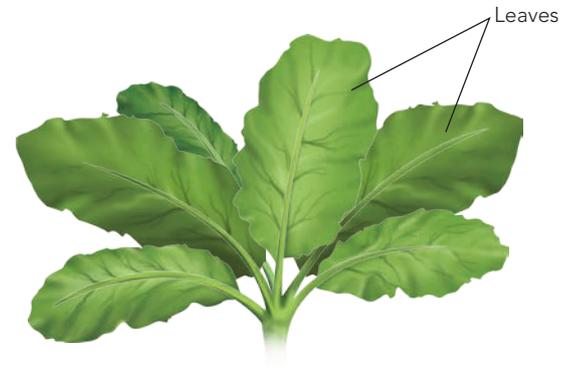


Figure 22.4 Leaf production

Stem extension

In this stage the internodes extend and thus the stem elongates. An internode is a part of the stem between two nodes, and a node is where a leaf is attached to the stem. A well-grown canola plant has 10–14 internodes.



Figure 22.5 Stem extension

Flower bud development

The flower buds develop on the ends of the stems. At first they are clustered together, surrounded by leaves and cannot be seen without peeling back the young leaves. As the stem emerges, the buds can be seen from above and are still surrounded by leaves. This is the 'green bud stage'. The stem further elongates, pushing the buds above the leaves. The stalks of the lower buds extend and these buds are the first to become yellow. This is the 'yellowing bud stage'. The buds progressively turn yellow up the stem with the topmost buds yellowing last.

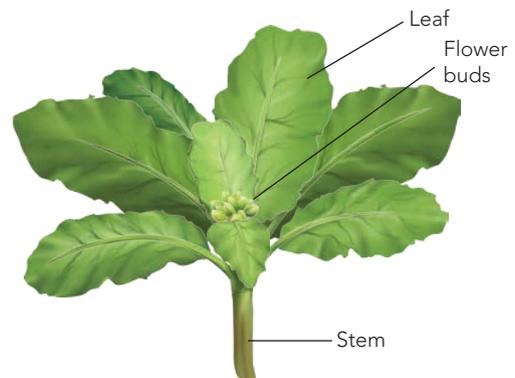


Figure 22.6 Flower bud development

Flowering

Flowering begins when one bud on the main stem opens and ends when no viable buds are left to flower.

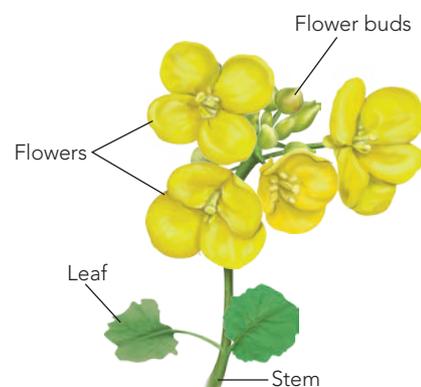


Figure 22.7 Flowering

Pod development

Pod development starts on the lowest third of the branches on the main stem.

Seed development

Seed development also occurs on the lowest third of branches on the main stem. There are several stages of seed development and they can be described by the seed colour.

- Seeds are present.
- Most seeds are translucent but full size.
- Most seeds are green.
- Most seeds are green-brown mottled.
- Most seeds are brown.
- Most seeds are dark brown.
- Most seeds are black but soft.
- Most seeds are black but hard.
- All seeds are black and hard.

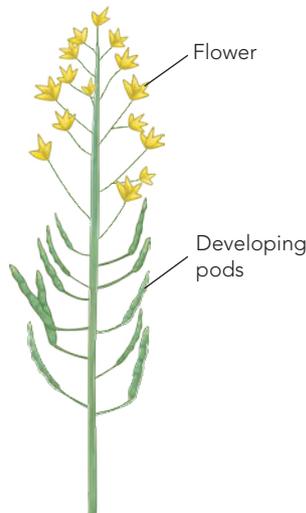


Figure 22.8 Pod development

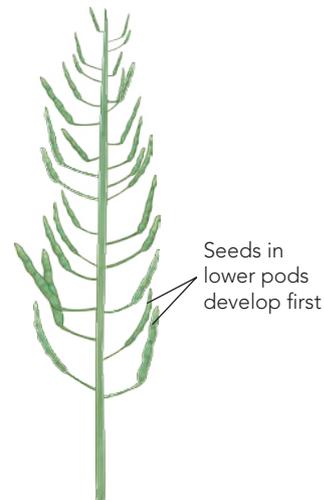


Figure 22.9 Seed development

- 7** Create a table that lists the stages of development of the canola plant and summarises what happens at each stage.

Physiological maturity

Farmers must be able to recognise when the canola plants reach physiological maturity because this indicates that the seeds have reached their maximum dry weight and the crop can be **windrowed**, which is the first step in harvesting. At this time 40–60 per cent of the seeds have started to change from green to their mature colour; they are green-brown mottled and brown. Most seeds are firm enough to roll between the thumb and forefinger without being squashed. The moisture content is 35–40 per cent. Over a 12-day period all seeds can transform from translucent to black. Windrowing too early will reduce the yield by 3–4 per cent each day. Some seeds will not have developed completely, and the oil content will also be reduced.

Harvesting can take place when the black seed moisture content is 9 per cent.

- 8** Explain why it is important to be able to recognise when physiological maturity occurs.

Varieties

Each year the Department of Agriculture in each state draws up lists of varieties that are recommended for growing in the coming cropping season. Factors to consider when selecting a **variety** from these lists are:

- maturity
- blackleg resistance
- yield
- oil content
- protein content
- herbicide tolerance.

Many varieties of canola are on the market, including genetically modified varieties. Genetically modified (GM) varieties of canola are herbicide tolerant, which reduces the number of sprays required to control weeds and therefore the production costs as well. GM varieties are also high yielding. The major negative impact of GM crops is the risk of transferring herbicide tolerance genes from GM crops to weeds. Marketing problems can also arise when crops become a mixture of GM and non-GM varieties as a result of wind dispersal of seed and pollen. This can occur up to 2 km between farms.

GM canola crops were approved for commercial release in Australia in Victoria and NSW in 2008. Western Australia followed in 2010. GM modified plantings represent 8.2 per cent of total canola plantings for 2012–13.

Organic markets and export markets are sensitive to the presence of GM material because of varying degrees of consumer acceptance between GM and non-GM products. The agricultural industry must consider the options for maintaining separate identities for conventional, organic and GM grains so that farming systems can co-exist and maintain the flexibility to respond to market needs. State regulations currently determine policies in these areas.

The variety of canola finally chosen for a particular paddock will be a compromise between all the following factors.

Maturity

The amount of rainfall in the area where canola is to be grown affects the maturity of the varieties selected. In lower rainfall canola-growing areas **early maturing** and early to mid-maturing varieties are recommended.

In higher rainfall areas mid-maturing and mid- to **late-maturing** varieties are recommended.

Blackleg resistance

Blackleg is the most important disease affecting canola. The Canola Association of Australia has an independent national system for rating all varieties for their resistance to blackleg. Table 22.2 shows the scale of 1–9, which indicates relative differences between varieties.

Table 22.2 Resistance to blackleg

Highly resistant	8–9
Resistant	6–7.5
Moderately resistant	5–5.5
Moderately susceptible	3–4.5
Susceptible	<3

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Blackleg in Canola

In areas with high risk of blackleg, select varieties that are rated at least 'resistant'; in lower blackleg risk areas, select at least 'moderately resistant' varieties.

Yield

Growers select the varieties with the potential to give them the highest yield for their particular situation.

Oil content

The price received for canola seed depends on the oil content. Seed with less than 42 per cent oil is discounted, and bonuses are paid for seed with more than 42 per cent oil. Growers select varieties that are capable of producing high quantities of oil.

Protein content

Seed with high protein content attracts higher prices, so growers should select varieties with potential for high protein content.

Herbicide tolerance

Canola varieties can be classified into the following three groups according to their tolerance to herbicides.

- 1 Conventional varieties with no tolerance to herbicides
- 2 Triazine tolerant varieties tolerant to atrazine and/or simazine herbicides
- 3 Clearfield® (imidazolinone tolerant) varieties tolerant to OnDuty® herbicide.

In general the **herbicide tolerant varieties** have slightly lower yields than the conventional varieties. Growers with particularly weedy paddocks may consider using herbicide tolerant canola, so that spraying the crop with herbicide controls weeds, providing a better yield.

Certified seed

With certified seed, growers are guaranteed a known purity and germination rate of the seed; they get the variety they selected; and there is little or no risk of importing weed seed (such as wild radish) onto the farm. A small proportion of the price of certified seed goes back to fund the breeding program developing new varieties.

Canola in crop rotations

Including canola in crop rotations has the following benefits.

- The yield of following cereal crops will be increased because they will be able to extract deeper subsoil moisture. Canola's deeper rooting will allow the cereal roots to go deeper in the soil.
- Because canola does not have the same root diseases as cereals, these root diseases will die out while the canola crop is growing. The cereal crop following canola will have less root disease and give a higher yield.
- Changing crops means different herbicides are used and this means there is less risk of weeds developing resistance to herbicides. There is also less accumulation of a specific herbicide in the soil.
- Canola's taproot system improves the structure of the soil. This means that the following cereal crop can be direct drilled into **friable** topsoil.

9 List the factors that must be considered when selecting a variety of canola.

10 Explain why 'maturity' is an important consideration when selecting a variety.

11 Explain why 'disease resistance' is an important consideration when selecting a variety.

Because canola is sown and harvested earlier than cereal crops, labour and machinery are used over a longer period of time.

The result of these benefits can be a more profitable and sustainable farm because:

- cereal crops are higher yielding than canola, and more profitable
- income comes from more sources
- machinery and labour is more effectively used over a longer period of time
- there is less competition for storing other grains on the farm because canola is delivered directly to the **crusher** for processing.

An ideal rotation that includes canola is shown in Table 22.3.

Table 22.3 An ideal rotation that includes canola

Year of rotation	Type of crop to be grown	Example of crop
1	Legume pasture	Clover
2	Broadleaf	Canola
3	Cereal	Wheat
4	Broadleaf	Lupins Field peas
5	Cereal	Barley

12 Outline three benefits of including canola in crop rotations.

13 Describe how crop rotation with canola results in a more profitable farm.

Selecting a paddock

Carefully consider all the options before choosing a paddock in which to grow canola, and take three factors into account: soil types, potential disease and **broadleaf weeds**.

Soil types

Highly fertile soil gives the best results with canola: the soil that grows the best wheat crops has the best canola crops. A paddock with uniform soil is desirable because sowing depth and crop ripening will be more uniform.

Soils with the following problems should be avoided.

- **Hardpans.** A hardpan is a compacted layer of soil not far below the surface that cannot be penetrated by the taproot of canola.
- **Waterlogging.** Canola does not like too much water. Waterlogging occurs where surface run-off accumulates and there is poor drainage in the soil. This may be caused by a **sodic clay** subsoil that is characterised by low permeability. A simple dispersion test can help identify this problem.
- **Crusting.** The surface soil loses its structure when it is wet – the aggregates disperse when wet and, as it dries out, a crust is formed on the soil surface. Emerging canola seedlings have difficulty penetrating this crust and do not establish.
- **Acidity.** Canola is affected by high acidity (low pH) and aluminium and should not be grown where the pH is 4.7 or less and there is 3 per cent **exchangeable aluminium** or more.

Potential disease problems

The fungal disease blackleg is the most important disease to consider. Almost all the spores that infest a crop come from the stubble of last year's crop, so a new canola crop should not be grown in a paddock that had a canola crop last year. Ideally it would be best not to grow another canola crop in a paddock for 4 years after the previous one. This may not be practical on many farms.

Weeds

-
- 14 List the factors that must be considered when choosing a paddock in which to grow canola.
 - 15 Outline two soil problems to avoid when growing canola.
 - 16 List the most important weeds affecting canola crops and explain why these weeds are of such concern.

The most important weeds are those that belong to the mustard family (Brassicaceae) – the same plant family as canola. Herbicides that control these weeds would certainly kill the canola crop. Weeds from this family include:

- charlock (*Sinapis arvensis*)
- wild radish (*Raphanus raphanistrum*)
- wild or Mediterranean turnip (*Brassica tourneforetii*)
- wild cabbage or hare's ear (*Conringa orientalis*).

As well as competing with the canola crop for moisture and nutrients, these weeds produce seeds that are very similar to canola seeds. If they are harvested with the canola, they contaminate the seed and the oil that is produced does not meet the quality standards required in the marketplace. Eliminate these weeds from a paddock before canola is grown.

Other weeds reduce yields through competition for resources.

The production cycle

-
- 17 What is required to ensure a uniform emergence and establishment of canola?

Above-average yields depend upon a uniform crop; that is, all the plants in the crop emerge at the same time and go through all the developmental stages together. Canola has a small seed relative to cereals such as wheat and barley, and it needs sufficient moisture and an even sowing depth to ensure a uniform emergence and **establishment**. Uniform establishment means greater profits because:

- uniform, quickly emerging seedlings deliver higher yields
- canola's ability to compete with weeds in the first 6 weeks is significantly improved
- there is even growth for insect control
- the crop ripens evenly and the timing of harvest is improved.

Preparing the seedbed

-
- 18 Describe how a seedbed is prepared using conventional methods.

With conventional cultivation methods the aim is to produce a seedbed that is fine, level, well consolidated and moist near the surface. The sequence of preparation should start with a deep cultivation to break up any hardpans. In following cultivations the depth is gradually reduced until the final cultivation before sowing is carried out at the depth the seed will be sown. Seedbed preparation should be completed by the end of March or early April.

A knockdown herbicide can be used instead of the final cultivation; this will reduce soil moisture loss because the soil is not disturbed. It is also the most effective killer of broadleaf weeds.

Direct drill and zero tillage techniques can be used to sow canola but weeds must be controlled using herbicides.

Sowing

-
- 19 Identify the row spacing and sowing depth for canola.
 - 20 Explain how sowing at the optimum time pays off.

The best sowing method is to drill canola seed into the soil, so the seed will come in contact with moisture and germinate uniformly. Seed is sown in rows 15–20 cm apart at a depth of 3–4 cm. It is important to place the seed at a depth where it will come in contact with moisture for germination. The machine most commonly used is the combine seed and fertiliser drill that is used for sowing other crops such as wheat. Canola can also be sown using broadcasting, an airseeder or aeroplanes.

The optimum time for sowing canola in the wheat belt is from mid-to-late April. When the crop is sown depends on when rain falls to provide moisture for germination and establishment. If canola is not sown by the end of May an alternative crop, such as a cereal, should be chosen instead. Sowing at the optimum time pays off in the following ways.

- The yield of seed and oil is higher because the crop finishes under cooler, moister, slow-maturing conditions.
- In the wheat belt, canola sowing and harvesting are kept well ahead of the busy wheat periods.
- Initially, crops grow more quickly, and therefore compete better with winter weeds.
- Crops have fewer problems with insect pests such as aphids in spring.

Sowing rate

The canola plant is very flexible in how it responds to the density of plants per square metre. If there are a few plants per square metre they develop more branches, grow bigger stems and produce more pods. When there are more plants per square metre the plants are smaller and have fewer branches and pods. Under similar environmental conditions both groups of plants produce approximately the same yield per square metre. Because of this, achieving a particular plant population density is not as critical as it is with crops such as maize. The recommended plant populations per square metre are:

- the higher rainfall areas of the wheat belt: 50–70
- irrigation: 50–70
- marginal areas: 30–50.

Many plant densities give good yields, but densities of less than 15 plants per square metre result in patchy, low yielding crops. A higher plant density is better because there is more coverage and therefore the crop is more able to compete with weeds. The recommended seeding rate is 3–4 kg per hectare (there are 250 000–350 000 seeds/kg). Individual seeds vary considerably in size, depending on the conditions under which the crop that produced them was grown (poor conditions such as drought give smaller seeds). Of the seeds sown, 40–60 per cent establish as growing plants. Table 22.4 shows the relationship between sowing rate, establishment percentage and the resulting number of plants per square metre, assuming 280 000–300 000 seeds/kg.

It is important to adjust and correctly calibrate the combine (seed and fertiliser drill) so that it sows seed at the desired rate before commencing sowing.

Table 22.4 Number of canola plants established per square metre from different sowing rates and establishment percentages

Sowing rate (kg/ha)	Establishment percentage		
	40%	60%	80%
3	34 plants/m ²	51 plants/m ²	69 plants/m ²
4	46 plants/m ²	69 plants/m ²	91 plants/m ²
5	57 plants/m ²	86 plants/m ²	114 plants/m ²

Coulton, R and Sykes, J.(1992) *Canola Agfact* P5.2.1 fourth ed. NSW Trade & Investment

21 Study Table 22.4. Describe what happens to the number of plants established per square metre when:

- the sowing rate increases.
- the establishment percentage increases.

22 What is the advantage of having a high plant density?

Controlling weeds

It is important to know the type of weeds that are likely to germinate in the paddock selected for canola, so that an appropriate weed management strategy can be planned. It is best not to use paddocks that have weed problems.

Effective weed control is essential in the first few weeks after emergence because canola seedlings do not compete very well during this time. After 6–8 weeks, when the **canopy** closes over, canola competes very well because the leaves of the plant shade the ground underneath, leaving weeds with little light.

Herbicides are used as well as cultivation and crop rotation to control weeds. The type of herbicide and the timing of application (a **pre-emergent** herbicide or a **post-emergent** herbicide) depend on the particular weeds that need to be controlled. Table 22.5 outlines this briefly. When using herbicides it is essential that all the manufacturer's directions found on the container are followed to treat the crop correctly and ensure the safety of both the operator applying the chemical and the environment at large.

In weedy paddocks effective weed control may be achieved by selecting one of the herbicide tolerant varieties of canola, triazine tolerant or Clearfield® varieties, and using the herbicides recommended for that variety.

Table 22.5 Herbicides used to control weeds in canola

Weeds controlled	Type of herbicide	Timing of application
Grass weeds	Pre-emergent	Just before sowing
Wild oat	Specific pre-emergent	Just before sowing
Volunteer cereals and grasses	Post-emergent grass	After establishment
Broadleaf weeds	Post-emergent broadleaf	After establishment

23 Explain why effective weed control is essential in the first few weeks after emergence.

24 Why does weed control become less important 6–8 weeks after emergence?

25 Write down two methods or management techniques used for controlling weeds in canola.

Nutrient requirements

Canola requires more of the major nutrients – nitrogen, phosphorus and sulfur – than cereals. Because most Australian soils are deficient in these nutrients, measures must be taken to ensure adequate supplies are given to the growing crop. To decide what types and rates of fertiliser to apply, the past history of the paddock and the results of soil tests should be considered. If the soil test results show that the acidity is pH 5 or less then there could be a problem with **aluminium toxicity**. Application of lime will be necessary to reduce the acidity.

Phosphorus

The amount of phosphorus fertiliser applied will depend on the current level in the soil. If there are high levels then it may not be necessary to apply any. In soils that are low in phosphorus apply 8 kg/ha of phosphorus for every tonne of grain expected to be harvested (so an expected crop yield of 2.5 tonnes per hectare would require 20 kg/ha of phosphorus). Phosphorus fertiliser is banded when it is applied; that is, the fertiliser is placed close to the seed in the soil. This is because phosphorus is very immobile in the soil and only spreads up to 1 cm from the fertiliser granule in the soil.

Nitrogen

Nitrogen is essential for high yields of canola. Soils that are used after several years of legume-dominated pasture may be high in nitrogen, but it is most likely that nitrogen fertiliser will be required. For each tonne of yield per hectare, canola requires 40–50 kg/ha nitrogen. Not all the nitrogen is applied at once; no more than 20 kg/ha should be applied with the seed at sowing and more can be applied later. Nitrogen should not be applied after bud formation, which occurs during July.



Figure 22.10 Canola responds well to increasing amounts of nitrogen (left to right)

Nitrogen fertilisers that could be used include urea, anhydrous ammonia and ammonium nitrate. The price of a kilogram of nitrogen from a fertiliser should be used as a guide in choosing the cheapest source of nitrogen. Urea is a commonly used fertiliser because it is cost-competitive, does not affect soil pH and it has a high percentage of nitrogen.

Sulfur

Sulfur is lost from the soil at about 20 kg per hectare when a canola crop yielding 2 tonnes per hectare is harvested. Canola uses much more sulfur than wheat and lupins, so sulfur fertilisers need to be applied to canola crops. Sulfur in the available sulfate form should be applied at 20 kg/ha. This may be increased in poorer soils or soils showing deficiency symptoms. It can be applied before sowing using gypsum; at sowing using single superphosphate; or during the vegetative phase as a top dressing of sulfate of ammonia.

Other nutrients

Other nutrients that may be deficient and reduce yields are boron, molybdenum and zinc. These nutrients are required at the following rates: boron at 1–3 kg/ha, zinc at 10–20 kg/ha, and molybdenum at 50 g/ha once every 5 years. There are various methods of applying these nutrients. Boron is combined with other fertilisers or applied as foliar spray mixed with insecticides, fungicides or herbicides. Zinc is broadcast and incorporated into the soil before sowing. Molybdenum is applied to the soil as a spray or mixed with seed or fertiliser at sowing.

-
- 26** List the major nutrients likely to be needed by the crop that are not present in sufficient quantities in the soil.
- 27** Describe two ways nitrogen can be made available for a crop.

Irrigating

The area of canola grown using irrigation has increased and yields of 3 tonnes per hectare or more are achieved. Irrigation systems most often used are raised beds and border check. Spray irrigation is also used.

Raised bed system

Using this system, the crop is grown in raised beds 1.5–2.0 m wide with the irrigation water running down between the beds. The water soaks into the beds, wetting the soil. Machinery and tractor wheels never run on the beds so compaction is reduced. Machinery has to be modified to operate this system successfully.

In April the seed is sown at a shallow depth and irrigation water is applied to germinate and establish the crop.

Border check system

The irrigation water is allowed to flood over the paddock, controlled by check banks. The land has to be levelled with a gentle slope so water is evenly distributed and excess water drains off. Irrigation is carried out before sowing in late March–early April and the seed is sown as soon as possible after that. If broadleaf weeds are a problem it is best to irrigate in February, apply herbicide, cultivate and sow after rain in April.

Crops are slower to establish after being **irrigated up** because the soil has a lower temperature. There is also a risk of waterlogging irrigated crops if there is a lot of rainfall in winter.

The crop is irrigated further in spring unless there has been sufficient rainfall. Canola has the highest water requirement during the period from stem elongation to the end of grain filling. It may be necessary to irrigate two or three times during this period. If irrigation water is in short supply it should be used to ensure moisture is available during flowering (late August–September).

28 Describe when irrigation is carried out if a crop is being grown under irrigation.

29 Calculate how many beehives would be required for 80 hectares of canola to achieve good pollination.

30 Identify the times in growing a canola crop when pests are most likely to cause problems.

31 How, and at what stage, do mites cause losses in the canola crop?

32 Explain why it is recommended that a pasture paddock to be used for a canola crop be sprayed for mites in the spring before the crop is sown.

Irrigation scheduling systems are available and should be used to ensure the best use of irrigation water. Private consultants and state departments of agriculture provide assistance with using this technology.

Pollination

Pollination and fertilisation have to occur before the seed will set. Without good pollination, yield will be reduced. *Brassica napus* varieties are self-pollinating and do not need insects and wind for successful pollination. *Brassica campestris* varieties require crosspollination and they rely mainly on bees to transfer the pollen from flower to flower; two strong hives per hectare of crop are required. Apiarists supply hives at a charge and they should be in place at the beginning of flowering. Care must be taken when spraying the crop with insecticides before and during flowering because it can have an adverse effect on bee populations that are feeding in the crop.

Controlling pests

Many types of pests can attack and reduce the yield of the crop. Circumstances cause some pests to be more of a problem in some years than others – organisms that were not considered pests in the past become pests. Pests cause problems for canola at two times in the lifecycle of the plant: at the establishment stage, and at flowering and maturity.

Mites

Two mites cause problems at establishment: the redlegged earth mite (*Halotyteus destructor*) (Fig. 22.11) and the blue oat mite (*Penthaleus majora*). In recent years the bryobia mite has also caused damage. These mites feed on the cotyledons and leaves of the seedlings. Plants with a heavy infestation of mites have mottled and white cotyledons and leaves. Plants can die and those that do not become stunted and weak.

The adult mites are about 1 mm long and have eight legs. redlegged earth mites have pinkish orange legs and mouthparts attached to a flattened black body. Blue oat mites have bright red or bright pinkish red mouthparts and legs attached to a rounded, brown or black body with a red streak in the centre of the lower back.

The redlegged earth mites feed on plants and hide in the soil. Both the redlegged earth mite and the blue oat mite prefer light sandy or loamy soils and are found in association with pastures. A crop grown immediately after pasture has a higher risk of attack.

The spring before the autumn when the canola crop is sown is the time to start control measures for mites. Spraying in spring reduces the population of adults that lay the eggs that allow the mites to survive over summer. The eggs hatch in autumn and infest the emerging crop. The CSIRO has developed a program called Timerite® that advises on the ideal time to spray redlegged earth mites in spring.

At sowing and emergence it is important to detect mites early for control to be effective. Not only the crop paddock but also adjoining paddocks and areas round the fences and edges of the paddock should be checked. Immediately after sowing crops are protected by spraying a residual insecticide on the soil surface of paddocks that are high risk. In low-risk paddocks spray the bare ground of the perimeter.



Figure 22.11 Redlegged earth mites on a leaf; the large silver patch is the damaged area

A chemical added to the seed at sowing gives protection by repelling mites and acting as an anti-feeding agent. Protection lasts for 3–4 weeks.

In addition to chemical control systems, integrated pest management (IPM) programs have been developed to reduce the population of redlegged earth mites and include strategies such as:

- green manuring in the spring to disrupt the laying of mite eggs
- intensive grazing in spring to lower mite numbers
- sowing canola at higher seeding rates and on time to limit mite damage to total production
- encouraging the activity of predatory mites.

Aphids

Three aphids attack canola and cause problems in the flowering and podding stages: Cabbage aphid (*Brevioryne brassicae*), turnip aphid (*Lipaphis erysimis*) and green peach aphid (*Myzus persicae*). The aphids cluster together on the upper stems, flower heads and developing seed heads and feed by sucking sap from the plant. Pod set, pod fill, seed quality and viability can be greatly affected.

The crop should be checked for aphids twice per week during flowering and podding. Aphids can multiply and spread very rapidly, so it is important to observe any increases in the numbers of aphids.

Treat with a recommended insecticide if most plants have 25 mm of the stem of the flower head covered with aphids and biological control agents are not very active. Biological control agents include lacewings, ladybirds, larvae of hover flies, tiny parasitic wasps and fungal diseases of aphids.

Controlling diseases

There are several diseases that affect canola, the most important of these being blackleg, a disease caused by the fungus *Leptosphaeria maculans*. Canola plants can be attacked at all growth stages. At seedling and rosette stages plants can be killed. The leaves show a red, purple or yellow discolouration at first and later rot off at ground level. In older plants grey lesions containing numerous black spots develop on leaves, stems, inflorescences and developing pods. The black spots are the spore cases of the fungus and they produce millions of spores that are carried in the air to infect other plants. Cankering (decay) at the base of the stem at ground level due to infection occurs in older plants. The flow of sap in the plant is restricted and the plant may even break off. Cankered plants produce very little seed.

The main source of spores that infect a crop is last year's **stubble** – the fungus survives from one season to the next on stubble and trash from the last crop. Weeds from the mustard family and volunteer canola plants may also be a source of infection. The rain in autumn causes a massive release of spores that blow in the wind and infect the seedling crop. Once a crop is infected spores are spread from plant to plant by water splash.

Blackleg can be controlled by the following means.

- *Plant resistant varieties of canola.* All varieties are rated for their level of resistance to blackleg and plant breeders work to produce new varieties that are resistant to new forms of the rust fungus.
- *Manage last year's stubble.* This should be reduced (by raking and burning) in the vicinity of the paddock that has been selected for the following year's crop to reduce the number of spores that could infect the crop.



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Figure 22.12 Aphids clustering; typically near the top of the plant

33 Explain how aphids affect the canola plant.

34 Explain how to determine when it is necessary to spray a crop with insecticide to kill aphids.



Holly Derksen/Manitoba Agriculture Food and Rural Development

Figure 22.13 Part of a plant leaf damaged by blackleg; the many, small rounded black structures on the leaf are spore sacs (also seen in a cluster on the lower left)

- 35** Describe the impact of blackleg on older plants.
- 36** Describe where the spores that infect a crop come from.
- 37** List the management strategies that can be used to control blackleg.

- 38** Describe windrowing.
- 39** Describe how the time to windrow is determined.

- *Use other strategies.* Canola should not be planted in the same paddock it was grown in last year or next to last year's crop. A fungicide can be used as the seed is sown. Volunteer canola plants and weeds from the Brassicaceae family should be controlled.

Harvesting the crop

The first step in harvesting the crop is windrowing, though some crops can be directly harvested without windrowing. Windrowing is cutting the top parts of the plants that have the seedpods on them and placing them into rows on top of the cut stubble. These rows can then be picked up by the harvester and the grain can be removed. Windrowing hastens the drying out of the crop, to reduce losses due to wind and hail and to ensure even ripening. Specialised machines called windrowers are used for this job. They can be self-propelled or pulled by a tractor and powered by the PTO.

When only 10 per cent of plants have any flowers left on them it is the end of flowering and windrowing should commence 25 days after the end of flowering – sooner if it is hot and dry or later if it is cool and wet. The crop is ready to windrow when 40–60 per cent of seeds in pods have changed colour from green to their mature colour of brown or black and all seeds are firm when rolled between the thumb and forefinger. It is important to look at samples from all over the plant because seed maturity varies from top to bottom.

Windrowing should be completed in 3–4 days because the crop dries out quickly and if it is too dry windrowing causes shattering of the pods and loss of seed. It is important that the windrower is properly adjusted and operating correctly. Using a contractor saves the expense of buying and maintaining a machine that is only used for a very short period each year.

Header harvesters are used to harvest windrowed crops. Open front machines are the most suitable. The crop is normally ready for harvesting 5–10 days after windrowing. Seed moisture content should be 9 per cent. If the seed moisture content is higher than 9 per cent, the harvested grain heats up and loses quality. As the machine moves along, it picks up the windrow, threshing the grain and separating it from the trash.



Figure 22.14 A self-propelled windrower



© Dave Reeder/All Canada Photos/Corbis

Figure 22.15 Windrows being picked up by the header harvester.

Direct harvesting

When harvesting without windrowing, again, open front machines are the most suitable. A canola crop is ripe and ready for harvest when the pods are dry and rattle when shaken. The pods at the bottom of the plant ripen first and harvesting can take place if a few of the topmost pods are still green. The seed moisture content must be 9 per cent or less.

Harvesting in the cooler part of the day and at night reduces losses due to pod shattering. Take care to set up the header harvester correctly so that losses are minimal.

Marketing

The market for canola is fully deregulated. The grower's agent must find a buyer and negotiate the price on either the domestic or the export market. Buyers of Australian canola have access to both conventional and genetically enhanced produce.

Domestically, Australia is self-sufficient in canola – it does not import any oil or grain. The annual consumption in Australia is 110 000 tonnes. Grain and oil not consumed domestically is exported (Table 22.6).

The main destinations for these exports are Japan, China, Pakistan and Bangladesh.

-
- 40** Identify the desired moisture content of the seed at harvest.
 - 41** Identify the machine that is most commonly used to harvest canola.

Table 22.6 Australian production and exports of canola, 2006–10

Year	Exports ('000 tonnes)
2009–10	1 238
2008–9	973
2007–8	276
2006–7	228

Used with permission of Australian Oilseeds Federation Inc.

42 Outline what happens to the canola that is not used on the Australian domestic market.

Pricing

Australia produces only a very small amount of the world's oilseed, so occurrences in the world market, in terms of oilseed production and price, very much influence the price of oilseeds in Australia, including canola. Because soybeans comprise 70 per cent of world oilseed trade, occurrences in that market also affect the canola market.

Marketing strategy

Growers use information from markets round the world and forecasts to form an opinion as to what the price will be like when their crop is harvested. They decide how much to plant based on this opinion. They use financial management programs to assess the relative profitability of canola and other crops such as wheat and barley. Once the crop is sown a weekly check is kept of the price of canola. Growers should use two or three independent sources of market information and also contact likely buyers.

There are several alternatives for selling the grain, which include:

- *A fixed tonnage contract.* Where growers decide to sell before harvest, they use a fixed tonnage contract, which is a contract to deliver a fixed quantity and quality of grain by a specified date. Growers have the advantage of knowing what their profit will be.
- *Accepting the cash price.* Growers may choose to take the cash price at harvest, whatever it is. The amount of grain is known but the price on the day has to be taken.
- *The guaranteed minimum price.* Some crushers offer the guaranteed minimum price, where a minimum price per tonne for the grain from an agreed area is contracted. There is less risk for the grower, but prices may well be lower. Growers may choose to use a combination of these selling alternatives to help give them the best returns possible.

43 Outline two alternatives open to growers for selling their grain.

Chapter review

Things to do

- 1 Perform a dispersion test on soils from your school farm to see if they are sodic. Collect soil samples from the topsoil and the subsoil. Disturb the soil as little as possible because to carry out the test you need aggregates (lumps) of soil. To do the test:
 - Place an aggregate of soil in the bottom of a beaker or glass jar.
 - Carefully add water by running it down the inside of the beaker or jar until the water level is 1 cm above the aggregate. Do not pour it directly onto the aggregate of soil and smash it.
 - Let the beaker stand and observe what happens to the aggregate. If it crumbles and disperses quickly the soil could be sodic.
 - Repeat the test for all your soil samples.
 - Record your results.
- 2 Conduct a trial to test the effect of gypsum on the surface crusting of a soil.

Prepare four plots of 1 m × 1 m. Add 100 g of gypsum to two of these plots and mix it into the top 5 cm of soil. Sow 100 canola seeds in each plot at a depth of 3 cm; sow the seeds in rows so that it is easier to identify the emerging seedlings. Use a sprinkler to thoroughly water the plots so the soil is wet to the depth the seeds were sown.

After a week, count the number of canola seedlings that have emerged in each plot and calculate the percentage emergence for each treatment. Record your results using a spreadsheet on the computer and use the graphing function to produce a column graph to summarise your results.

Did treating the soil with gypsum improve the emergence rate?
- 3 Grow a plot of canola and observe and record the seven stages of development of the plant, perhaps taking a digital photograph of the plant every week. Make sure you include something in the photograph that indicates scale, such as a ruler.

Things to find out

- 1 Describe how the Timerite® program for controlling redlegged earth mites works after visiting the [Australian Wool Innovation \(AWI\)](#) website.
- 2 How does burning stubble to control blackleg fit into sustainable farming, where retaining organic matter is desirable to maintain and improve soil structure and reduce erosion?
- 3 Investigate how canola products can be of use to people.
- 4 Research the pests other than mites and aphids that affect canola and what control measures are used against them. Were any of these pests a problem 3 years ago?
- 5 Identify two diseases of canola, other than blackleg, and find out the causal organisms and the management strategies used to control them.
- 6 Find out what the nutrient deficiency symptoms are in canola for phosphorus, nitrogen and sulfur.

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+ Extension activity

- 1 Imagine you are a canola grower and need to keep track of the price so that you can make better decisions about the area you grow next year. Find out the price of canola in your local area of Australia over a period of 10 weeks. Graph the prices (price on the vertical axis and weeks on the horizontal axis). Collect information on why the prices are changing or not changing. Write a brief explanation of the changes in price you observed over the 10-week period. Would you, as a grower using this information, increase the area you grow next season? Prices and information may be found in weekly rural newspapers or websites such as [The Land](#).

✓ Test yourself

- 1 Construct a calendar of operations for growing a canola crop in a high rainfall area. Start the calendar in the spring of the year before the crop is to be planted. Make the following assumptions.
 - The paddock chosen for the crop is a pasture with high clover content.
 - Canola crops have been grown on this and neighbouring farms every year for some time.
 - Rainfall is ideal, falling at precisely the right times of the year.
 - There is a possibility of a grass weed problem.
 - Redlegged earth mite is likely to be a problem.

CHAPTER 23

PASTURES

Words to know

annual plant a plant that completes its lifecycle within 12 months

biennial plant a plant that grows from seed in the first year and flowers in the second year

bloat a non-infectious disease caused by grazing animals overeating legume plants; rapid production of gases trapped in foam causes the rumen to swell, resulting in breathing difficulties and possibly death

creep grazing allowing smaller or younger animals in a herd or flock access to new pasture through specially constructed fences or gates while excluding older or larger animals

dormant when pasture seed that is still alive, but because of various factors does not germinate in reasonable conditions

exotic pasture a pasture of plants that have been introduced from overseas (introduced pasture species)

inoculum a mixture of nitrogen-fixing bacteria, peat and a sticky medium

native pasture contains plants originating in that particular country; for example, Australian native plants planted in Australia

natural pasture contains plants of both native and naturalised origins (exotic plants that have responded well to local conditions)

nitrogen-fixing bacteria a bacteria that allows the legume to produce protein from nitrogen gases in the atmosphere; some are found in nodules on legume plant roots and some are free-living in the soil

nodules lumps or swellings on the root systems of legumes, caused by bacteria invading or infecting the plant root system

palatable feed that is easily eaten and digestible; feed that grazing animals like to eat

pasture a balanced community of plants (generally grasses and legumes) that provides grazing animals with their food requirements

perennial plant a plant that grows from season to season

permanent pasture a plant community that lasts longer than 5 years

rotational grazing moving livestock in a pattern from one paddock to the next to allow grazed areas to recover

strip grazing grazing sections of a paddock divided by an electric fence

succulent feed that is juicy and therefore high in water content

temporary pasture a mix of plants that lasts from 3–5 years

Introduction

A **pasture** is a balanced community of plants providing grazing animals with their food requirements. These plants convert energy from the Sun and raw materials such as water and carbon dioxide into sugars, by the process of photosynthesis. The animals that graze these plants are in turn supplied with these products.

The two main types of plant in a pasture mix are grasses and **legumes**. The grasses supply most of the sugar (hence energy) to the animals, and the legumes supply them with the proteins. The term 'legume' refers to plants (such as clovers and medics) that can take nitrogen from the air and use it to make proteins.

A suitable pasture needs to satisfy several requirements. It should:

- supply a reasonable quality feed throughout the year (e.g. for a dairy cow it should supply 20–30kg of dry matter per day per cow and protein levels of 15–19 per cent)
- be easily eaten and digested (i.e. be **palatable**)
- contain sufficient moisture (i.e. be **succulent**)
- be drought resistant, or tolerant of dry spells
- provide good surface cover due to its habit of growth
- exhibit a quick recovery after drought or grazing (i.e. regenerate quickly)
- provide adequate seed production for survival and dispersal
- show an absence of inferior species (e.g. thistles)
- have few plants with toxic substances (some pasture plants when young and actively growing can cause poisoning of livestock; e.g. young sorghums and phalaris).

There are several types of pasture plant. **Annual plants** live for 1 year only and must be replanted each season. **Biennial plants** grow from seed in the first year and flower in the second. **Perennial plants** grow from season to season and are the best-suited pasture plants.

On this basis, pastures can be divided into temporary or permanent pastures (Fig. 23.1). **Temporary pastures** are designed to last up to 5 years at the most and contain annual or biennial plants such as Italian ryegrass, red clover, some strains of subterranean clover and different native medics. **Permanent pastures** last for many years and contain perennials such as phalaris, paspalum, kikuyu, white clover and some strains of subterranean clover.

- 1 Describe the difference between:
 - a grasses and legumes.
 - b native, natural and improved pastures.
 - c annual, biennial and perennial plants.
- 2 List examples of temporary pastures.
- 3 List examples of permanent pastures.
- 4 For how long are temporary pastures designed to last?

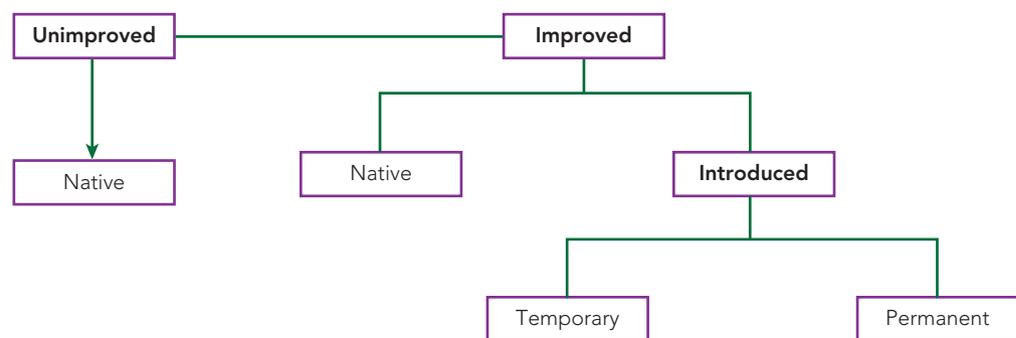


Figure 23.1 Pasture types

Native pastures

Native pastures are made up of plants that originated in Australia. On the coast and tablelands, they are commonly wallaby and kangaroo grasses. In the desert areas, they are spinifex, saltbush and bluebush. These pastures are well adapted to the dry conditions and poor soils of Australia, respond quickly after rain, and can survive periods of drought.

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Feeding sheep on native fodder

View the program and answer the questions.

Native pasture plants are very high in fibre and have little leaf. This means they have a low feed value for grazing animals. The production levels from native pastures are variable and low compared to other pastures. If native pastures are improved by the addition of fertiliser and irrigation, the native plants eventually die out.

Some pasture plants grow in areas for so long that they are considered native, such as couch grass in coastal areas. Pastures containing native grasses and these plants, growing in improved conditions, are **natural pastures**.

Exotic pastures

Exotic pastures (or artificial pastures) contain many varieties of plants introduced from overseas. The plants have a higher yield and better quality levels of output. Figure 23.2 shows an example of a grass and a legume in this category.



Figure 23.2
Introduced plants
a lucerne (*Medicago sativa*) **b** kikuyu (*Pennisetum clandestinum*)

Legumes

Legumes provide a high protein feed and contribute to soil fertility. Pasture grasses make use of the nitrogen that legumes add to the soil. Legumes fix nitrogen from the air through a symbiotic association with the bacteria that live in their roots (**nitrogen-fixing bacteria**). The cysts or **nodules** where these bacteria are found can be seen as pink or white bumps on the plant roots, as shown in Figure 23.3. Pink nodules are generally more efficient producers of nitrogen compounds that the plant can use – they are larger and fewer in number than the corresponding white nodules.

There are a number of species of bacteria in the soil and each species will only infect a particular group of related legume plants; for example, bacteria infecting subterranean clover will not infect lupins or peas. This factor may lead to poor establishment of legumes in some pastures. Factors affecting the number of micro-organisms in the soil are moisture level, soil acidity, temperature and the presence of other microbes. Figure 23.4 illustrates the process of infection of the legume's root system.

Several groups of legume plants exist. True clovers (*Trifolium* genus) are naturally adapted to more acidic soils; examples include subterranean clover, white clover and red clover. The medics (*Medicago* genus) are another large group, and are naturally adapted to more alkaline soils; examples include lucerne and barrel medic. Figure 23.5 shows the essential differences between clovers and medics.



Figure 23.3 Nodules on a plant root

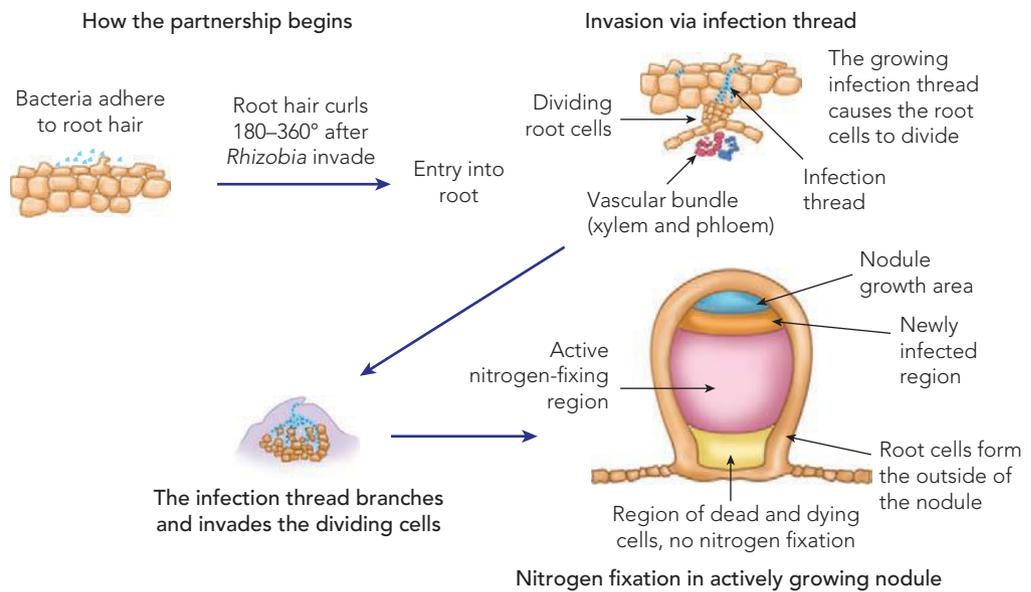


Figure 23.4 The development of nodules from nitrogen-fixing bacteria (*Rhizobia* species)

- 5 Explain how legumes obtain nitrogen to make protein.
- 6 Draw Figure 23.5 in your notebook, showing the basic differences between a clover and a medic.

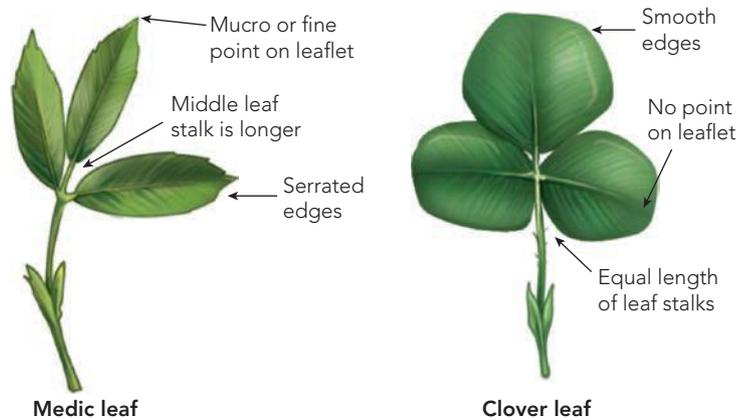


Figure 23.5 Differences between clovers and medics

Vetches are another important legume included in pasture production. Woolly pod vetch (*Vicia villosa*) is often used on farms in the north-west wheat belt of New South Wales, in the pasture phase of a crop rotation system used when growing wheat. In subtropical areas, several vine-like legumes are used in pasture mixes; examples include glycine, siratro, silverleaf desmodium and Townsville stylo.

Clovers

The main pasture plants in this group are subterranean, white and red clovers.

Subterranean clover (*Trifolium subterraneum*)

This free-seeding, self-regenerating annual originated in the Mediterranean area. The plant is hairy on the underside of its leaves and has a prostrate habit of growth (that is, it lies out low on the ground). Low temperatures over winter are needed to encourage some varieties to set seed. These clovers are sown in March to May and flower in late winter to spring; the white flowers turn purplish with age.

'Sub clover' likes hot, humid summers and mild winters and combines well with grasses such as perennial ryegrass and cocksfoot. The seed of this clover does not all germinate at once – up to 20 per cent of hard seed (seed with a thickened coat) remains **dormant** to germinate in the following season if conditions are good. Some subterranean clover strains, such as Geraldton, Yarloop, Dwalganup and Marrar, can cause problems with sheep. They contain high levels of a female sex hormone called oestrogen and sheep can become infertile if they graze on too many of the plants.



Figure 23.6 Subterranean clover



Figure 23.7 White clover

-
- 7** Read the description of subterranean clover and white clover. Identify and draw these two clovers, indicating their features, from samples found in the field.

White clover (*Trifolium repens*)

Originating possibly in Holland, white clover is a hairless perennial creeper that roots at the nodes. It is a poor autumn or winter grower but excellent during spring and early summer. This legume combines well with grasses such as paspalum. White clover prefers fertile soils with high levels of superphosphate. The seed is very small; suggested sowing rates for a pasture mix are 1–2 kg/ha.

Red clover (*Trifolium pratense*)

This is sown at a rate of 3 kg/ha in a pasture mix and grows in spring to summer. It has red veins and an erect habit of growth, but is not as persistent as the other clovers.

Medics

Medics are mainly annual plants, introduced from the Mediterranean area. They grow in autumn to winter, regenerating from seed produced in the previous season. All are legumes, classified in the same genus (*Medicago*) and produce plant material and seeds that are high in nitrogen content. Grazing animals such as sheep can maintain condition on medic-based pastures over winter, and during droughts sheep can obtain protein by eating the seed pods of medics. Important pasture medics include barrel medic, burr medic and spotted medic. The blue-green aphid and the spotted alfalfa aphid have caused damage to these types of pasture plant.

Lucerne (*Medicago sativa*)

Lucerne is a deep-rooted perennial legume, grown in a variety of climates across Australia. Lucerne is extremely drought resistant but cannot stand waterlogged situations. It is an excellent plant to cut for hay, producing up to 4–5 cuts per growing season. Many varieties of lucerne are available. Some are winter growing,

-
- 8** Select a variety of clover and:
- provide a brief description.
 - outline the growing period for this plant.

such as Trifecta, while others show resistance to the spotted alfalfa aphid and the blue-green aphid. Lucerne may not regenerate well after overgrazing that causes crown damage (lucerne grows from the crown, the swollen area located just above or just below ground level). In addition, **bloat** problems caused by overconsumption of any legume (including lucerne) occur in both sheep and cattle if strict grazing management systems are not used.

Sainfoin (*Onobrychis viciifolia*)

Sainfoin is a perennial forage legume and is a possible replacement for lucerne. This plant prefers well-drained soils that are high in lime. A bloat problem does not occur when sainfoin is grazed.

Grasses

A number of common grass varieties are used in Australian pastures. Cocksfoot (*Dactylis glomerata*) is a stout tussock-forming grass. The root system is fibrous and the leaves are a blue-green to bright green colour. Maximum growth occurs in spring, and the plant is sown in autumn or spring at the rate of 2–4 kg/ha.

Paspalum (*Paspalum dilatatum*) grows in clumps of varying sizes and has long, broad leaves. It is a good pasture plant, because it recovers well in drought times, although there are some problems with ergot.

Kikuyu (*Pennisetum clandestinum*) is a very leafy plant that grows very long runners. It is a summer-growing perennial that is established by planting runners or planting seeds. This plant has a high water content that can affect its nutritional value.

Perennial ryegrass (*Lolium perenne*) is usually sown with white clover in rainfall areas of over 500 mm per year. This plant must be grazed heavily to maintain protein levels and growth.

Phalaris (*Phalaris aquatica*, also called *Phalaris tuberosa*) is a perennial grass grown in tableland areas. It can withstand both hot dry summers and cold wet winters. On the coast, poor establishment may occur. A disadvantage of using phalaris in pastures is the disease called phalaris staggers or poisoning, which affects the livestock that graze on young phalaris plants.



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Figure 23.8 Cocksfoot (*Dactylis glomerata*)

Figure 23.9 Perennial ryegrass (*Lolium perenne*)

Figure 23.10 Phalaris (*Phalaris aquatica*)

Fodder and forage crops

Fodder crops are crops grown specifically to supplement pastures. They are cut and fed to the animals, so planting rates are usually high. Examples include oats, barley, kale, rape and turnips in winter; and sorghum, Sudan grass, millet and cowpeas in summer.

Forage crops are ones grazed by the animals. These again are pure stands of a particular plant, rather than a mixture of plants. Figure 23.11 illustrates a possible combination of forage crops for summer.

Millet as early feed	Hybrid sorghum, Sudan grass, Sudax ST6, SX6	Sweet sorghum
Late winter	Summer	Autumn

Figure 23.11 Forage crops

Pasture mixes

In a pasture a farmer ideally attempts to obtain a mixture of 60 per cent grass and 40 per cent clover. Natural pastures can contain grasses such as couch, Parramatta grass, red leg grass, wire grass or love grasses, and a few legumes such as barrel medic. Improved pastures can contain mixtures of perennial ryegrass, paspalum, and white and subterranean clover.

Because summer pastures have higher production levels than winter ones, the area of a farm sown to pastures reflects this: summer pastures occupy only 30 per cent of available land on a farm, while winter pastures are extensive and often treated with large amounts of fertiliser to promote plant growth.

The importance of pastures

Pastures are important in grazing systems because they:

- supply food to livestock cheaply throughout the year
- improve soil fertility
- improve soil structure
- decrease soil erosion
- influence soil temperature and moisture levels
- may increase grazing capacity by the growth of quality pastures
- offer the farmer a choice of selling both plant and animal products.

Improving pasture quality

Opportunities arise for farmers to improve pasture quality when:

- animal products are attracting high market prices, so that the cost of pasture improvement can be covered (pasture is the cheapest form of fodder for grazing animals)
- introduced species of plants enable provision of superior quality feed
- introduced plants can be grown in many areas and out-produce other plant species
- soil fertility is improved by many of the introduced plants.

Figure 23.12 illustrates the procedure used to introduce new plants into Australian pasture production systems.

9 Copy Figure 23.11 into your notebook. Use it to determine why it is important to be able to plant a range of plant types on a farm.

10 List five reasons why pastures are important.

11 What are the percentages of grass and clover in an ideal pasture mix?

12 Outline four reasons why farmers may wish to improve their pastures.

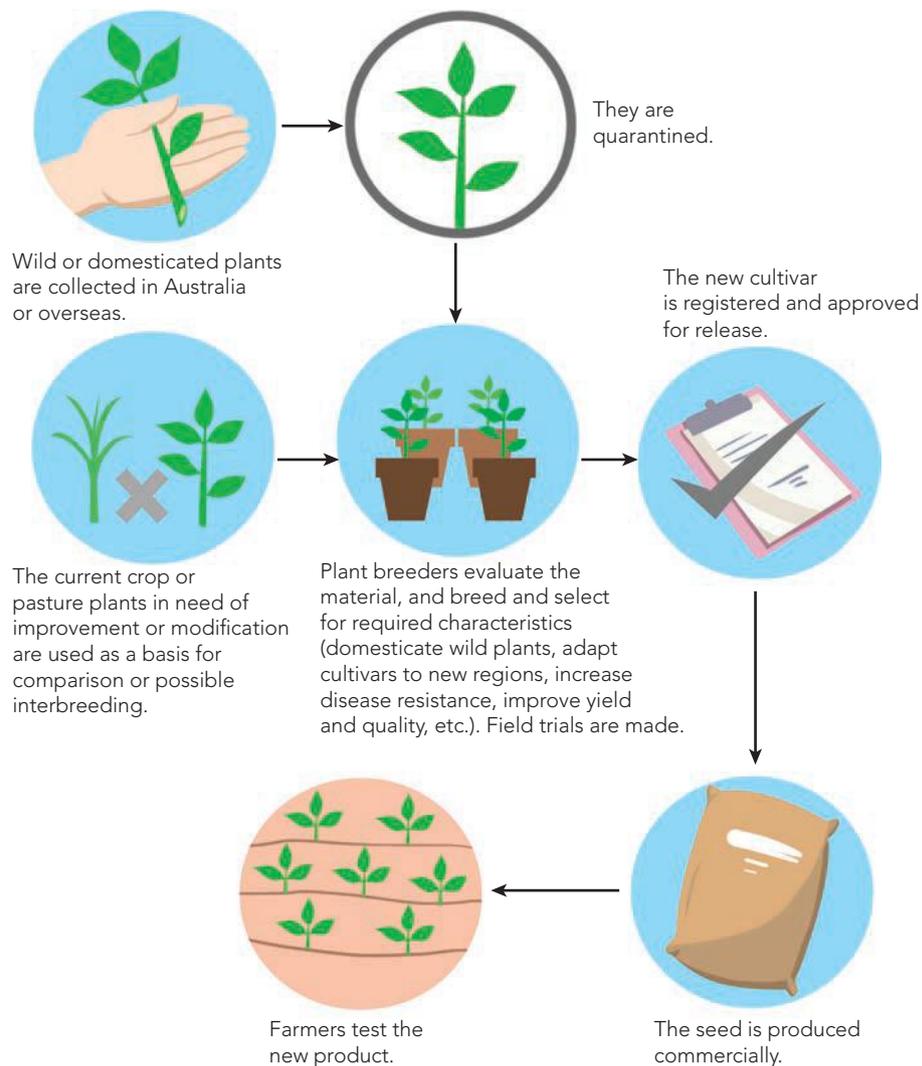


Figure 23.12 Procedures for development and introduction of new pasture plants in Australia

Steps to improve pasture quality

Subdividing

Subdividing a pasture improves control over grazing, allowing pasture plants to survive and reproduce. In a well-managed system a continuous supply of short, nutritious food is available. Cows about to calve and animals with young at foot can be placed into better paddocks, while dry animals can be placed in less productive paddocks.

Fertilising

Fertilisers such as superphosphate encourage the growth of legumes, while nitrogen fertilisers encourage the growth of grass. Many soils lack sufficient potassium and other elements (such as sulfur) that are required by plants in reasonable amounts for growth. Other elements are required in smaller amounts; for example, molybdenum is an important trace mineral necessary for nodules formation on legumes.

Seeding

To ensure the right strains of bacteria are present to allow legume nodulation, many farmers inoculate legume seed before it is planted. This involves coating the seed with a sugary or sticky mixture of bacteria (**inoculum**) and peat. The mixture is then planted, allowing the legumes to be infected by the correct form of bacteria. Farmers also pellet seeds, especially inoculated seeds, in lime. This produces a protective layer around the seed and assists in its establishment. The lime neutralises soil acidity, creating the more neutral conditions that favour the nodule-forming bacteria and it increases the spread of broadcast seed.

The essential feature of any pasture is its plants. Consequently many farmers sow new pastures directly into existing pastures as the older pastures die out. This is called sod seeding and ensures the pasture subsystem of a farm is not out of production for a long time.

Irrigating

To ensure healthy pasture plants, water must be freely available for plant growth. Various systems are available to overcome water shortages. Some are fully mobile, using travelling irrigators, while others involve the shifting of aluminium pipes from paddock to paddock on a regular basis.

13 List four steps involved in improving a pasture.

Deteriorating pastures

Poor management results in deterioration or decline in both quality and quantity of pasture production. This may include the farmer's stocking rates and grazing routines or a failure to control pest infestations.

Overstocking

Grazing too many animals in an area causes the more palatable plants to be eaten out. A build-up of coarse tufty types of plant or weeds may also occur. Rank growth may also occur around dung or manure heaps in paddocks. Animals tend not to eat this growth, so such manure heaps should be scattered on a regular basis using pasture harrows.

Understocking

When stock is insufficient to eat down the coarser types of plant, only the most palatable plants are eaten. This allows the coarser grasses to dominate and most legumes soon disappear.

Selective grazing

Horses are very selective grazing animals. They tend to remove all the fine grasses and frequently horse paddocks become tussocky. Cattle are the least selective of the grazing animals.

Continuous grazing

If the pasture is not allowed enough time to re-seed, annual plants rapidly disappear. Perennials may have their growing points severely damaged, which prevents them from regrowing.

Controlling pests

- 14** List five reasons why a pasture may deteriorate.

Rabbits and kangaroos often cause damage to developing pastures if allowed to graze unchecked. Feral pigs can cause severe isolated damage in some areas, where they dig up large sections of pasture. Insects such as black beetle and crickets can also affect the growth of a pasture.

Establishing a pasture

The establishment of a pasture covers the initial stages of land preparation up until the time when the young plants are able to withstand grazing. A number of factors determine the success of this operation.

Before planting a pasture, the farmer must ensure the seed is placed on or below the soil surface, by removing as much ground cover as possible. The seedbed must be carefully prepared and the most suitable species planted. The seed selected should be of a high quality, with guaranteed germination rates. If legumes are planted they should be inoculated. Pay attention to nutrient requirements, soil pH and the correct placement of fertiliser. Weed control must be effective. Before commencing seedbed preparation, slash the paddock and, if necessary, treat existing plants with a herbicide.

There are four methods of preparing a paddock to establish a pasture.

Prepared seedbed method

The soil is cultivated to produce a good clean bed for the seed to germinate. If the soil has not been used for pasture before, it is necessary to turn under any residue, preferably with a mouldboard plough or disc plough. The soil should be moist when worked and the depth of ploughing set so that the subsoil is not brought to the surface. Once the surface material is removed, a chisel plough can be used to further break up the soil.

The soil is then left to lie for 6 weeks to 8 months (normally this fallow period is 6–8 weeks so that the soil is not out of production for very long). During this period herbicides are used to control weeds. While the soil remains bare, several cultivations are made to break up soil clods and to check weed growth. The final cultivation is only very shallow, designed to produce a fine seedbed. The use of a rotary cultivator is undesirable because the soil structure could be permanently destroyed. When this process is finished, the soil should be lightly compressed.

Because of the number of cultivations required, the range of equipment needed, and the fact that the land remains bare and unproductive for a period of time, more suitable methods of pasture establishment have been developed.

Direct sowing or direct drilling method

Seed is placed into the previously undisturbed surface of an existing pasture by a cereal drill, sod seeder or spring release combine. Delivery tubes drop seed just on the soil surface and a trailing harrow or sheet of steel mesh is then used to cover the seed. All care should be taken not to sow the seeds too deeply because most pasture seed is very small. (Fig. 23.13 shows various ways machines direct drill seed.) If the existing pasture is allowed to dominate, it will compete with the newly germinated plants and result in poor establishment.

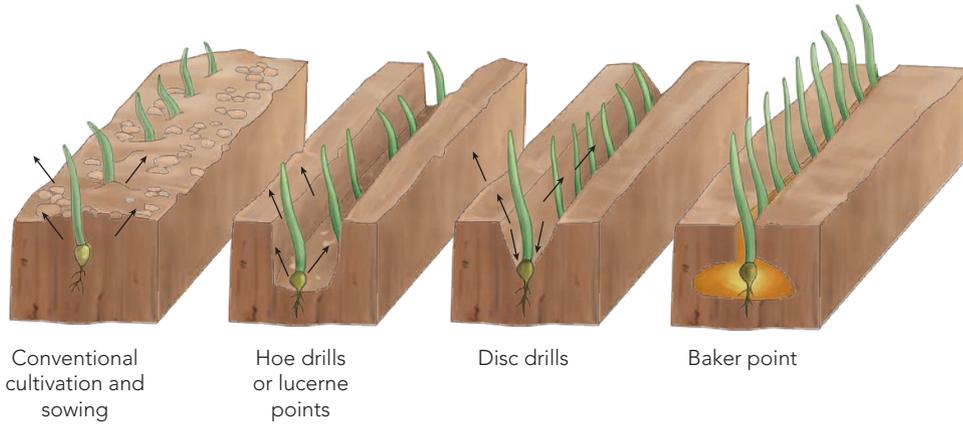


Figure 23.13
Methods of seed drilling

Reduced cultivation method

This method covers any management system that uses fewer than the normal number of cultivations to prepare land for planting.

Many systems use herbicides and strategic grazing to reduce the plant material covering the soil. The soil is then lightly cultivated, usually with tined cultivators, to a depth allowing for seed sowing and the adequate placement of fertiliser. The seed and fertiliser are either directly drilled into the soil (Fig. 12.13) or placed over the surface and covered by means of harrows. If necessary, a post-emergent herbicide may be used to control weed growth.

Surface sowing method

In this method, seed is simply dropped onto the soil surface – either aurally sown or broadcast from the ground. This method is often used on land that is too steep for tractors with seeding machinery to operate on. Little surface preparation is done. Rainfall needs to be sufficient for reasonable success. Care should also be taken to select only very vigorous types of pasture plants. Seeding rates need to be fairly high and initial grazings should only be light.

-
- 15** Describe three factors to be considered by a farmer before planting a pasture.
- 16** Describe four methods of preparing and sowing a paddock.

Managing pastures

No single pasture species supplies an ideal diet for animals throughout the year. Good management can assist, however, through such techniques as:

- use of fertiliser
- good grazing systems
- use of sensible pasture mixes
- giving producing animals first access to pasture
- allowing time for pasture to re-seed.

Using fertiliser

Pastures require a certain amount of fertiliser when established, then regular topdressings during periods of active growth in spring or autumn. During the time it takes to develop an improved pasture, several changes occur in its composition. During the initial stage, care must be taken to avoid starving the livestock while pasture plants establish themselves. Clovers grow quickly and dominate the pasture within 3 years. In this time the livestock may suffer from clover-produced diseases such as bloat. By the end of the third year, any native grasses will have disappeared. Vigorous grasses use the nitrogen built up in the soil by the clovers and grow actively by the fifth year.

From this time onwards grasses begin to dominate. Care must be taken to break up the mass of grass and renovate the pasture. This involves lightly ripping the surface of the pasture to tear out some of the grass, allowing clovers to persist. Eventually the grasses dominate and there is a chance that animals will suffer from grass tetany, a common disease in grass-dominant pastures.

As a pasture grass grows, its nutritional value changes. Young grasses are high in sugars and proteins while cells actively grow and divide. As the plant ages, the fibre increases. Three ways to maintain the protein and sugar levels are to slash the pasture, fertilise regularly and irrigate to encourage active growth.

Good grazing systems

The aim of correct grazing management is to maintain maximum plant growth but also protect vulnerable parts of the plant. During summer, it is important to keep seed heads off the pasture until they are required. During autumn the standing dry feed needs to be removed. In winter, grazings are limited so that plants are not eaten out. During spring a well-managed grazing routine is needed.

Types of grazing systems include:

- *Continuous grazing.* Livestock run in a paddock continuously over time with no, or only infrequent, spells from grazing. Continuous set stocking refers to the situation where livestock numbers in a paddock vary little from month to month, or from year to year.
- *Strip grazing.* Sections of the pasture are divided by the use of an electric fence. Animals are then placed in these areas in high numbers and allowed to graze for a set period of time. The pasture is grazed section by section. When completed, the cycle is set to start again.
- *Rotational grazing.* Animals are moved from one paddock to the next to avoid overgrazing and the build-up of pests such as worms. This method is usually used in conjunction with **strip grazing**. Cell grazing and time-control grazing are similar to **rotational grazing**, but are more intensive and involve more paddocks or 'cells'. In time-control grazing, paddock moves are determined by plant growth; the faster the growth, the more moves.
- *Creep grazing.* Animals are moved progressively through a paddock via a series of collapsible fences. The aim of **creep grazing** is to allow young animals first access to good pasture; older animals with lower nutritional needs (lower energy requirements) go last.
- *Zero grazing.* Pastures too dense or high to be grazed effectively are often mowed and the green feed given to the animals in feeders. This method needs to be cost-effective, and under high stocking rates it can reduce trampling, especially on wet clay soils.

Effective management is the key to successful pasture production.

Producing and marketing pasture seed

The production of pasture seed is a small part of the pasture industry. Specialist pasture seed producers grow pasture species as crops and harvest the seed. They produce about 20 000 tonnes of seed each year and most is sold on the domestic market. Export destinations include Saudi Arabia, the United Arab Emirates, Portugal, Argentina, Egypt, Morocco, Spain and the United States.

Seed that is sold is usually certified. This certification guarantees the seed is of the variety on the label and meets germination and purity standards.

-
- 17 List the various management techniques for a pasture.
 - 18 List three changes that occur in a plant as it ages.
 - 19 Describe three ways of maintaining active pasture growth.
 - 20 Describe four methods of grazing a pasture.

Chapter review

Things to do

- 1 Look at some local pastures and obtain and press examples of:
 - a native grasses.
 - b natural grasses.
 - c introduced grasses.
- 2 Collect an example of:
 - a grass (e.g. kikuyu).
 - b a medic (e.g. lucerne).
 - c a clover (e.g. white or red clover).

Paste each of these into your notebook and label the leaf, stem and roots. Look closely at the leaf veins and describe what you see.
- 3 Collect the 10 most common pasture weeds in your local area. Press and name each specimen. (Try to include flowers on the specimens.)
- 4 Prepare a seedbed and sow a fodder or forage crop for use on the school farm.
- 5 Prepare a seedbed and sow a trial crop that is innovative or new to your area.
- 6 Dig up a legume and draw the root system. Label the nodules. Cut a section through a nodule and note its colour. Smear the sectioned nodule across a microscope slide and stain with iodine. Place a cover slip on the slide and examine it under a microscope. Draw what you can see in your notebook.
- 7 Make a collection of important pasture plants in your region. Press each full plant specimen (use only plants that have a seed head or that are in flower).
- 8 Obtain some samples of pasture seed and set up 1 m × 1 m trial pasture plots. Label each one with the name of the pasture and the date when the seed is sown. Record the germination and flowering dates. Which plants best suit your area?
- 9 Obtain seeds of lucerne or woolly pod vetch and inoculate and lime-pellet half of the seed sample. Sow the seeds into separate but similar areas and observe the growth of these two groups of plants.

Things to find out

- 1 What is the most common pasture mix in your local area for:
 - a the summer period?
 - b the winter period?
- 2 Obtain pictures or a description of:
 - a glycine.
 - b Townsville stylo (*Stylosanthes humilis*).
 - c silverleaf desmodium (*Desmodium uncinatum*).

- 3 Describe the symptoms of:
 - a bloat.
 - b poisoning (such as grass tetany).
 - c clover infertility.
- 4 Describe the work performed by an agronomist.
- 5 For your local area, are there times during the year when a pasture cannot grow well enough to feed animals? How are the animals fed during this time?
- 6 Use your local library to find out why pasture development in the north of Australia was much slower than that in the southern areas.
- 7 Discover the most commonly planted long-term pastures in your district. List what a farmer does to maintain these pastures.
- 8 What are the most commonly used grazing systems in your area? Describe these systems.
- 9 Choose one of the conditions from Question 3. Describe how the farmer treats the problem.
- 10 Explain why pastures species were specifically developed for the Australian environment.

+ Extension activities

- 1 Cell grazing has become very popular. Explain the management system for this process. Compare and contrast this system with rotational grazing and strip grazing methods. Why has it become popular?
- 2 Discuss the idea that 'the most important point is to graze a pasture at the correct times – not what plants make up a pasture'.

✓ Test yourself

- 1 What are the features of a good pasture plant and how do these features contribute to the development of good pastures?
- 2 Outline two metabolic animal diseases that may arise from poor pasture management. How can these situations be avoided and what must farmers do to help animals recover from these diseases?
- 3 Why is it necessary to be able to distinguish between grasses, clovers and medics? Outline how you would teach other students to develop this skill.
- 4 Discuss the steps involved in establishing an improved pasture. Compare this with the establishment of a native pasture area on a farm.

CHAPTER 24

FODDER CONSERVATION

Words to know

fodder plant material grown to feed livestock; includes stored material such as hay, silage or grain

nutrients chemical constituents of fodder that are digested and used by an animal (e.g. starch, vitamins and inorganic salts)

pasture a balanced community of plants (generally grasses and legumes) that provide grazing animals with their food requirements

silo a structure used for storing silage or grain

supplementary feed additional feed given to an animal in times of need to maintain sufficient nutrient levels

vermin animals that are destructive, annoying, or harmful to human health, including rats and mice

Introduction

In spring and summer, provided that it has been a good season, more feed is usually growing in the paddocks than the grazing animals can eat. Conversely, in autumn, and especially winter, it is too cold for plants to grow very quickly so **pastures** are not likely to be able to supply the needs of the grazing animals.

- 1 Identify the two reasons why a farmer conserves fodder.

The idea of fodder conservation is to harvest and store the excess pasture in spring and summer so that it can be used in winter when there is a shortage, as shown in

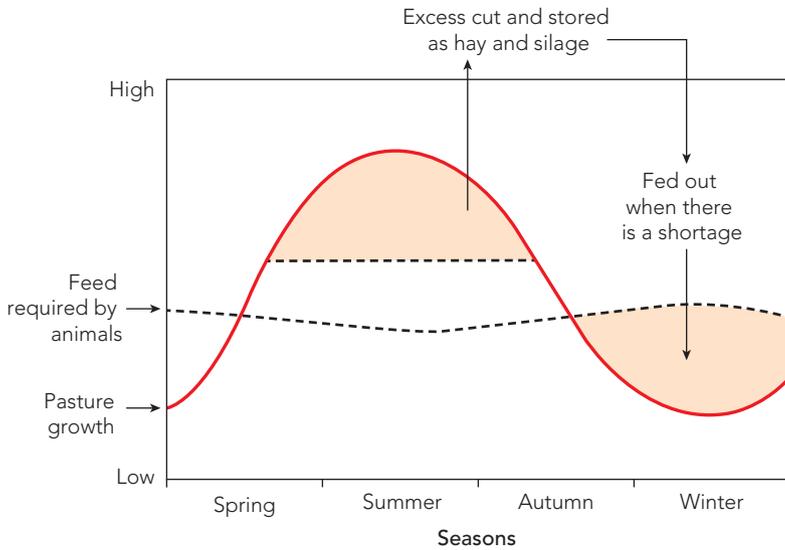


Figure 24.1. It also means that farmers have a supply of feed in times of natural disaster such as flood and bushfire and, especially, in times of drought. The concept of fodder conservation has been developed further by growing crops (such as lucerne) especially for cutting and storing as hay or silage. Some farms have become specialised in producing hay (especially lucerne) as their main source of income.

Fodder can be conserved as hay, silage or grain. For crop or pasture material to be stored without going rotten and spoiling, it must be treated in some way. Hay and grain are dried out, and silage is preserved by storing in conditions unsuitable for the bacteria and fungi that would cause its decay.

Figure 24.1 Seasonal pasture growth

Haymaking

In haymaking the cut crop or pasture material is allowed to dry out in the paddock to a moisture content of about 20 per cent. It is then pressed into bales and stored in a hayshed. Fine weather is needed for haymaking. If it rains after the hay has been cut and before it is safely stored in the hayshed, its quality can be destroyed or greatly reduced – the **nutrients** are leached out of the cut material by the rain. To speed up the haymaking process, machines have been developed to cut the crop and lightly crush the stems between rubber rollers so that they dry out quickly.

- 2 How is the cut plant material preserved in haymaking?
- 3 What happens if it rains while hay is being made?

There is now a variety of systems for cutting and making hay. The size and shape of the bales produced range from small rectangular ones weighing 20–30 kg to large square, rectangular or cylindrical bales (called ‘round bales’) weighing up to 2 tonnes. The small rectangular bale is popular as the form in which hay is most



Figure 24.2 Various kinds of hay bales **a** rectangular bales **b** round bales

often traded and transported. The development of machines to load, stack and feed out the large round and square bales has seen an increase in their use and they are becoming more popular. Crops and pastures used for haymaking include mixed pasture, clover dominant pasture, lucerne, oats, wheat, barley, sorghum and millet.

Silage making

In silage making the cut and chopped plant material is not dried out as much as in haymaking. Instead, it is collected and put into a silo while still quite moist. The secret to preserving this material is to seal the silo so that air cannot get in – decay-causing fungi and bacteria in the material cannot live without oxygen from the air. Some bacteria do survive without oxygen and they start to break down the plant material, but they cannot live for long because they produce acids and ‘poison’ themselves. The plant material is thus preserved until the silo is opened again. It is important to compact the silage while it is being stored so that as little air as possible is left in it.

Many different kinds of silos are used to store silage, as shown in Figure 24.3. A silo may be a pit or trench, two concrete walls forming a bunker or a glass-lined steel tower, but storing silage in round bales wrapped in plastic is now common. This has the advantage that the bales can be transported with a tractor fitted with a forklift.

The crops that can be used for silage making are pasture, lucerne, oats, maize and sorghum.

Most often the silage is fed out to stock on the farm where it was made. It is not easily transported because of its high moisture content and, once a silo is opened, the silage must be used fairly quickly or it will go off.

- 4 When making silage why is it important to have as little air as possible in a silo, and also to prevent air from getting in?
- 5 Why is silage most often used on the farm where it is made?

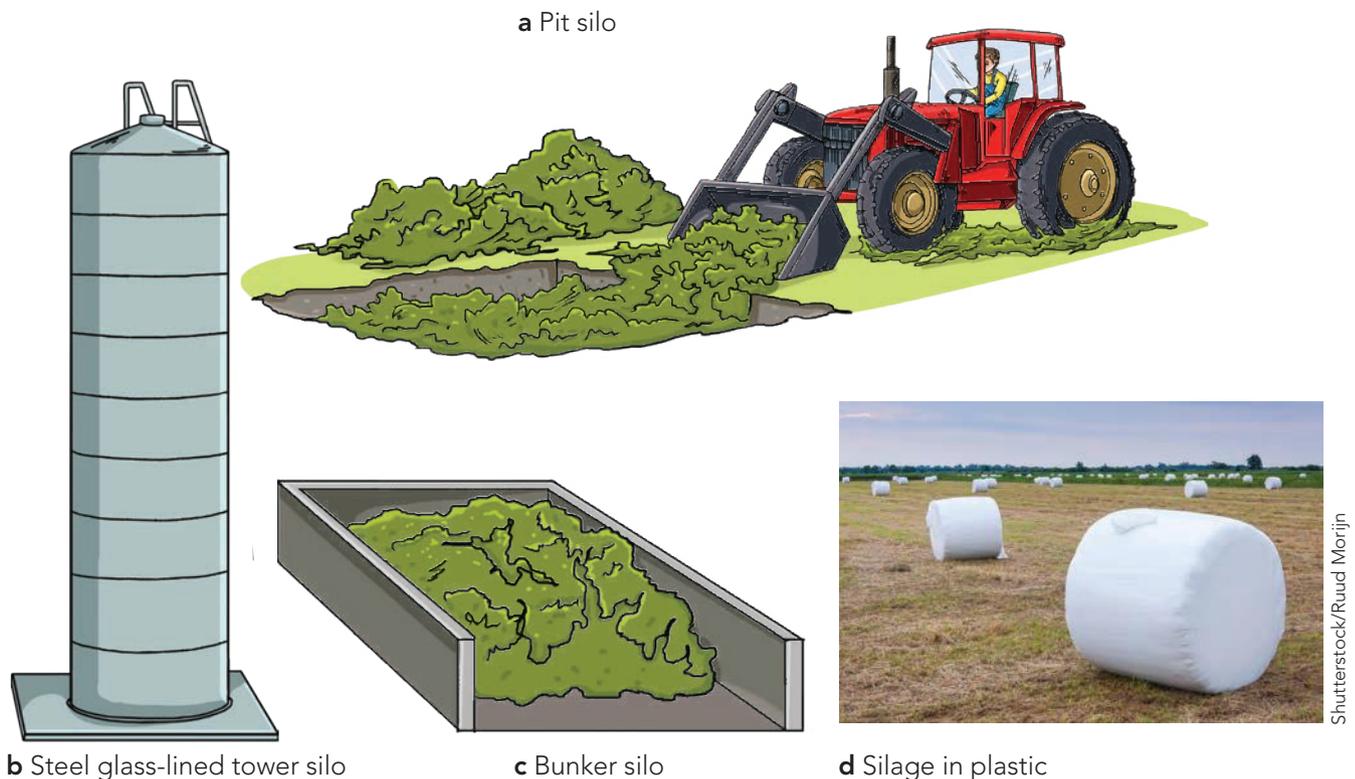


Figure 24.3 Various ways to store silage



Shutterstock/Phillip Minnis

Figure 24.4 Modern silos for storing grain on a farm

Stored grain

Cereal grains such as wheat, oats, barley, triticale, maize and sorghum are often stored on farms as a source of livestock feed. These grains make up a large part of the diet of pigs, and many piggeries are located on grain farms. The grains are also used as **supplementary feed** for cattle and sheep. They are very useful in times of drought because they are of high food value and can be easily transported. Cereal grains are stored in **vermin**-proof steel silos, like the ones in Figure 24.4. The grain is usually treated with special insecticide as it is put into the silo to prevent attack from grain-eating insects. Grain stored on the farm can also be sold if it is not needed.

- 6 Describe two ways that a farmer can use grain stored in a farm silo.
- 7 Why is grain treated with insecticide as it is put into the silo?
- 8 Explain why lucerne crops would be harvested for hay and silage when they have just started flowering.
- 9 Why would a cereal crop cut when the grain was mature not make very good quality hay?

Harvesting

For grain crops, harvesting is carried out when the seed has matured and dried out to a moisture content of 12 per cent or less. Grain can be stored for several years with little loss in quality.

Cereal crops cut for hay and silage are ready when they are at the stage of filling the grain in the seed heads. The grains are not solid but milky inside. Lucerne is ready for cutting just after it has started to flower (the farmer can judge this time when he sees a purple tinge from the flowers across the green paddock of lucerne). Figure 24.5 shows the appropriate time to cut a crop or pasture.

For hay and silage, the harvest time for crops and pasture is when the plants have plenty of protein and bulk and not too much fibrous material, which is hard to digest. As crops and pastures mature, the amount of indigestible fibre increases rapidly and the level of digestible nutrients and protein decreases. If crops are harvested too early they do not have sufficient bulk, even though they contain digestible nutrients.

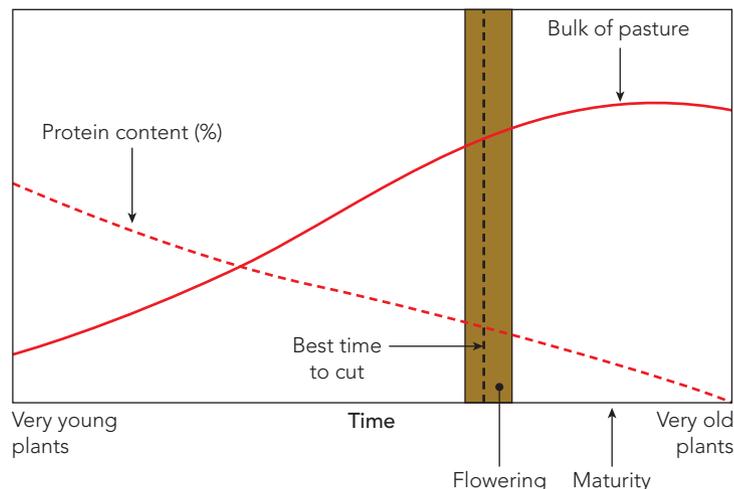


Figure 24.5 Graph showing when to cut a crop or pasture for hay or silage

Costs

Fodder conservation can be very expensive. There is a high cost in buying the special machinery, or in hiring contractors; silos and storage sheds also cost money. Labour costs used to be high, but with increased use of modern labour-saving machinery they have been reduced. For example, one person can now mow, bale and store a lucerne hay crop; 50 years ago this would have required at least three people. Whether or not fodder conservation is worthwhile depends finally on the value of the products produced by the livestock that consume the fodder.

10 How has the cost of labour been reduced in conserving fodder?



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Figure 24.6 Pasture quality and animal production levels are closely linked.

Chapter review

Things to do

- 1 Collect pictures from rural magazines and newspapers showing the machinery used for making either hay or silage and produce a collage.
- 2 Make silage on a small scale by cutting lawn or pasture with a lawn mower and collecting the cut material. Stuff this into at least three plastic garbage bags. Squeeze out as much air as you can and seal two of the bags. Leave one bag unsealed. After 3–4 weeks examine and compare the 'silage' in the sealed and unsealed bags. Record any differences in smell, colour and appearance.
- 3 Cut some lucerne and make two small piles weighing the same. Record the weight. Condition one pile by bending the stems until they crimp – put a crimp every 15 cm along the stem. Allow the 'hay' to dry out for 1 week and weigh each pile again. Is there a difference in the weight of each pile? Does conditioning make the hay dry out faster? Why would it be an advantage when making hay?

Things to find out

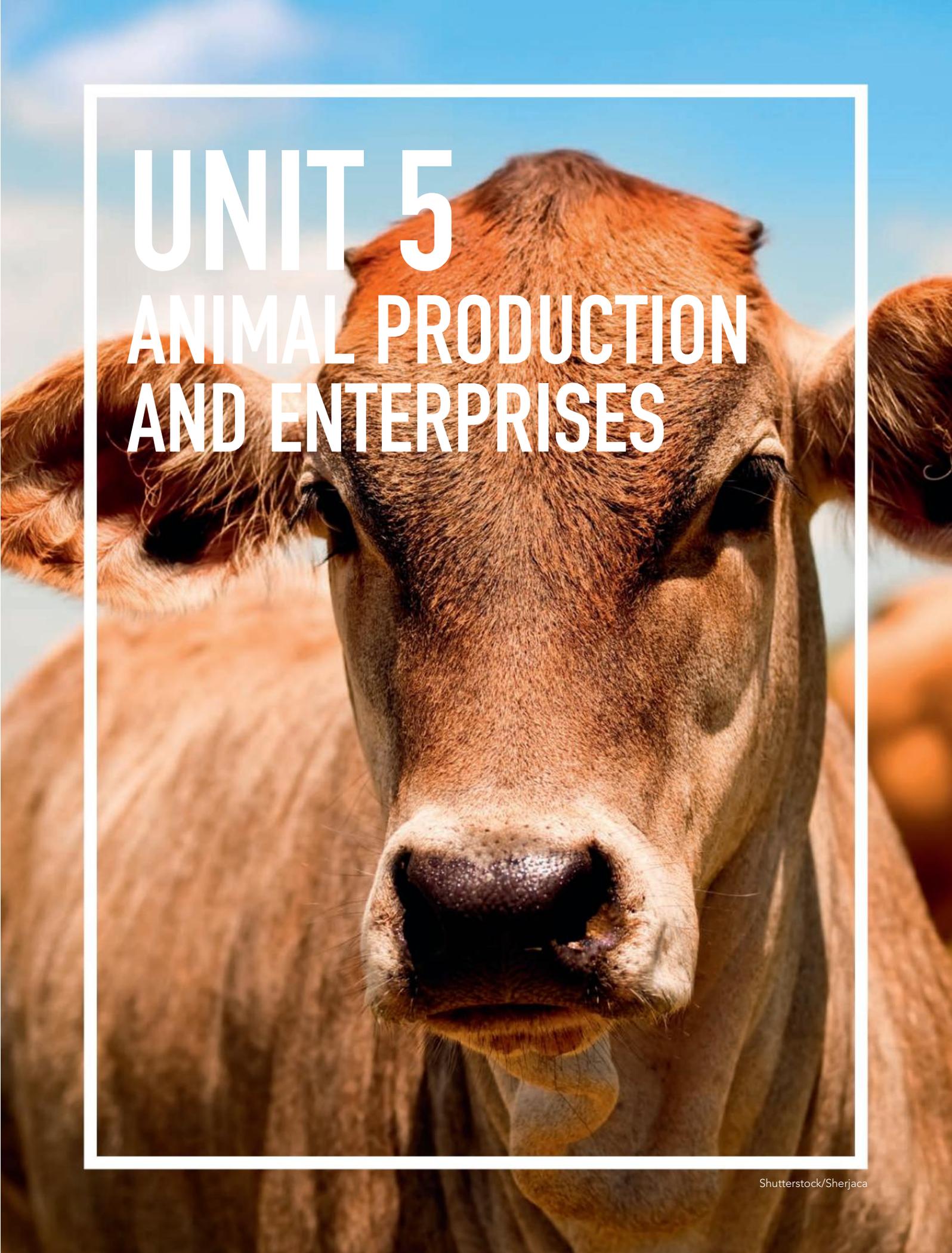
- 1 Where in the state are there farms that specialise in growing and making hay?
- 2 Discover whether any fodder conservation is carried out in your district. What crops are used? How are they stored? For what kinds of livestock are they used?

Extension activities

- 1 Some silos maintain an internal vacuum, especially if kikuyu has been finely chopped and stored. Explain the theory behind this form of fodder conservation. Is this common?
- 2 When driving in the country many forms of fodder conservation are seen. Explain how the following fodder conservation processes are carried out and give reasons why this system of fodder conservation may have been adopted compared to the manufacture of standard hay bales.
 - a Large round bales
 - b Large rectangular bales
 - c Round bales wrapped in heavy plastic

Test yourself

- 1 Explain the process for storing grain and feeding it to livestock.
- 2 Compare and contrast haymaking with silage manufacture.



UNIT 5

ANIMAL PRODUCTION AND ENTERPRISES

CHAPTER 25

ANIMAL ANATOMY AND PHYSIOLOGY

Words to know

abomasum the fourth and true stomach of a ruminant animal where digestive juices are produced

anatomy the study of the structure of organisms

cell the basic structural unit of all living things; living things are made up of either a single cell (unicellular) or many cells (multicellular) and cells are either eukaryotic (having a nucleus) or prokaryotic (having no nucleus); all animal cells are eukaryotic

endocrine glands ductless glands producing hormones or body regulators

fertilisation one sperm from the male unites with one ovum from the female

hormone a chemical substance secreted by ductless or endocrine glands directly into the bloodstream to control body actions or processes

omasum the third stomach of a ruminant animal, sometimes called the bible because of leaf-like partitions that line its walls, which remove 60–70 per cent of the water from the rumen fluid

organ a collection or group of tissues (similar or different) that combine to perform a specific function

ovulation the release of an egg from a mature follicle

physiology the study of functions of the animal body or any of its parts

reticulum the second stomach of a ruminant animal, closely joined to the rumen or first stomach. The reticulum is also called honeycomb due to its physical appearance. This stomach breaks down coarse fibre until it is fine enough to enter the rumen for fermentation

rumen the first stomach of a ruminant animal where food is fermented by bacteria and fungi and cellulose is digested

semen the fluid that contains sperm produced by the male sex organs

system a group of organs working together to perform a specific function

tissue a specialised group of cells that together carry out a specific function (e.g. muscle cells form muscle tissue)

urea nitrogenous waste collected and excreted by the kidneys

Introduction

Anatomy is the study of the structure of organisms, especially the internal structure. **Physiology** is the study of the functions of the animal body or any of its parts. The physical and chemical processes that occur in the body are studied; for example, contraction of muscles or transmission of nerve impulses. When describing an animal, we say that the head is at the anterior end, the tail hangs at the posterior end, the back is the dorsal region and the surface facing the ground is the ventral region (Fig. 25.1).

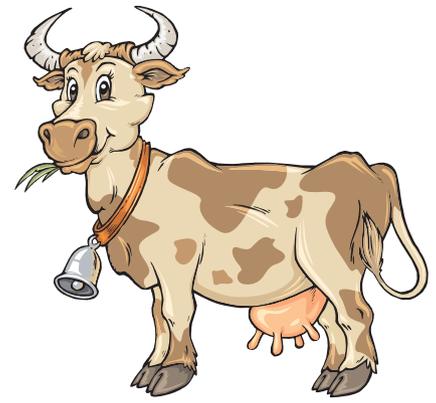
The bodies of animals are composed of millions of small units called **cells**. When the number of cells increases, certain cells become specialists in one or more functions of the animal body. Specialised groups of cells are called **tissues**. For example, cells that specialise in conducting impulses help make up nervous tissue.

Various tissues are associated in functional groups called **organs**. The stomach is an organ that functions to digest food. A group of organs that are involved in a common enterprise make up a **system**. The stomach, liver, pancreas and intestines are all part of the digestive system. The main structure or structures in each body system is listed in Table 25.1.

To gain a thorough understanding of body function, you must have a good basic knowledge of the structures involved. The science of anatomy and physiology has become so broad that different parts of the body can be divided into many specialised areas, as demonstrated by the list of body systems in Table 25.1.

Table 25.1 Body systems

System	Chief structure
Skeletal	Bones
Muscular	Muscles
Nervous	Brain, spinal cord and nerves
Circulatory	Heart and blood vessels
Lymphatic	Lymph glands
Respiratory	Lungs and air passages
Digestive	Stomach and intestines
Urinary	Kidney and bladder
Endocrine	Ductless glands
Reproductive	Ovaries and testes



Shutterstock/Enache Dumitru Bogdan

Figure 25.1 The head of a cow is at the anterior end; the tail at the posterior end.

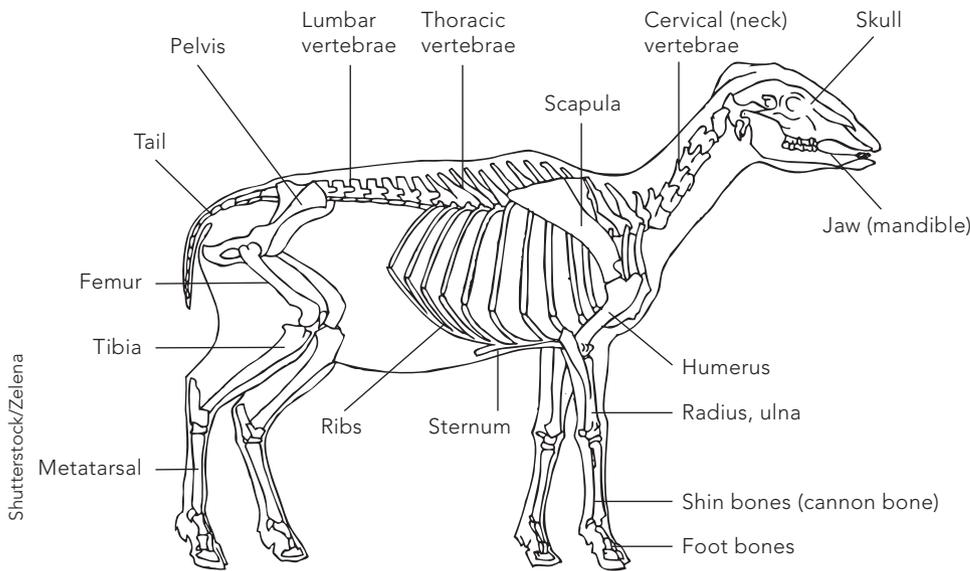
- 1 Define 'anatomy'.
- 2 What is the dorsal region of an animal?

Animal anatomy and physiology

The skeletal system

The skeleton of a living animal is made up of bones that are themselves living structures. They have blood vessels, lymphatic vessels and nerves that are subject to disease but that can repair themselves. Approximately one-third of the weight of bone consists of an organic framework of fibrous tissue and cells that gives toughness to the bones. The remaining two-thirds of the weight of bone consists of inorganic salts – mainly calcium and phosphorus deposited within the organic framework. The functions of bones include providing protection, giving rigidity and form to the body, acting as levers, storing minerals and providing a site for blood formation.

- 3 List four functions of bones.
- 4 List the bones in the hind legs of a sheep.



A typical long bone consists of a 'head' or joint surface at each end and a shaft in between. The shaft is made of very dense or compact bone. Blood vessels and nerves enter the marrow inside a bone through many small holes called foramina. At the ends of the bone a thin layer of tissue called cartilage provides a smooth surface upon which the bones move. The skeleton of a sheep is shown in Figure 25.2.

Figure 25.2 Skeleton of a sheep

The muscular system

Muscle cells are highly specialised for the function of contraction. Muscle contraction is important for activities such as walking, breathing, blood circulation and most activities associated with reproduction.

A muscle consists of thousands of small muscle cells grouped together into small and large bundles. These bundles are further grouped together and held by a wrapping of connective tissue. The ends of a muscle change into strong tendons that join the muscle to the bone. A muscle is usually attached at one end directly to a firm, non-moving bone surface, and at the other end by the surface of a moving bone by means of a tendon. When a muscle contracts the bones are pulled together.

The animal body contains several important groups of muscles. These are located in different parts of the body and include muscles of the:

- back and loin
- hind leg
- neck
- foreleg and shoulder
- body wall.

In mature animals the muscles of the hind leg are usually the largest and the most valuable on a beef carcass. The condition of an animal can be assessed by looking at the back region and hindquarters. The muscles at the front end of an animal contain a lot of tough connective tissue and are of less commercial value.

The nervous system

The main structures of the nervous system are the brain and the spinal cord. The cranial nerves, which come from the brain, are concerned with the senses of sight, touch, taste, hearing and smell. The spinal nerves, which arise from the spinal cord and run to different parts of the body, are concerned with the sensations of touch and movement.

The brain and the spinal cord form the central nervous system and their associated nerves form the peripheral nervous system. Connected with each pair of spinal nerves is a pair of sympathetic ganglia – groups of nerves from which run the nerve fibres that make up the sympathetic system. This system regulates the automatic

5 Identify four activities that involve muscle contraction.

6 Identify the muscles that are the most valuable on a beef carcass.

functions of the body, such as the activity of the kidneys, the stomach, the liver and the circulatory system.

Spinal nerves are referred to as mixed nerves. They contain nerve fibres of two types – sensory and motor. The sensory fibres carry impulses from the organs and tissues to the spinal cord. The motor nerves carry messages in the reverse direction, stimulating the organ or tissue to respond. The circuit of impulses from the sensory or receptor tissue to the central nervous system and back to the muscle or gland is called a reflex arc. A reflex arc also allows the body to respond very quickly to immediate danger (e.g. touching a hot object) without sending a message to the brain first. An organism has no conscious control over some reflex actions (e.g. fast movement away from a hot object).

The circulatory system

The circulatory system is made up of the heart, the blood vessels and the blood (cells and plasma) (Fig. 25.3).

The heart is an organ made up of special muscle tissue so that it can contract and relax. The hearts of animals such as sheep, cattle or goats consist of four chambers – the right atrium and ventricle and the left atrium and ventricle. The right-hand side of the heart receives blood from the body that is low in oxygen and sends it to the lungs to be oxygenated (i.e. given a high concentration of oxygen). The left-hand side of the heart receives oxygenated blood from the lungs and pumps it out to all parts of the body.

The main artery of the body is the aorta, which leaves the heart and passes up and backwards close to the backbone. The aorta branches off into smaller arteries that transport blood to all parts of the body. Veins collect the blood from every part of the body and return it to the heart.

The heart of a sheep, goat or cow is found in the chest between the front legs. If an animal is ill a stethoscope can be used to listen to its heart beat. The heart beat will be faster if an animal is excited or if there has been an increase in movement or muscular activity.

The blood has a number of important functions.

- Its red blood cells transport oxygen to all the cells of the body.
- It carries nutrients from the intestines to all the body cells.
- It takes waste substances such as **urea** from the body cells to the kidneys.
- It carries **hormones** to different parts of the body.
- It carries antibodies and white blood cells to combat foreign substances or organisms that may have invaded the body.

The lymphatic system

This system consists of millions of small tubes found in every part of the body. Their function is to drain excess fluid and to transport bacteria or poisons that may have entered the body through wounds.

Lymphatic vessels take unwanted materials to the lymph glands or nodes, where they are destroyed. A diseased animal will have swollen lymph glands. Meat inspectors look at the lymph glands of carcasses for signs of disease such as the presence of bacteria causing tuberculosis.

7 Identify the senses that the cranial nerves are concerned with.

8 Name one important feature of reflex actions.

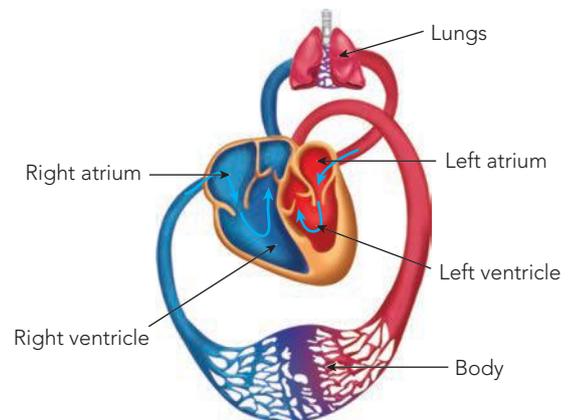


Figure 25.3 Path of blood flow

9 How many chambers are there in a sheep's heart?

10 Identify the instrument that is used to listen to an animal's heart.

11 Outline the function of the lymphatic system.

12 Explain what swollen lymph glands in an animal would indicate.

- 13 What is the name given to the tiny air sacs in the lungs?
- 14 Briefly explain the function of the lungs.

The respiratory system

Air enters the body via the nose and mouth, passing down a tube called the trachea. The trachea divides into two smaller tubes called bronchi, which take air to the two lungs. Each of these tubes divides into many smaller tubes, called bronchioles, which have tiny air sacs called alveoli at their ends.

In most four-footed animals the lungs lie high up in the chest, protected by the ribs and backbone. The function of the lungs is to absorb oxygen from the air and pass out carbon dioxide as a waste product. In animals that do not sweat through the skin, the lungs are also used to rid the body of excess heat. This is why sheep breathe very rapidly in hot weather.

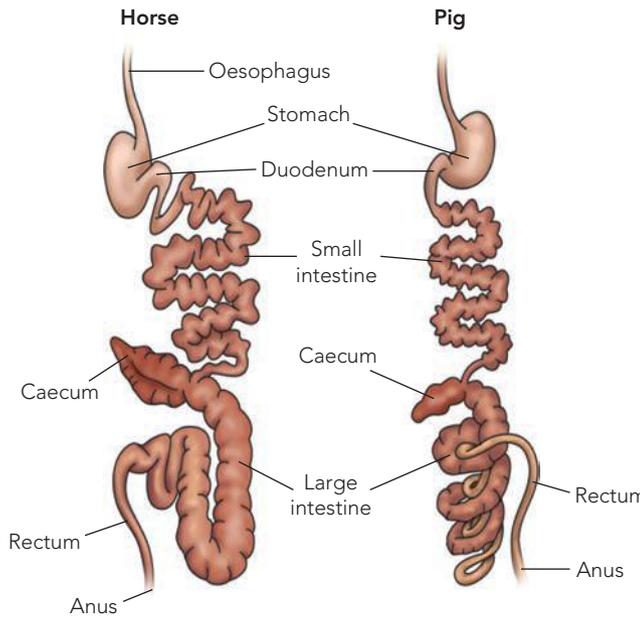


Figure 25.4 Digestive tracts of a horse and a pig

juice contains enzymes that break down proteins, fats and carbohydrates. Most of the absorption of nutrients into the bloodstream occurs in the small intestines. Figure 25.4 illustrates the monogastric digestive tracts of a horse and a pig.

The caecum – the sac at the beginning of the large intestine – varies in structure for different animals; digestion occurs in the caecum as a result of bacterial fermentation. The large intestine is almost non-existent in poultry but is very important in horses and pigs. Much of the material that enters the large intestine is indigestible (e.g. cellulose and lignin), but some digestion occurs there as a result of bacterial fermentation. Removal of water from food occurs in the large intestine.

The digestive tract in birds has some unusual features (Fig. 25.5). The bird has no teeth and must swallow its food whole. Food may be stored temporarily in the crop, which secretes mucus and so moistens and softens the food before it passes into the proventriculus. The proventriculus is the only true stomach; it secretes gastric juice that consists of hydrochloric acid and the enzyme pepsin (needed for protein digestion). The food mixes with the gastric juices, then passes into the gizzard. The gizzard is unique to the bird; its walls are muscular and strong, contracting to break up food mechanically. For this reason, the diet of poultry should include pieces of grit. The grit passes through to the gizzard where it assists in breaking up food particles. After the food leaves the gizzard it passes into the duodenum or the first part of

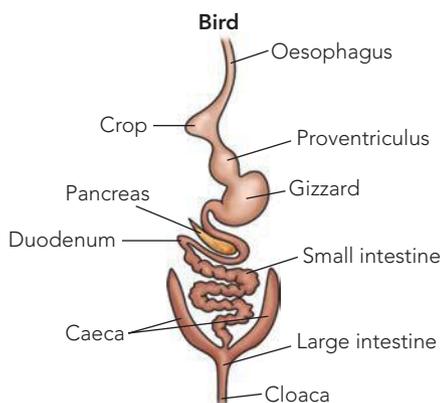


Figure 25.5 Digestive tract of a bird

The digestive system

The function of the digestive tract in animals is to break down food so that it can be absorbed into the body. In monogastric animals there is only one stomach. In ruminant animals there are four stomachs, including a large **rumen**.

Monogastric digestion

Pigs, poultry and horses are the most common monogastric farm animals. In these animals the oesophagus is connected to the stomach. The wall of the stomach contains cells that secrete gastric juices. The stomach leads into the duodenum (the upper part of the small intestine), into which the bile and pancreatic ducts empty. The bile is produced in the liver and is stored in the gall bladder. Its main purpose is to break down fats in the food. Pancreatic

the small intestine. Pancreatic juice and bile enter the lower end of the duodenum, mixing with the food. The enzymes in the pancreatic juice break down the carbohydrates, fats and proteins into simpler components including amino acids, simple sugars, glycerol and fatty acids. These are absorbed into the bloodstream as they pass through the small intestine. Unabsorbed food particles pass into the large intestine, where some water is removed. The paired caeca mark the beginning of the large intestine.

Waste products of the digestive process (faeces) and the urinary system (urine) are released via a common opening called the cloaca.

Ruminant digestion

Sheep, goats and cattle are the most common ruminant farm animals.

Their digestive organs are different in structure and function from those of monogastric animals. A ruminant's digestive tract has four stomachs, which are called:

- 1 the **reticulum**, which filters fibre until it is fine enough to enter the rumen
- 2 the rumen, which ferments food with the aid of bacteria and fungi
- 3 the **omasum**, which absorbs water from the broken-down food
- 4 the **abomasum**, or true stomach, where digestive juices break down food.

Digestion is a slow process in a ruminant, because the animal needs to store and ferment the food within its digestive tract. This occurs in the rumen and reticulum. Food is further softened by being regurgitated and re-chewed. This is common to all ruminants and is termed 'rumination' or chewing the cud.

Ruminant animals feed on bulky, fibrous foods that would be indigestible to a monogastric animal. In monogastrics, fibre is only needed to provide bulk to ensure that food continues to move along the digestive system. The ruminant is able to break down cellulose in the fibre of plants with the help of bacteria, protozoans and anaerobic fungi that live in the rumen.

The rumen and the reticulum are closely joined and have the same function; they are often referred to as the 'paunch'. The paunch has strong muscular walls that are continuously moving, causing the contents to be churned and thoroughly mixed. Food from the paunch is regularly returned to the mouth for re-chewing. The rumen–reticulum acts like a fermentation chamber. It contains a large population of micro-organisms that secrete enzymes, consequently assisting in three processes:

- 1 the breakdown of carbohydrates such as cellulose, sugars and starch into volatile fatty acids
- 2 the synthesis of proteins
- 3 the synthesis of vitamin B.

The omasum or third stomach is often called 'the bible' because of leaf-like partitions that line its walls. The omasum removes 60–70 per cent of water from the rumen fluid that enters it. The abomasum is the true stomach that secretes gastric juices from cells in the walls of the stomach lining. Protein digestion occurs because of the action of an enzyme, while hydrochloric acid kills the majority of rumen microbes. Food leaves the abomasum and is mixed with bile from the pancreas in the small intestine where several enzymes are secreted. Starches, proteins and fats are broken down into soluble compounds (glucose, amino acids from proteins and fatty acids from fats) and absorbed into the bloodstream through structures in the small intestine walls termed villi. The caecum allows for further fermentation of food and marks the start of the large intestine. The undigested food residues pass into the large intestine where water, vitamins and minerals are absorbed and some bacterial action continues to digest food. The residues pass into the rectum and out of the body through the anus as dung or faeces. Digestion in sheep is discussed in Chapter 29 (see Figs 29.11 and 29.12).

15 Where does most of the absorption of nutrients occur in monogastric animals?

16 What organisms are involved in the breakdown of cellulose in ruminant animals?

17 What do you think the rumen does in digestion?

18 What happens in the reticulum?

19 Why is the abomasum important?

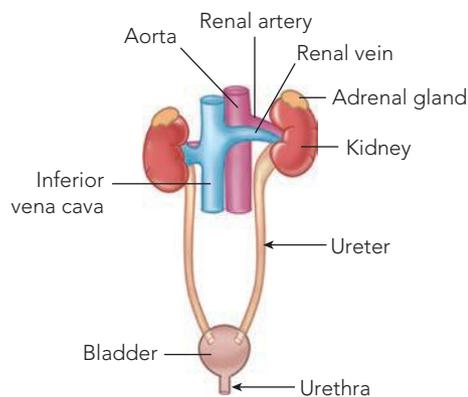


Figure 25.6 The kidneys and the bladder

The urinary system

Blood transports the waste products of cell metabolism to the kidneys. There are two kidneys in the body and they lie in the abdomen, one on either side of and against the vertebral column. From each kidney emerges a tube called a ureter, which is attached to the bladder. At the bottom of the bladder is another tube called the urethra, which leads to the outside of the body. These structures are shown in Figure 25.6.

The main function of the kidney is to purify the blood. The kidneys filter urea (a nitrogenous substance), excess mineral salts and excess water from the blood. The new concentrated fluid, called urine, passes from the kidney, via the ureter to the bladder. It is stored in the bladder until it is discharged from the body through the urethra.

The endocrine system

The **endocrine glands** (or ductless glands) manufacture chemical messengers, or hormones, to control body activities. At the appropriate time these hormones are secreted in the bloodstream, which carries them to all parts of the body. Usually, each hormone only affects one organ or system of organs.

The pituitary gland is located at the base of the brain. It is called the master gland because it controls other endocrine glands. Its functions are to control growth of the skeleton and to regulate the metabolism of food, the muscles of some internal organs and the functioning of the kidneys.

Two other endocrine glands are the pancreas and the thyroid. The pancreas releases the hormone insulin, which allows the body cells to use blood sugar, and the thyroid gland produces the hormone thyroxine, which governs the rate at which cells use energy.

The reproductive system

In sexual reproduction one sperm from the male unites or joins with one ovum from the female. This is called **fertilisation**. The fertilised egg is called a zygote and it grows into a young animal.

The main reproductive organs of a bull are the testes, in which the male sex cells or sperm are produced. The testes lie outside the body in a sac called the scrotum. This sac keeps the sperm at a temperature slightly below body temperature. If the testes were retained inside the body the sperm would be over-heated and would be infertile.

The sperm pass from the testes into a long coiled tube called an epididymis where they are stored. They travel via the vas deferens or spermatic duct to the seminal vesicles. Here the sperm become mixed with a fluid made by the accessory glands (prostate, seminal and Cowper's glands). This fluid causes the sperm to swim actively, so that they will travel up the female reproductive tract quickly. The mixture of sperm and other fluids is called **semen**. In males, the urethra carries both urine (urinary system, see Fig. 25.6) and semen. These structures are shown in Figure 25.7.

The main reproductive organs of the cow are the ovaries. The ovaries produce female sex cells or ova, which are released at regular intervals. This process is called ovulation, and it occurs every 21 days in cattle if they are not pregnant. The female reproductive organs are shown in Figure 25.8.

-
- 20** What is the name of the tube that connects the bladder to the kidney?
- 21** What is the main function of the kidney?

-
- 22** Identify the hormone produced by the thyroid gland.
- 23** List four functions of the pituitary gland.

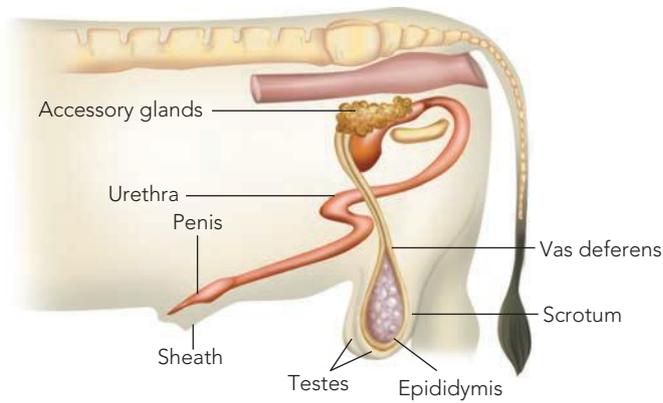


Figure 25.7 Male reproductive organs (bull)

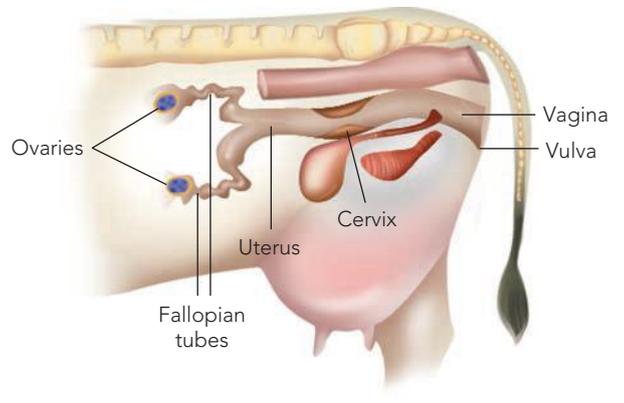


Figure 25.8 Female reproductive organs (cow)

The released ova or egg enters the Fallopian tubes. If the egg is not fertilised at this stage, it degenerates. If the egg is fertilised by a sperm it moves down to the uterus, or womb, where it becomes attached to the wall and begins to develop into a foetus (Fig. 25.9).

Towards the end of pregnancy, changes in the hormone level of the blood cause the passage through the cervix and the vagina to enlarge and the uterine wall to contract. These contractions cause the foetus to be expelled, and it is followed by the afterbirth, or placenta. Table 25.2 indicates the length of pregnancy or gestation period for some farm animals.

Table 25.2 Length of pregnancy for some farm animals

Animal	Gestation period (days)	Gestation period (months)
Cow	280–5	9
Sheep	150	5
Goat	150	5
Pig	114	4

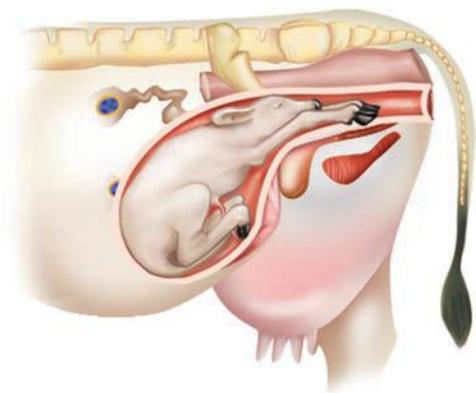


Figure 25.9 The foetus develops within the uterus.

-
- 24** Describe the main function of the ovaries.
 - 25** Explain what happens to an egg or ovum after fertilisation.

Chapter review

Things to do

- 1 Look at a mounted skeleton of a sheep, cow or goat. Draw and label the bones of the back leg.
- 2 Obtain a sheep's heart from a butcher. Dissect the heart and sketch the main features. Which ventricle has the thickest wall and why?
- 3 Obtain a set of sheep's lungs and windpipe from a butcher. Dissect the trachea and lung. Draw the main structures and describe their texture.
- 4 Go to the [Livestock identification](#) website and complete the activities on skeletal systems and body parts.

connect

Livestock identification

Things to find out

- 1 Define 'reflex arc'.
- 2 List the functions of the cervix in a female reproductive tract.
- 3 Look at a mounted skeleton of a sheep, cow or goat. Which joints allow the most movement? Find out the correct names for each kind of joint.
- 4 The holes in bones allow blood vessels to enter them. Why do you think blood circulates through the bones?
- 5 Explain why animals such as sheep and cattle can live on fibrous foods (hay and pasture), while animals such as pigs and poultry cannot.

+ Extension activities

- 1 List the male reproductive organs shown in Figure 25.7 and outline the function of each organ.
- 2 Describe the main structural differences between the anatomy of a monogastric and a ruminant digestive system and draw and label a diagram.
- 3 Describe the main features of the male and female reproductive systems and draw and label a diagram.

Test yourself

- 1 Describe a typical long bone.
- 2 Name the locations of the main muscles of the body.
- 3 State five functions of the blood.
- 4 State the function of the endocrine system.
- 5 In your notebook, write each of these words with the correct definition from the list below.

physiology, anatomy, hormones, tissues, ovulation

- the study of the structure of organisms, especially the internal structure.
- the study of the functions of the animal's body or any of its parts.
- specialised groups of cells.
- a chemical substance secreted by ductless or endocrine glands directly into the blood stream to control body actions or process.
- the release of an egg from a mature follicle.

CHAPTER 26

FACTORS INFLUENCING ANIMAL PRODUCTION

Words to know

genotype the genetic makeup of an individual organism (animal)

intravenous injection the injection of fluid into a vein

monogastric an animal with one stomach

phenotype the appearance and production of an organism

ruminant an animal with four stomachs, including a rumen inhabited by millions of microbes (e.g. sheep, cattle and goats); alpacas are called ruminants but have only one stomach with three compartments

vaccination the injection of a substance to produce immunity or resistance to a disease

Introduction

The ability of an animal to produce meat, wool, mohair, eggs or milk is affected by a number of factors. These include nutrition, pests, disease, genetics, climate and management. These factors set a limit to animal production. In Australia, nutrition or feed is usually the major limiting factor in grazing or extensive animal industries (cattle, sheep and goats).

If an animal lacks the genes that permit rapid growth and a high reproduction rate, their production will be limited. Progress has been made in the poultry industry by breeding fast-growing meat strains and prolific egg-laying strains. Improvement has been made in the dairy and beef industry by using semen from high-producing bulls. Some of this semen has been imported from other countries.

Climate is often a limiting factor in animal production. In northern Australia it is common for high temperatures to decrease the productivity of cattle. This has been overcome to some extent by introducing tropical breeds that are better suited to this environment; for example, Brahman cattle from India. These cattle are now used extensively in crossbreeding with European breeds.

Animal disease causes ongoing losses in animal production. Australia is fortunate not to have some of the more devastating diseases found in other countries, but some diseases are a major source of lost income; for example, mastitis lowers production in dairy cattle and its treatment is costly.

Management includes the decisions and routine practices performed by the farmer to control the stocking rate, growth rate, reproduction rate and survival rate of the flock or herd. The farmer can change the diet of the animals, vaccinate them to prevent disease, or introduce new genetic material by artificial insemination.

Figure 26.1 shows Angus cows and calves. The calves are produced by using semen from a Canadian bull. This practice has led to the development of larger, better muscled Angus cattle.

The productivity of animals depends on their density (the stocking rate, e.g. three sheep per hectare) and on their rates of growth, reproduction and survival. These rates depend on nutrition, pests, disease, genetics, climate and management. Production or productivity varies between animals of the same breed and between different breeds. It can be measured and performance records are often used to measure productivity in terms of, for example:

- kilograms of wool produced per sheep per year
- number of eggs laid per hen per year
- weight gain in kilograms per animal per year
- number of lambs born per ewe per year
- litres of milk produced per cow per year.

- 1 List five factors that might affect animal production.
- 2 In Australia, which factor most limits production of grazing animals?
- 3 Explain how productivity is measured in poultry.



Shutterstock/MBoc

Figure 26.1 Angus cows and calves

Nutrition

Animals need food:

- as a source of energy so that they can maintain the working of their organs (e.g. the lungs and heart), maintain their body temperature and be able to move
- as structural material for building and maintaining body structures such as bones, muscle, skin, wool, hair and teeth
- to regulate body processes (e.g. nutrients are needed to produce hormones)
- to store chemical energy for growth and for milk, wool or egg production.

Foods are substances that can be digested and absorbed by the body of an animal. The main nutrients or kinds of food substances are carbohydrates, proteins, fats, vitamins, minerals and water.

Although animals must be able to absorb all these nutrients from their intestines, it is not always essential that their diet contains all these substances. **Ruminants** (sheep, cattle, goats) carry a large population of bacteria, fungi and protozoa and are able to make amino acids in their rumen. **Monogastrics** (pigs and poultry) have no rumen so the essential amino acids must be added in the feed or the animal will not grow properly. Animals exposed to sunlight may not have to be supplied with vitamin D in their diet. This nutrient is formed under the skin by the action of sunlight.

An animal's requirement for energy and protein can be considered under two headings: maintenance and production. The maintenance requirement consists of the amount of food needed to keep the animal alive and healthy without producing any product (e.g. milk, eggs, wool) or making any growth (weight gain). The maintenance requirement of an animal is affected by many factors, including:

- weight
- body composition (fat or thin)
- physiological status (pregnant, lactating or dry)
- whether it is diseased or healthy
- the surrounding climate
- genetic-makeup (breed).

The production requirement is largely independent of the size of the animal and is proportional to the quantity and quality of the product that it gives. For example, a cow producing 22 litres (L) of milk per day has a production requirement greater than that of a cow producing 11 L of milk per day and should be given extra feed.

Feed ingredients are classified as either concentrates or roughages. Concentrates have high concentrations of major nutrients. They include cereal grains (maize, wheat, oats and barley) and by-products such as oilseeds, meat meal and fish meal. Roughages contain substantial amounts of fibre. They include pastures, forages, hays, silages and fibrous by-products such as cottonseed hulls.

The diets of pigs and poultry are normally made up of concentrates and the diets of herbivores (sheep, cattle, goats and horses) are normally based on roughage, with some concentrates when the nutrient content of the roughage is inadequate (e.g. during a drought or during winter).

-
- 4 List and briefly describe four reasons why animals need food.
 - 5 List the six main nutrients or kinds of food substances.
 - 6 Define 'concentrate' and list three examples.

Disease

An animal disease is any kind of upset to the normal body functioning that has an adverse effect on the animal. Diseases may result in death, weakening, slower growth and lower production. All diseases are costly to the farmer. Farmers may lose the animal, have a loss in production and spend money on expensive treatment programs.

Types of disease

There are four main types of disease that can affect animals.

- 1 Hereditary diseases are passed on to the offspring by one of the genes.
A featherless condition in poultry is passed to chickens in this way.
- 2 Metabolic diseases occur when one section of the body does not work normally.
Milk fever in cattle occurs when calcium in the blood drops to a low level, usually just after calving. This disease can be treated by an **intravenous injection** of calcium borogluconate.

- 3 Microbial diseases occur when a pathogen enters the animal. A pathogen is a disease-causing organism and can be a virus, bacterium, fungus or protozoan. Some examples of microbial diseases are:
- viral disease (e.g. Newcastle disease of poultry and swine fever of pigs)
 - bacterial diseases (e.g. tuberculosis, mastitis, enterotoxaemia (pulpy kidney) and footrot in sheep and cattle)
 - fungal diseases (e.g. lumpy jaw and ringworm in cattle)
 - protozoal diseases (e.g. coccidiosis in poultry).
- 4 Metazoal diseases are caused by animals that can be seen with the naked eye. These organisms include:
- flatworms (liver fluke, tapeworms and hydatid worms)
 - roundworms (threadworm, nodule worm and barber's pole worm)
 - insects (bot fly of horses and sheep blowfly)
 - ticks and other arthropods (sheep ked, sheep itchmite and cattle tick).

Controlling disease

Many methods are used to control or prevent animal diseases.

- *Eradication*. The disease is removed from a farming system by testing all animals and slaughtering those that are infected with it. This method has been used to eliminate brucellosis in cattle from New South Wales.
- *Vaccination*. The host is inoculated (injected) with part or whole of the pathogenic organism, resulting in immunity or resistance to further infection.
- *Chemical control*. Internal parasites have been controlled by chemicals administered as drenches, as seen in Figure 26.2, and external parasites by chemicals applied as dips. Insecticides to kill lice and keds and to prevent fly strike in sheep are usually applied by plunge-dipping, shower-spraying or pour-ons (backlining). Chemicals can also be added to the feed ration of pigs and poultry to control diseases of the gastrointestinal tract (e.g. coccidiosis is controlled by adding a coccidiostat to the feed).
- *Biological control*. This approach has been used to eradicate the screw-worm fly from the southern part of the United States. This parasite lays its eggs in open wounds and the larvae burrow into the body, causing severe loss of production and death. The females mate only once. Large numbers of male flies are bred artificially, sterilised by irradiation and then released by aircraft. The females that mate with the irradiated males do not produce offspring, so numbers are reduced.
- *Genetic control*. The ability of hosts to develop resistance to disease is often inherited. It is possible to select and breed animals that have a high degree of resistance to parasites. Zebu cattle are more resistant to ticks than European cattle.
- *Management control*. An important method of disease control is the planning of the layout and relative position of facilities on the farm. For example, chickens should be kept separate from old stock; parasites can be starved out of grazing areas by resting paddocks and using pasture rotation; areas (usually swamp areas) that harbour snails (involved in the lifecycle of the liver fluke) can be fenced off.
- *Integrated pest management (IPM)*. IPM aims to use a variety of techniques to control a pest. This combines chemical use with other methods such as breeding strategies and effective management.

-
- 7 List four possible effects of disease on an animal.
- 8 List four types of organisms that cause microbial diseases and name one disease caused by each.
- 9 What is 'chemical control'?

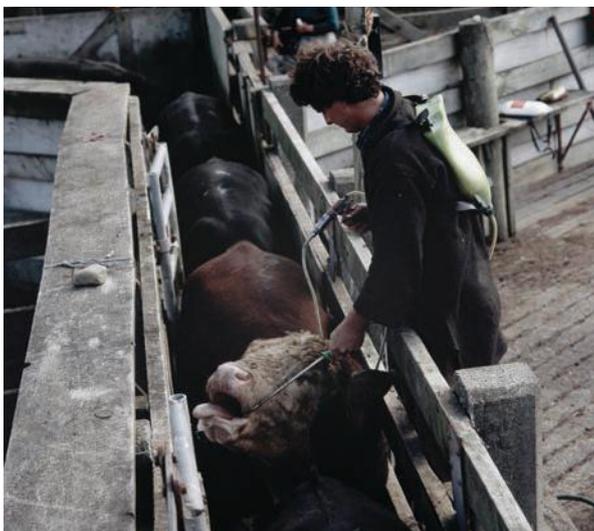


Figure 26.2 Drenching cattle for internal parasites

Genetics

The ability of an animal to produce meat, wool, mohair, eggs or milk is governed by its heredity or ancestry. The genetic makeup of an animal sets an upper limit to its possible production. If productivity in an animal industry is limited by some environmental factor (e.g. nutrition), then improvement in this shortcoming will do much more to increase productivity than attempts to improve the quality of livestock through genetics.

The genetic makeup of an animal is its **genotype**. Each animal is a product of its genes and the environment (which includes all non-genetic factors, such as climate, nutrition, disease and stress). The interaction of the genotype and the environment results in the **phenotype**. The phenotype includes the productive capacity of the animal as well as its shape or appearance.

Where there are no serious limiting factors, considerable progress can be made in improving the quality of livestock by using proven methods of animal breeding. Robert Bakewell (1725–95) began the planned improvement of livestock by breeding. He selected animals according to how much meat or wool they produced and mated 'the best with the best'. He based selection on productivity and not on the appearance of the animal.

In selective breeding the farmer chooses the animals to be mated. The main selective breeding systems are:

- *Inbreeding*. This involves the mating of close relatives – brothers and sisters, mothers and sons. It produces a uniform line of animals but it can also bring together undesirable genes; for example, dwarfism in cattle or lack of fur in rabbits.
- *Line-breeding*. This is a type of inbreeding based on a single common ancestor; for example, a sire (or dam) used over several generations of mating. A high degree of uniformity of type and production is obtained.
- *Crossbreeding*. This involves the mating of two different breeds of the same species of animal. In this system new genes are brought into the flock or herd. The crossbred progeny or hybrids are usually more vigorous in their growth and less likely to be susceptible to disease than either of the parents. This phenomenon is called hybrid vigour or heterosis.

10 What sets the upper limit to an animal's production of meat, wool, mohair, eggs or milk?

11 Define 'genotype'.

12 Describe one disadvantage or problem that can result from inbreeding.

Climate

Animals are greatly affected by climate. The following four aspects of climate are important factors in animal production.

- 1 *Temperature*. In Australia the biggest problem is the range of temperature extremes that animals may endure. This causes a variety of issues. During periods of mild heat stress animals will drink more water and eat less food, reducing their productivity. When animals are exposed to cold weather they eat less food and divert much of the energy obtained from the food into body heat. In dairy cattle, heat stress causes a reduction in milk production; in poultry it causes thin-shelled eggs; and in rams it causes poor quality sperm. Heat stress can be minimised by planting shade trees and using breeds that are appropriate to the environment; for example, Brahman cattle that are able to withstand high temperatures. Rams to be joined during hot summers should be provided with adequate shelter and carry some cover of wool. Cold temperatures are a problem for the survival of newly hatched chickens, because they have trouble controlling their body temperature. In large broiler sheds temperature is controlled through the use of insulation (in the walls and roof) and brooders.
- 2 *Humidity*. High humidity reduces the amount of heat an animal can lose by evaporation: sweating helps animals to cool themselves. Pigs and sheep cannot sweat adequately. Poultry have no sweat glands and have to rely on the moist air

- 13** What effects do periods of mild heat stress have on animals?
- 14** Describe briefly how temperature is controlled in large broiler sheds.
- 15** What factor influences when cattle shed their long winter coat?
-
- 16** To win and maintain an animal's confidence, how should a farmer behave when approaching and handling an animal?
- 17** Why should sheep, cattle and goats always be worked through a set of yards in the same way?
- 18** List five important questions that should be asked when carrying out a routine inspection of sheep, cattle or goats.

connect

Virtual farm

Take a virtual tour of three different farming systems. Make notes on the factors that influence farm productivity and the challenges facing the farming families.

connect

Australian Animal Welfare Strategy

Discuss examples of welfare initiatives in class.

- passages of the trachea, lungs and air sacs for cooling. High humidity can cause problems in totally enclosed poultry sheds, but can be reduced by installing fans.
- 3** *Solar radiation.* This can affect animal growth and reproduction. Ultraviolet rays can cause sunburn, skin cancer and eye cancer. Pigs suffer from sunburn, and the white-skinned breeds are more likely to be affected. Eye cancer is almost unknown in certain animals such as Santa Gertrudis cattle, which have a ridge of protective bone that shades the eye.
- 4** *Day length.* Changes in day length affect reproduction. Decreasing daylight hours causes increased sexual activity in rams, so the reproduction of sheep is upset in the tropics, where the animals will breed during all seasons of the year. The timing of cattle shedding their long winter coats is also controlled by day length.

Management

Farm management includes all the decisions the farmer makes about feeding, breeding, husbandry practices (e.g. drenching, mating, vaccinating and weaning) and selling stock.

Animals respond quickly to the type of handling they receive, so farmers must be consistent in their approach and behaviour. They must be quiet but firm so that they can win and maintain the confidence of the animal.

The behaviour of farm animals sometimes has a very marked effect on their production so farmers need to have some knowledge about animal behaviour to manage their animals well and get the highest production from them. Domesticated animals are creatures of habit and quickly become accustomed to repetitive procedures. Sheep, cattle and goats that are always worked in the same way through a set of yards quickly become used to this routine and are easier to handle than they are when worked in different ways.

There are a number of routine husbandry procedures or operations to which sheep, cattle and goats are subjected in order to maintain their productivity. These include drenching, jetting, mating, marking of offspring (ear marking/tagging, castration of males), weaning, vaccination and foot care. All animals should also be given routine inspections, during which the following questions should be answered.

- Are all animals grazing normally?
- Are any animals in the mob lame?
- Are any animals scouring?
- Are any animals away from the main mob?
- Do any animals have signs of discharge from noses or eyes?
- Are any animals rubbing unduly on posts or trees?
- Are any animals moving in ways that indicate their sight is impaired?

After the general inspection of a mob, there should be a closer inspection with as little disturbance as possible. If any animal is found to have a health problem steps should be taken to treat it.

Animal welfare

The Australian Animal Welfare Strategy (AAWS) is a blueprint for animal welfare in Australia. It was developed through input from industry bodies and animal welfare organisations. The animal welfare guidelines ensure all animals receive a high standard of care relating to housing, handling, sanitation, provision for food and water, veterinary care and protection from natural disasters.

Effective animal welfare management is essential in obtaining higher economic outcomes from well-cared-for and stress-free animals. Animal survival rates are higher, growth rates optimised and operator safety enhanced. Marketing strategies now highlight those production systems with ethical approaches to animal welfare and consequent premium market prices are achieved.

Chapter review

Things to do

- 1 Weigh a lamb or chicken each week for 2 months. Make a chart showing the weight gained per week or graph your results in spreadsheet software.
- 2 Visit a dairy farm. List the feeds eaten by the cows and classify the feeds as concentrates or roughages.
- 3 Visit a sheep stud. Find out if the farmer uses line-breeding. List the advantages and disadvantages of this breeding system.
- 4 Visit a broiler farm and describe how the temperature in the shed is controlled.
- 5 Watch a litter of newborn piglets every day for their first 3 weeks of life. At what age do the first signs of social order appear (when you can identify dominant piglets and the runt of the litter)?

Things to find out

- 1 Research the routine husbandry procedures or operations that are carried out at lamb marking.
- 2 Find out how pigs are artificially inseminated.
- 3 What is jetting and how is it carried out?
- 4 Visit a beef cattle property. Find out how the farmer weighs the animals.
- 5 In Europe foot-and-mouth disease is a serious problem. Find out what causes this disease, what the symptoms are and how it has been kept out of Australia.
- 6 Visit the [Aussie pig farmers](#) website. Read the section on looking after our pigs. Prepare a report on the welfare initiatives in this industry and how these initiatives are linked to quality management systems.

connect

Aussie pig farmers

Extension activities

- 1 Milk fever is a metabolic disease affecting dairy cattle. Report on:
 - a symptoms.
 - b cause.
 - c impact on the animal.
 - d treatment.
- 2 Outline how the following climatic factors affect animal production.
 - a Temperature
 - b Humidity
 - c Solar radiation
- 3 Research the following issues in relation to animal welfare.
 - a What standard husbandry practices may compromise animal welfare?
 - b Do current methods of animal transport take into account animal welfare?
 - c Are animal housing standards compatible with animal welfare requirements?

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Animal welfare

- 4 Visit the [Animal welfare](#) website. Outline the purpose of animal welfare organisations.

✓ Test yourself

- 1 Copy out the following statements and indicate if each is true or false.
 - a Genotype is the appearance and production of an animal.
 - b A ruminant is an animal with four stomachs, including a rumen.
 - c Vaccination is an injection of a substance to produce immunity or resistance to a disease.
 - d Concentrates have a high concentration of fibre.
 - e Inbreeding involves the mating of unrelated animals.
 - f Decreasing daylight hours causes decreased sexual activity in rams.
- 2 Define 'heterosis'.
- 3 List and describe the main methods that are used to control animal diseases.
- 4 Evaluate why quality welfare management systems are so closely linked to optimum productivity on farms.

CHAPTER 27

DAIRY CATTLE

Words to know

antibody a protein made by animals in response to bodily invasion by pathogens; it combines with the pathogen (or poison) rendering it harmless

artificial insemination the process in which semen is deposited in the female reproductive tract by a person using artificial insemination equipment

barren not capable of breeding

calf a young animal of either sex, from birth up to 10 months of age

colostrum the first milk that a mammal (e.g. a cow) makes to help its newborn fight disease

culling removing an animal from a herd because of age, disease, low production or physical deformity or abnormality

dry cow a cow that is not lactating or producing milk; usually she has completed her lactation and is pregnant

gestation period the time from conception to birth

heifer a female cow older than a calf, from 6 months of age until she has had a calf herself

lactation period the time from calving until the cow stops producing milk

mastitis inflammation of the udder, usually from a bacterial infection

milk yield the volume of milk produced during lactation

quota a quantity (e.g. of milk) which the farmer is required to produce; this term has been replaced with the term 'contract'

springer a cow showing signs of approaching calving

steer a male calf castrated when young

Introduction

Cows kept for milk production are called dairy cattle. The milk from dairy cattle can also be used to make butter, cheese, custard, yoghurt, cream, milk powder, and flavoured and condensed milk.

Most dairy cattle have to be raised on pastures because it is not profitable to buy feed for dairy cattle except in some city areas. This means that dairying is confined largely to the better rainfall areas where suitable feed is available. Dairy farms are found in every state of Australia, often in the coastal areas of southern and eastern Australia. They are also found in inland areas where water from rivers and dams can be used to irrigate the pastures. The average Australian dairy herd consists of 220 milking cows with an average annual production of 5445 L per cow per year. The average size of a dairy farm in Australia is 235 hectares.

After a cow gives birth she produces milk to supply the **calf** with all the nutrients it needs for survival and growth. Domesticated animals often produce more milk than the calf needs so farmers milk their cows to provide milk and milk products for human consumption. In dairies calves are removed from their mothers to maximise milk production.

The parts of a cow are shown in Figure 27.2.



Shutterstock/Ingrid Balabanova

Figure 27.1 Milk products

- 1 List five products that can be obtained from the milk of a dairy cow.
- 2 Explain why most dairy cattle are raised on pastures.
- 3 Identify the average number of milking cows and size of the average Australian dairy herd and farm.

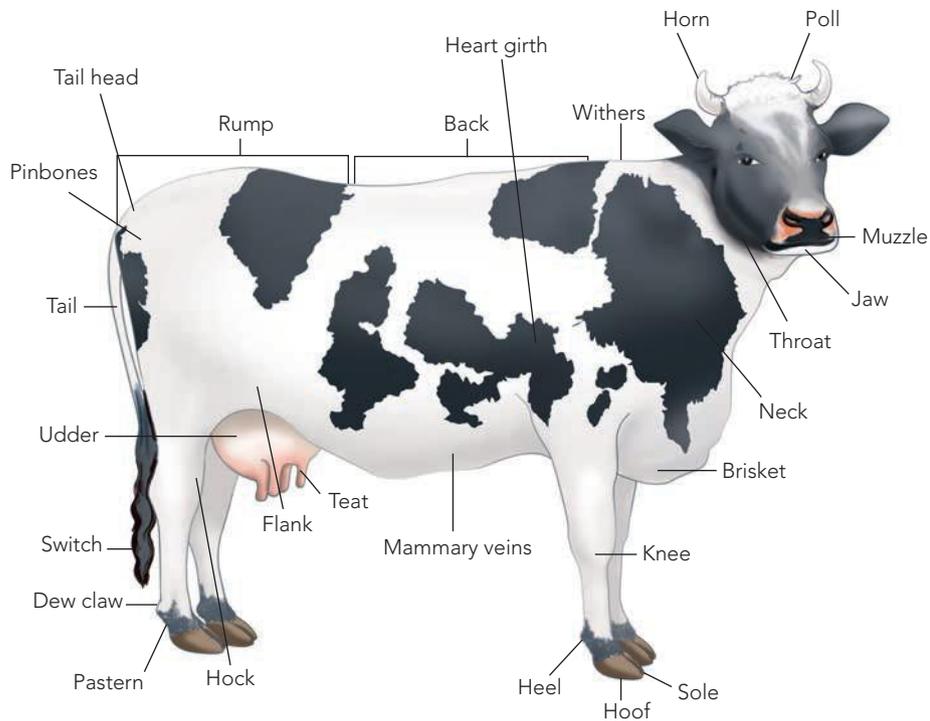


Figure 27.2 Parts of a cow

Breeds of dairy cattle

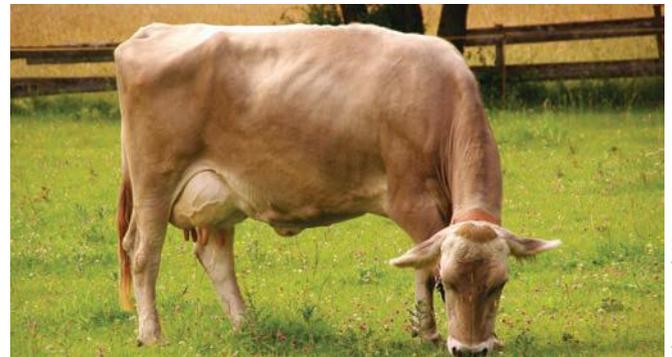
Figure 27.3 There are seven main breeds of dairy cattle in Australia: Australian Milking Zebu, Ayrshire, Brown Swiss, Guernsey, Holstein–Friesian, Illawarra and Jersey



Image courtesy of Dairy Australia

Australian Milking Zebu (AMZ)

The AMZ was developed in northern Australia by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The CSIRO crossed Sahiwal and Red Sindhi cattle, breeds from Pakistan, with Jersey cattle for milk production in tropical and subtropical areas. The parent breeds were selected for heat tolerance, tick resistance and milk production.



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Brown Swiss

The Brown Swiss originated in Switzerland. It has been selected for dairying for at least 125 years and was introduced to Australia in 1974. Ranging in colour from light brown to grey, they are used in a wide range of climates and are relatively tick resistant. Brown Swiss cows produce a medium amount of milk with 4 per cent butterfat. The breed's milk is higher in protein than most breeds, so they are good recipient mothers in embryo transfer programs.



Shutterstock/Margo Harrison

Ayrshire

The Ayrshire breed originated in Scotland. The standard colour of an Ayrshire is usually a combination of red or brown with white markings. The breed has large horns. Ayrshire cows produce a large quantity of milk with a high fat percentage of 4–5 per cent.



Alamy© Tim Gainey

Guernsey

The Guernsey breed originated on the Island of Guernsey in the English Channel. The breed is a little larger than the Jersey, and is yellow and white or brown and white in colour, with no black tips on the points of the body. The Guernsey produces a reasonably large quantity of milk, with a high fat percentage of 4.9 per cent.

Shutterstock/Catherine311



Holstein–Friesian

Once known as the Friesian, the Holstein–Friesian was developed in the Low Countries of Europe. The standard colour is black with white markings. It is the largest of the dairy breeds. The Holstein–Friesian is popular because it produces large quantities of milk. The breed’s milk fat percentage is approximately 3.5 per cent. Today, the Holstein–Friesian is the most popular dairy cow in Australia.

Courtesy Treeton Illawarras



Shutterstock/Joe Gough

Jersey

The Jersey was developed on the island of Jersey in the English Channel. Jerseys are small cattle of fawn colour, with black tips to the muzzle, horns, ears, feet and tail. Jersey cows produce a smaller quantity of milk than most other breeds but the percentage of milk fat it produces is the highest of all dairy cattle breeds, at 5.2 per cent.

Illawarra

The Illawarra was developed by farmers on the south coast of New South Wales and was once very popular. Until 1984 this breed was known as the Australian Illawarra Shorthorn (AIS). In that year, however, it was renamed the Illawarra by the Illawarra Cattle Society of Australia. The standard colour of the breed is a rich dark red, though some whites and roans exist. The Illawarra produces a large quantity of milk with the average fat percentage of approximately 3.9 per cent.

Sustainable dairy farming

- 4 Which cattle breed or breeds were developed in Australia?
- 5 Which breeds were used to develop the Australian Milking Zebu?

A sustainable dairy farm is one that remains profitable, producing milk of acceptable quality and quantity. To achieve this, the farmer must conserve soil and water resources and protect the environment. Sustainability issues especially relevant to dairy farming include:

- rotating the types of antibiotics used for the treatment of **mastitis** in cows to avoid resistance to antibiotics (e.g. penicillin)
- rotating the types of drenches used to avoid internal parasitic worms becoming resistant
- disposing of effluent carefully to avoid rivers and creeks becoming polluted.
- increasing water efficiency on farms.

Production cycle

A cow lactates, or produces milk, after she has given birth. The volume of milk produced is called the **milk yield**. In most animals milk yield rises for a period following birth of offspring, reaches a peak, and then steadily declines. In the dairy cow milk yield reaches a maximum usually 6–8 weeks after calving and the length of the lactation period is approximately 10–11 months. Milk yield is usually low towards the end of lactation. A 'lactation curve' is a graph of milk yield against time; Figure 27.4 shows a typical lactation curve.

To ensure maximum milk yield, the dairy farmer aims for each cow to produce a calf every 12 months. To achieve this, a cow should be mated 3 months after the birth of her last calf; the **gestation period** (pregnancy) for cattle is 9 months (or 270 days). For the 1–2 months prior to the birth of the next calf, the cow is usually 'dried off' and not milked. A **dry cow** then does not produce milk. This allows time for the cow's reserves to build up so that she can produce a healthy calf and a high milk yield in her next lactation.

Heifers are mated at approximately 15 months so they have their first calf at 2 years of age. They have one calf each year, and can produce about eight calves in their lifetime.

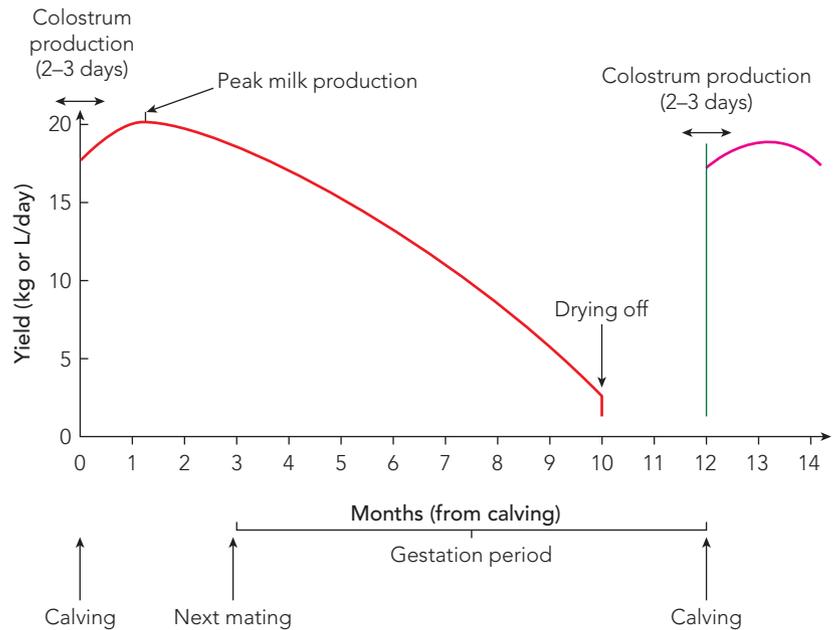


Figure 27.4 A typical lactation curve

- 6 What is the gestation period for a cow?
- 7 Explain why a cow is 'dried off' 1–2 months before calving.
- 8 At what age are heifers first mated?

Lactation

The time when a cow is producing milk is called the **lactation period**. Lactation in dairy cows lasts approximately 9 months.

Structure and function of the udder

The udder has four separate mammary glands, or quarters, and each has its own teat and duct system (Fig. 27.5). The mammary artery supplies blood to the udder. Blood delivers nutrients and water for making milk then leaves the udder in the mammary veins.

Milk is made in the small glands called the alveoli (singular alveolus). These glands are scattered throughout the udder in each of the four quarters. From each alveolus the milk drains through fine ducts, or tubes, and then into the larger lactiferous ducts. The milk empties into a large cavity called the gland cistern. This gland holds about 500 mL of milk. When this fills up, the milk drains into the teat cistern.

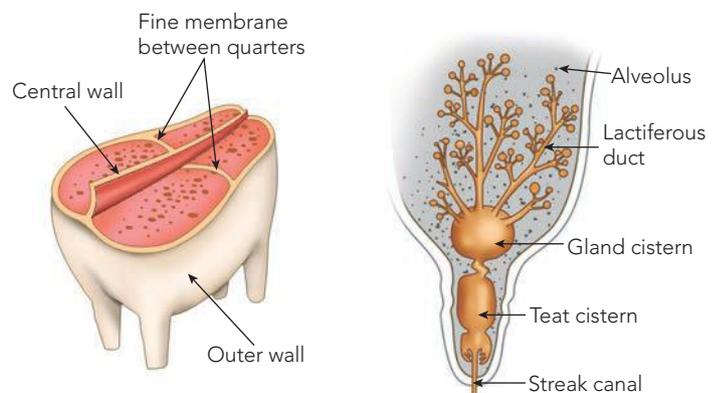


Figure 27.5 The structure of an udder

- 9 Identify the name of the small gland where milk is made.
- 10 Describe the function of the sphincter muscle.

At milking time, the milk is forced from the alveoli to the cistern and out of the udder through the teat canal. The teat canal is closed at the bottom by the sphincter muscle, which prevents dirt and bacteria entering the teat.

Milk letdown involves all the processes whereby milk contained in the mammary gland at suckling or milking is made available for withdrawal. It is a complex reflex, involving the nervous system, the circulatory system, glands and hormones. It is often called a neuro-hormonal reflex. The skin of the udder is particularly sensitive to physical stimulation, provided by a suckling animal, hand massage or teat cups. When this stimulation occurs, the nervous system carries an impulse to the brain and the hormone oxytocin is released into the blood. This causes the muscle fibres surrounding each alveolus to contract. Milk is consequently forced out of the alveolus into the duct system and is readily available for withdrawal – the milk letdown or milk ejection. The interval between stimulation and letdown is approximately 40 seconds. If a cow is frightened or suffers pain, the hormone adrenalin is released into the blood, restricting blood supply to the udder and the skin of the udder, blocking the effect of oxytocin and limiting milk letdown.

Colostrum and milk

- 11 Why is it important that a newborn calf gets colostrum from its mother?

In late pregnancy and for the first few days after birth the mammary gland secretes a substance called **colostrum**. The components of colostrum are important for the survival of the newborn animal for the first few days of life.

Colostrum differs from normal milk in that it contains higher amounts of certain vitamins and **antibodies**. These antibodies are absorbed through the small intestine during the first 1–2 days of life to give the newborn animal immunity to bacterial diseases. A few days after birth the composition of colostrum gradually changes to that of normal milk. Colostrum is a thick, yellow substance that may show traces of blood in the early stages.

The average composition of a cow's milk is shown in Table 27.1. Solids-not-fat (SNF) refers to the solid components in milk that are not fats.

- 12 What does 'SNF' stand for?

Table 27.1 The average composition of a cow's milk

Component		Average percentage (%)
Water		87.25
Butterfat		3.75
Protein	Solids-not-fat (SNF)	3.20
Lactose		4.80
Ash and minerals		0.75
Other		0.25

Milk composition and yield

The following factors affect the composition and yield (or quantity) of milk.

- **Nutrition.** Underfeeding causes a drop in milk yield, butterfat and SNF content. The butterfat level is mainly influenced by the fibre (roughage) content of the feed, while the SNF level is influenced by the energy content of the feed. Grazing

young, succulent pastures, which are high in energy but low in fibre, will increase milk yield but lower the butterfat content.

- *Breed.* Jersey and Guernsey cattle have higher percentages of butterfat and SNF in their milk, but generally produce less milk than Friesians. Milk that is high in butterfat is also usually high in SNF.
- *Stage of lactation.* The percentages of butterfat and SNF in the milk gradually fall over the first 2–3 months of lactation. They are lowest at the time when the cow is producing her largest quantity of milk. Butterfat then slowly rises until the cow is dried off, while SNF levels remain low until near the end of lactation.
- *Age.* Both butterfat and SNF percentages decrease after the first lactation.
- *Season and weather.* Seasonal changes alter milk composition by their effect on the availability of feed. In high temperatures cows tend to eat less, which lowers total milk volume, SNF and protein levels, but increases butterfat percentages. In low temperatures, the opposite occurs.
- *Disease.* Diseases such as mastitis reduce milk yield. The lactose content falls, causing a decrease of SNF. Butterfat is also reduced.
- *Stress.* Any factor that frightens or upsets the cow during or immediately before milking will affect milk yield and composition. Cows may also suffer stress at the time of their reproductive (or oestrous) cycle when they are 'on heat', resulting in lower milk production during this time.
- *Milking technique.* The first milk to be let down is usually lower in butterfat, while the last milk to be milked out of the udder is higher in butterfat. Therefore, if the cups are removed before the cow is completely milked out, the butterfat percentage of the milk will be lower. It is important for milking machines to be well maintained to reduce the chance of bacterial infection.

Milk quality

Milk quality refers to more than just the chemical composition of milk. High quality milk should not be tainted or contain bacteria, sediments or traces of disinfectants. There are several ways in which milk quality can be affected. Milk can be contaminated while in the udder, during milking or during storage.

- *Contamination in the udder.* Milk may become tainted if the cow grazes certain types of feed, silage or weeds. Diseases, particularly mastitis, can cause bacterial contamination of milk in the udder.
- *Contamination during milking.* Milk can be contaminated by dirty udders, which should be washed and dried properly before milking. It can also be contaminated if the milking cups and milk lines are not cleaned thoroughly at the end of each milking session.
- *Contamination during storage.* To prevent contamination of the milk during storage, the bulk storage tank should be cleaned carefully after it is emptied, using a disinfectant such as iodine, and then thoroughly rinsed.

Testing milk

Milk is collected once daily in a bulk tanker and taken to a milk factory. The factory then tests a milk sample from each farm to ensure that it is fresh and safe for people to drink.

The tests measure the quality of the milk – the percentages of protein, fat and other milk solids are calculated, and any harmful bacteria are detected. The milk can be rejected by the factory if it contains mastitis (indicated by a high somatic cell (white blood cell) count), low protein, or contamination by dirt, blood or faecal matter.

13 How does underfeeding affect milk yield, butterfat and SNF content?

14 Which breeds produce the highest protein percentages in their milk?

15 Which disease can cause bacterial contamination of milk?

16 How can contamination during milking be prevented?

17 List reasons why milk is rejected by the milk factory.

Managing the farm

- 18 Explain how the paddocks used by the milkers are grazed.
- 19 What happens to excess pasture?
- 20 Name one protein concentrate.
- 21 How can farmers provide feed all year round for their cattle?

Farm operations include all the management practices or activities that are carried out by the farmer on a daily, continual or seasonal basis. The daily routine includes milking the herd twice daily, feeding calves, culling milkers, mating or artificially inseminating cows, and moving the electric fences.

Continual (or frequent) operations include **culling** milkers (where cows are sold if they have chronic mastitis or are too old). Animal health operations such as drenching and vaccinating are also carried out throughout the year.

Seasonal activities include slashing pastures, haymaking during spring and summer, fertilising and harrowing pastures, fencing, maintaining machinery and supplementary feeding.

Managing pastures and grazing

Farmers should manage their farms to provide feed all year round. This may mean growing crops such as oats in winter and lucerne in summer. The main pastures used are a mixture of grasses (such as kikuyu and ryegrass) and legumes (such as white clover, red clover or lucerne). The paddocks used by the milkers are strip grazed with an electric fence. The animals are given a small strip, approximately one-tenth of a hectare per cow per day, of highly nutritious feed (depending on the number of cows and the quality or quantity of feed). The electric fence stops the cattle from trampling feed in the rest of the paddock (Fig. 27.6).

These pastures are maintained by harrowing and slashing after the cattle have grazed each paddock. The harrows spread out the manure and the slasher cuts any tall unpalatable stems or weeds.

Paddocks are top-dressed with superphosphate and sulfate of ammonia. Irrigation can be used to overcome water shortages and encourage pasture growth. The paddock is then closed off from cattle until it regrows.

In spring and summer excess pasture is cut and made into hay or silage to be fed to cattle in winter or in times of drought.

Feeding

The quantity and quality of feed available to a cow both before and after calving will affect the amount of milk produced and the length of the lactation period.

Protein concentrates such as linseed meal can be fed to cows at milking time, but these are expensive. In many areas, better feed can be cheaply and effectively provided by pasture improvement. To reduce the need for concentrates, farmers can include legumes in crops grown for hay. To provide feed all year round, it may be necessary to store fodder (hay or silage).



Alamy/© FLPA

Figure 27.6 Strip grazing

Breeding

A bull may be used for breeding from 18 months of age. A heifer should be mated at 15 months of age if she is mature – she will come on heat and will mate with the bull every 21 days until she is in-calf or pregnant. The heat period lasts for approximately one day, and during this period the cow will stand to be mounted by the bull. The gestation period is 9 months. The farmer aims to mate the cow so that she calves every 12 months, so she will have to be mated 3 months after calving.

If a cow fails to conceive, she is referred to as **barren** and is generally culled from the herd.

A cow showing signs of approaching calving is called a **springer**. Such signs include the appearance of the water bag (the sac that contains the calf), a full udder and restlessness in the cow. The period from the appearance of the water bag until the completion of calving is usually 1.5 hours. In a normal birth the calf's front legs and head should appear first (see Chapter 25, Fig. 25.9).

A farmer usually keeps one bull for every 60 cows. Alternatively, **artificial insemination** can be used (Fig. 27.7). Some farmers choose to use sexed semen; that is, on dairy farms farmers would use semen that has a very high chance of producing a heifer calf and not a bull calf. Mating is carried on throughout the year. Many dairy farmers have made greater use of artificial insemination because semen from superior bulls can be used. This means there is a greater chance of the cows fathered by these bulls having higher levels of milk production.

Another way to improve the production of the dairy herd is to have the best cow in the herd produce more than one calf per year, achievable now with **embryo transfer** technology. Fertilised eggs (embryos) are collected from a superior cow and placed in other cows who carry the calves until they are born. The best cow can have 20–30 calves in one year instead of just one. Visit the [Genetics Australia](#) website for more information on the services available to farmers.

Milking

The most important part of dairy management occurs in the milking shed. The shed should be built so that a minimum of dust blows into the bails, and designed so that the floors can be thoroughly cleaned after milking. The holding yards should have a gentle slope away from the dairy to help drainage. A large concrete apron should extend from the bails out into the yards to reduce problems with mud and dust. Figure 27.8 shows a herringbone dairy.

The effluent waste that is washed out of the dairy is collected in holding ponds or dams. While the waste is stored in these dams, bacteria help to break down the waste. The waste, if not handled carefully, could pollute the rivers and creeks.

- 22** How old is a bull when he is first used for mating/breeding?
- 23** Describe the normal birth position for a calf.
- 24** Why have farmers made greater use of artificial insemination in recent years?

connect

Genetics Australia



Getty/Science Photo Library

Figure 27.7 Artificial insemination



Alamy/© Chris Robbins

Figure 27.8 A herringbone dairy

- 25 Go to the [Future dairy website](#). How could this benefit the farms that adopt it?
- 26 List the main features to be considered in the design and construction of a modern dairy shed.
- 27 Name the two methods used to castrate bull calves.

Dirty milking machines (ones that have not been cleaned thoroughly and sterilised) are the greatest source of milk contamination and udder infection in the milking shed. Before milking, a cow’s udder should be washed down properly with clean water (and soap when necessary) to reduce the chance of infection.

Cows are milked twice each day at as close as possible to 12-hour intervals. A few dairy farmers milk cows three times each day at 8-hour intervals to increase production. However, over-milking may damage the udder and cause mastitis. The same routine should be followed at each milking to obtain maximum production per cow.

To lower production costs and increase efficiency in total farm production of whole milk, new technologies are being applied to many basic management operations.

Calves and calf rearing

The rearing of calves is an important occupation on all dairies. All new calves should be left with their mothers for the first few days. The calves are then put into pens and fed milk twice daily from buckets (Fig. 27.9). They are fed milk for the next 8 or so weeks and then weaned. Before they are weaned, they are fed pellets and hay.

Bull calves not required as sires are sold at 1 week (as veal), or reared and sold as **steers**. Stock management will be easier if dehorning is carried out before weaning; a mechanical dehorner, used in the first 2 weeks, is the most common method. Castration of bull calves is done at 3–6 months; the testes are either entirely cut out, or caused to wither by crushing of the cords (**emasculation**). Castration rings are only recommended for animals up to 2 weeks of age. Young bulls should have rings inserted in their noses at 10–12 months for easy leading. Some of the equipment used for these operations is shown in Figure 27.10.

connect
Future dairy



Alamy© Ian Shaw

Figure 27.9 A calf drinking milk from a bucket



Figure 27.10 Cattle equipment

Controlling pests and diseases

Five common pests and diseases affect dairy cattle.

Bovine Johne’s disease (BJD)

Bovine Johne’s disease (BJD; also called Johne’s disease) is a chronic wasting disease in ruminants caused by the bacterium *Mycobacterium paratuberculosis*. BJD crosses species to transfer between cattle, goats, alpaca and deer (sheep appear to be resistant to the cattle strain). The main symptom is chronic diarrhoea that results in severe weight loss and eventually death. BJD has a long incubation period (1–15 years), so only adult animals, usually over 3 years, show clinical signs.

Calves up to 30 days old are extremely susceptible and, although susceptibility decreases with age, calves up to 12 months remain susceptible. Cattle over 12 months become increasingly resistant, so it is rare for adult cattle to become infected.

Ingestion of contaminated faeces is the most common method of spread; for example, from contaminated pastures and by calves suckling contaminated udders. Some calves of infected cows are born infected, and some infected cows shed the organism in their milk. Spread of the disease between farms is usually through the movement of infected animals. The bacteria can live on contaminated ground for up to 12 months.

The two types of diagnostic tests available to test for BJD in live cattle are:

- 1 blood tests (serology) to detect antibodies in the blood
- 2 faecal cultures to detect bacteria being shed in the dung.

Once it is determined that a property is infected, all stock movements are subject to restrictions. The Market Assurance Program (MAP) provides a sound, standardised basis for assuring that herds have a low risk of being infected. This assurance is provided by combining negative testing of the whole herd (rather than just a few head) with management practices to reduce the risk of introduction of disease.

This disease should not be confused with bovine spongiform encephalopathy (BSE) or mad cow disease, which currently does not occur in Australia and is severely restricting world trade in beef and dairy products.

Leptospirosis

Leptospirosis is spread in the urine of affected animals. It causes fever, bloody urine and anaemia, and can be fatal to calves. In adults it can cause stiffness, blood in the milk and abortion. It can be spread to humans through organisms in cow urine. Cows should be routinely vaccinated to prevent this disease.

Mastitis

Mastitis is an important cause of loss in milk production. It occurs when disease-causing bacteria enter the udder, which becomes swollen and sore, and the milk contains pus. Most simple cases of mastitis appear as a few clots of pus in the milk. Mastitis is spread through a herd by poor hygiene in the milking shed, dirty milking machine cups, muddy yards and paddocks, and poor milking techniques. Infected cows can be cured with antibiotics. Milk from infected cows cannot be sold while the cow is being treated. Mastitis testing can also be performed automatically during milking. Go to the [Mastitis](#) website and summarise the process.

Milk fever

Milk fever can affect cows just before or after calving and is caused by a lack of calcium in the blood. Cows are not usually affected until they have had two calves. Affected cows first become unsteady on their hind feet, and finally collapse onto the ground. The fever is treated with an injection of a calcium solution into a neck vein.

Roundworms (Phylum Nematoda)

Many species of roundworm exist. Most cattle, especially those in high rainfall areas, have a mixed infection. Symptoms include anaemia, rough coat, stunted growth and weight loss. Control can be achieved by spelling or resting paddocks (to allow the worm larvae to die) and by drenching cattle.

connect

Mastitis

- 28 Describe the purpose of the Market Assurance Program (MAP program) for BJD.
- 29 How is leptospirosis spread?
- 30 Describe the symptoms of mastitis.
- 31 How are cows with milk fever treated?

Animal welfare

connect

Dairy Australia

Record the information shown in the table on everyday practices.

Farmers are concerned about the welfare of their animals, both from a humane and an economic perspective. Distressed and injured animals are unable to thrive or effectively reproduce and consequently economic returns are reduced.

An Australian Model Code of Practice for the welfare of animals has been developed to enable the states to develop codes of practice suitable to their needs. The code aims to:

- promote humane and considerate treatment of animals
- inform all people responsible for the care and management of animals of their responsibilities
- set industry standards by defining acceptable management practices.

Dairy cattle are kept in situations ranging from extensive grazing to close confinement and owners and managers have a legal and moral responsibility to care for the welfare of the animals under their control. Basic needs include the provision of adequate food, water, air, shelter, comfort and freedom to move and express normal behavioural patterns; these needs must be met irrespective of the nature of husbandry or farming system. People involved with the animals must be competent and aware of how to manage animals, maximise normal behavioural patterns and avoid stress. They must be able to identify early stages of stress and be trained to take preventative or remedial action.

Housing for artificially reared calves should be hygienic, free from draughts and well drained, with adequate climate control and lighting. For multiple calf rearing, where pens are used, calves must be able to see and hear at least one other calf, with a floor space of 1.5–2.0m² per calf.

Dairy cattle should be milked at regular times, with cows in full milk being milked at least twice a day. Milking machines should be checked and correctly adjusted by a competent technician on a yearly basis and the milking technique must minimise the risk of discomfort or injury to the cow and limit the development or transmission of disease.

Sheds, pens, yards and ramps must all be constructed and maintained in a manner that minimises stress, injury and disease. Consequently surfaces in yards and on ramps should minimise slippage. Yard floors should be level, with adequate lighting and feed troughs; water containers, latches and gate hinges should be designed to minimise injury. Electric fences should be designed, maintained and used so that contact with them does not cause unnecessary pain or distress.

Cattle at all times should be handled quietly. The use of dogs or goads should be limited to the minimum necessary.

Keeping records

Farm records tell the farmer what is happening on the farm – they help with running the farm enterprise. The important records on a dairy farm are herd records, paddock records and financial records.

Herd records

The production of the herd and individual cows is monitored by herd recording. Each cow is identified by an ear tag with a number or an electronic tag or collar. One day each month the production of milk from each cow is measured using a milk-flow meter, or with an electronic record. A sample is taken to the factory and used to determine the protein and butterfat percentage. The test will also show if the cow has mastitis.

A report is compiled of all cows tested in a herd and their production, usually in the form of a computer printout (Fig. 27.11). This information is used to help decide feeding levels, and to select the cows that should be used for breeding and the cows that should be removed from the milking herd.

32 What common method is used by farmers to identify individual animals in a herd?

DEPARTMENT OF AGRICULTURE NSW										
HERD no.	157 2157	Dairy herd improvement program								
SAMPLING DATE	16/6/14	PRODUCTION REPORT DHIP-101								
VISIT NUMBER	147	MANAGEMENT ACTION LIST OPTION					NO	PAGE 0003 (00869)		
SHED NAME	COW RECORDING No.	LAST SAMPLING					SOMATIC CELL COUNT	ACTION	DATE	
		MILK L.	% FAT	FAT KG.	% PROTEIN	PROTEIN KG.				
KEMP HERBIE	282	8.5	4.6	0.40	3.4	0.30	199000	COMPLETED 300 DAYS	14/6/14	
ACE REWARD	283	11.0	4.2	0.48	3.6	0.41	168000	COMPLETED 300 DAYS	19/6/14	
J MANDY	284	8.5	3.5	0.31	3.5	0.31	173000	300TH DAY	3/7/14	
GRANNIE	285	12.0	4.3	0.53	3.9	0.48	231000	300TH DAY	16/7/14	
CANDY	286	8.0	4.9	0.40	3.7	0.30	169000	300TH DAY	19/7/14	
UNREGISTERED	287	10.5	3.6	0.39	3.7	0.40	173000	300TH DAY	12/8/14	
HOLMLAND MAGGIE	288	11.5	4.4	0.52	3.9	0.46	190000	300TH DAY	13/8/14	

Figure 27.11 Part of a herd-recording report

Paddock records

These records show what has happened on each paddock on the farm; for example, types of crops grown, fertilisers used, and dates paddocks are grazed.

Financial records

It is important for the farmer to be aware of what is happening to the farm business financially. Is it making a profit?

Calculating the **gross margin** of an activity on the farm provides an indication of its profitability (Fig. 27.12). The gross margin includes only variable costs (i.e. the costs that change during production) and does not include fixed or overhead costs. Gross margins are worked out per cow or per hectare.

The formula for a gross margin (Fig. 27.12) is:

$$\text{Gross margin} = \text{gross income} - \text{variable costs.}$$

Marketing

In 2009–10 Australia produced 9102 million litres of milk per year, valued at \$4 billion. Australia exports 45 per cent of its annual milk production and produces 10 per cent of world trade in dairy products. The main export markets are Japan, China, Singapore, Indonesia and Malaysia. There is likely to be future opportunities for increased sales into Asian countries.

Gross income (GI)		\$
Milk	240 000	
Cull (cow)	14 000	
Calves	5 200	
Total income	259 200	
Fixed costs		
Rates	8 000	
Depreciation	3 000	
Total fixed costs	11 000	
Variable costs (VC)		
Seed, fertiliser, fodder, pellets	68 000	
Electricity	9 000	
Stock health (veterinary)	3 000	
Artificial insemination	5 000	
Herd recording	5 000	
Herd registration (stud cattle)	1 600	
Freight, cartage	920	
Dairy requisites	3 200	
Bulk milk collection	7 200	
Total variable costs	102 920	
Gross margin (GM)		
GI – VC = 259 200 – 102 920	= \$156 280	
GM/COW/(GM/90) Production herd	= \$1 736.44/cow	
GM/hectare (GM/100)	= \$1 560.28/hectare	

Figure 27.12 Gross margin for a dairy farm

Milk is sold into two main markets. The first is called liquid (fresh) milk, and is where the milk is processed for immediate fresh consumption. Farmers usually receive a higher price for this milk, although in many areas farmers receive a single price for milk delivered to the processing factory. The second market is manufacturing milk. This milk is to be manufactured into dairy products such as cheese, butter, yoghurt and milk powder. Farmers usually receive a lower price for this milk.

The major consumer dairy products on the Australian market are drinking milk (fresh and ultra high temperature (UHT), white and flavoured), cheese, butter and dairy blends, and yoghurt.

Prior to July 2000, milk production on farms was regulated by a **quota** system supervised by a marketing authority. This has been replaced by an entitlement system administered by individual processing companies. (Individual milk factories control the pricing and distribution of milk for the liquid milk market. The price paid to farmers depends on the quality of milk, as determined by factors such as high fat and protein levels and low levels of micro-organism activity.) Dairy farmers now operate in a completely deregulated environment, where international prices are the major factor in determining the price received by the farmer for milk. Australian dairy farmers receive a low price by world standards; consequently they must efficiently manage their production system.

Milk is processed both by farmer owned co-operatives and by public and private companies.

Substantial change has occurred in the dairy industry, with many farmers leaving and others accessing loans to stay in production. The problem is twofold: the low price paid to the farmer for the raw product; and the need to market milk and milk products in forms that encourage consumer demand and arrest the decline in consumption. Farmers are also assessing ways to add value to their raw product; for example, developing niche marketing opportunities with speciality Australian cheeses that are successfully expanding both their domestic and their export markets.

Dairy Australia is an organisation funded by farmer-paid levies, which are imposed on the fat and protein content of all milk produced in Australia. It injects money to improve farm productivity and farmers' management skills.

Recently, competition between the major supermarket chains has forced milk pricing arrangements to change and farmers generally receive a lower price per litre.

Farm incomes are under pressure from milk pricing competition and increasing input costs, and productivity growth appears to have slowed in recent times.

33 List three pieces of production information recorded for each cow on a herd-recording report.

34 Recalculate the gross margin in Figure 27.12 if there had been a drought and price of pellets had gone up by \$12000.

Chapter review

Things to do

- 1 Visit a dairy farm and observe the milking.
- 2 Hand milk a cow.
- 3 Drench cows or heifers.
- 4 Observe the vaccination of calves.
- 5 Rear a calf and take weekly measurements of heart girth and shoulder height. Graph these measurements over a 10-week period.
- 6 Weigh a growing calf regularly, recording the figures. Calculate the average daily weight gain.
- 7 Look at a dry cow and describe its udder development. Compare this to development in a cow that has just calved.
- 8 Determine the age of cattle using Figure 27.13 as a guide.

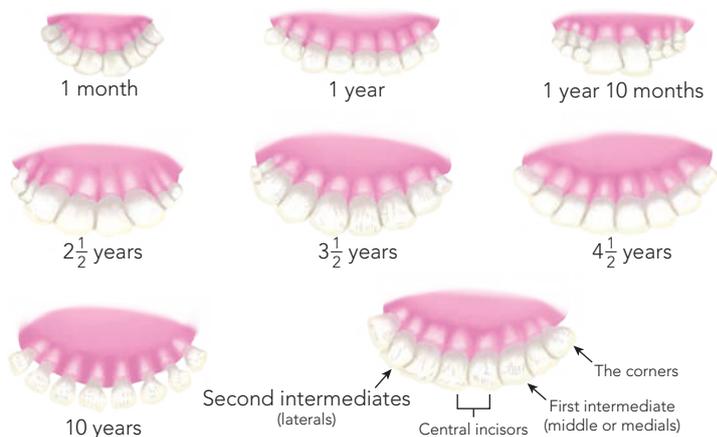


Figure 27.13 Cattle's teeth indicate their age

Things to find out

- 1 What did 'milk quota' mean? Describe the current method of supply.
- 2 Define 'herd recording' and explain how it is conducted.
- 3 Why are cattle vaccinated?
- 4 Why have herringbone sheds replaced the walk-through sheds on many farms? What other dairy design can be found on some Australian dairy farms?
- 5 Why are cattle ears tagged with a NLIS ear tag before they are sold?
- 6 Find the cost of a straw of unsexed and sexed semen.
- 7 Find a recipe for artificial colostrum that would be suitable for feeding to orphan calves.
- 8 Why is embryo transfer used on stud properties?
- 9 For a milk product, such as skim milk, consider to whom the manufacturer is aiming to sell this product.
- 10 Why have low-fat dairy products become more popular in recent years?

+ Extension activities

- 1 List 10 products made from milk that you can find in the supermarket.
- 2 Make your own butter using the following recipe. Weigh the butter produced and record its weight. Express this as a percentage of the weight of cream used initially.

Equipment needed	Method
<ul style="list-style-type: none"> • 300mL thickened cream • 5 g table salt • egg beater • small mixing bowl • plastic sheeting • spatula 	<ol style="list-style-type: none"> 1 Weigh the thickened cream and record the weight. 2 Pour the cream into the bowl and beat until yellow globules appear (this is butter). 3 Pour off the buttermilk. 4 Remove as much butter from the beaters as possible using spatulas. 5 Spread the butter thinly onto plastic sheet and sprinkle with salt.

- 3 Compare five different types of liquid milk. Check the food labels for differences in composition and taste the difference.
- 4 Describe computer software that is used to assist with dairy herd and farm management.
- 5 Sexed bull semen is now available in Australia. What are the advantages of this technology to the dairy industry?
- 6 Describe the concept of robotic milking. Evaluate the potential impact of this technology in Australia.
- 7 Research and describe the use of technology in the production cycle of milk from the cow to the consumer.

✓ Test yourself

- 1 The milk from dairy cows can be consumed as liquid milk or it can be used to make a number of other products. Unscramble the following words to find two of these products and write the answers in your notebook.
eseche
htrugoy
- 2 In your notebook, write each of these words with the correct definition from the list below.
gestation, antibody, mastitis, heifer, lactation
 - a type of protein that helps fight disease
 - a female from 6 months of age until she has had a calf
 - the secretion of milk
 - the period from conception to birth
 - inflammation of the udder, usually from a bacterial infection
- 3 Construct a calendar of operations for a dairy farm. Discuss the implications of needing to produce milk all year round on the management of a dairy farm.

CHAPTER 28

BEEF CATTLE

Words to know

bloat a non-infectious disease caused by grazing animals overeating legume plants; rapid production of gases trapped in foam causes the rumen to swell, resulting in breathing difficulties and possibly death

bullock a castrated male bovine 3 years of age or older

carcase remains of the animal body after the head, feet, hide, tail and internal organs (except kidneys) are removed

castration removing testicles from a male not required for breeding

condition score an assessment of an animal's condition based on its fat and muscle score

dressed weight weight of the carcase

fertility the ability of an animal to reproduce

marbling fine flecks of fat within the meat (intramuscular)

marking the time when several important management operations, such as branding, castration and dehorning, are carried out on beef calves

oestrus (heat) the period when a cow is willing to mate with a bull

polled an animal without horns

puberty the age at which an animal can first reproduce

store an animal of any age or sex not in fat-enough condition for slaughter for a good quality carcase

wealer a calf reared on its mother for purposes of slaughter at 8–12 months

weaner a young animal that has been weaned from its mother

Introduction

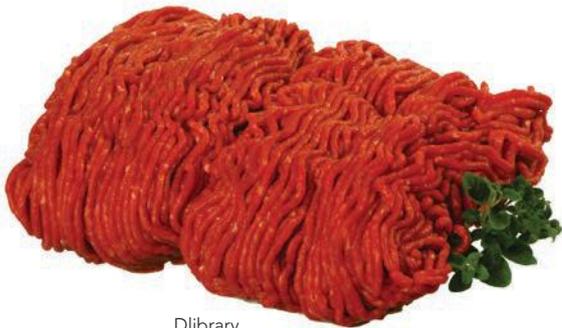
Beef cattle properties are found in all states of Australia, but major differences exist between the production systems in the northern and southern parts of the country. In northern Australia cattle properties are generally very large, pastures are unimproved and fodder crops are not grown. Beef cattle production is usually the only farm enterprise and herds are large. In southern Australia properties are usually smaller and there is a greater emphasis on pasture improvement. Beef cattle are usually run with sheep, dairying or cropping (i.e. grain growing). The properties are more intensively managed and cattle herds are smaller.

Beef cattle properties may be family farms or corporately owned.

The meat from cattle is called beef. Cattle can also supply us with leather (from the skin or hide), bone meal, glue, hormones and vitamin extracts. Figure 28.2 shows the parts of a bull.



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Figure 28.1 Beef products

- 1 In southern Australia what other farming enterprises are often run with beef cattle?
- 2 List five products that can be obtained from beef cattle.

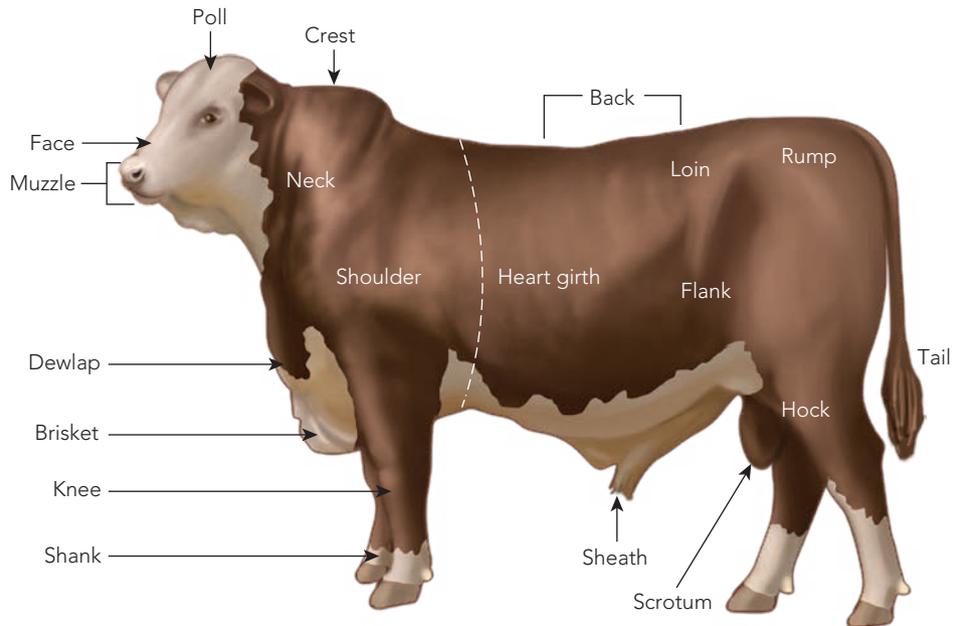


Figure 28.2 Parts of a bull

Breeds of beef cattle

Figure 28.3 Some popular breeds of beef cattle. Others include Devon, Droughtmaster, Chianina, Braford, Brangus, Charbray, Mandalong Special, Red Poll (a dual-purpose breed), and lesser-known exotic breeds including the Maine-Anjou, Romagnola and British White.



Alamy/© Brandon Baker

Angus

The Angus was developed in Scotland. It is a medium-sized breed and is very popular. The Angus is black and **polled**.



Seifert Belmont Stud

Belmont Red

The Belmont Red was developed by the CSIRO in Queensland. The breed was obtained by crossing Hereford, Shorthorn and Afrikaaner animals. It is red in colour.



Shutterstock/Bejjim

Brahman

The Brahman was imported from the United States and was originally developed from Indian cattle (Zebu). It is medium-sized and has a hump. It is grey, red or black in colour.



Alamy/© Design Pics Inc.

Charolais

The Charolais was developed in France. It is a large-framed and well-muscled breed. It is white to straw in colour, and horned or polled.



Shutterstock/MustafaNC

Hereford

The Hereford was developed in the county of Herefordshire in England. It is a medium-sized breed. Its colour is rich red, with white face, throat, legs and tail, and a white strip along the back of the neck. The Hereford is horned, but a poll strain (Poll Hereford) also exists.



iStockphoto/© JohnFScott

Limousin

The Limousin was developed in France. It is a heavily muscled animal and is well known for its **carcase**. It is smaller than some of the European breeds and is mid-brown in colour.

Vitulus Lowline Stud



Lowline

The Lowline was developed in Australia. The cattle are small in stature and are polled. They have been derived from Angus cattle. These animals have stocky bodies characteristic of small breeds and are black or red in colour and early maturing.



Pilotux Trading Company Ltd.

Murray Grey

The Murray Grey was developed in Australia's Murray Valley. It is a medium-sized breed. Its colour varies from silver through to dark grey, and it is polled. The breed was obtained from the mating of an Angus bull and a Shorthorn cow.

Alamy/Terry Smith Images



Santa Gertrudis

The Santa Gertrudis was developed in the United States by crossing Brahman and Shorthorn cattle. It is red in colour and horned or polled.



Corbis© Yann Arthus-Bertrand

Shorthorn

The Shorthorn was developed in England. It is a medium-sized breed. It is either red or white in colour, or else a mixture of the two colours called roan. Shorthorns, too, have a polled strain.

Alamy© UK Farms



Simmental

The Simmental was developed in Switzerland. It is a large-framed and well-muscled animal. The breed is white faced with varying shades of red or brown on the body.



Mabelle Square Meter Stud

Square Meater

The Square Meater was developed in Australia from Murray Grey cattle. It is a small compact breed which is heavily muscled and polled. It can be grey or silver in colour. It is well known for its carcase quality.

Sustainable beef farming

A sustainable beef cattle property is one that remains profitable, producing calves and meat of acceptable quality and quantity. The farmer should also conserve soil and water resources and protect the environment. Sustainability issues especially relevant to beef cattle farming enterprises include:

- ensuring chemical residues are kept out of the carcasses, because consumers do not want to eat residues
- rotating or using different types of drenches to avoid worms (internal parasites) becoming resistant
- using sensible stocking rates
- positioning feedlot practices away from waterways.

Production cycle

There are different types of beef enterprises, including:

- breeding and selling **weaners**
- breeding and selling **vealers**
- breeding and selling yearlings or young cattle
- breeding and selling older **steers**
- buying and growing out (fattening) cattle
- a combination of the above.

The type of enterprise carried out on a farm will depend on the carrying capacity of the property, and the management and marketing skills of the farm manager. The profitability of the enterprise will be affected by the stability of the markets and how well the enterprise is managed.

In a 'buy and grow out' enterprise, cattle are purchased and fattened, then sold. The aim is to maximise growth, which is measured in terms of live weight gain. Growth follows an S-shaped curve as shown in Figure 28.4, but is affected by diet, sex, breed, weaning and disease.

In a breeding enterprise, the main aim is to breed cows to produce calves each year. Male calves are **castrated** and grown out for a number of years until they are sold. Female weaners either become breeders or are fattened and sold. Cows that do not become pregnant after mating with bulls, have faults (such as eye cancer), or are too old are **culled** and sold.

Managing a breeding herd involves yearly cycles of mating bulls to cows (which usually have a **calf** at foot at the time of mating), weaning calves and calving. The **fertility** of cows starts to decrease at approximately 8 years of age. Bulls reach **puberty** at 12–18 months of age and their fertility and function declines after several years. They are culled before they can breed with too many of their daughters (inbreeding).

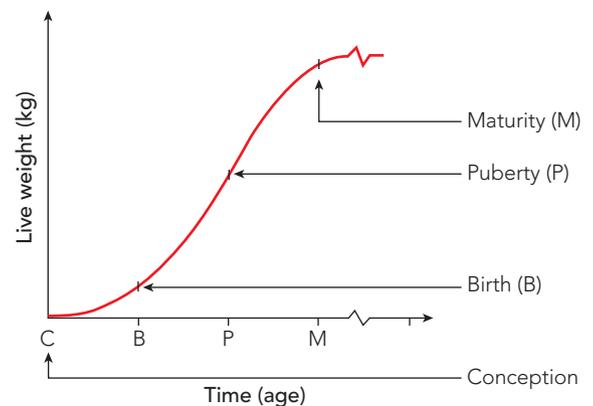


Figure 28.4 Growth in beef cattle

- 3 Which two colours produce a roan coat colour?
- 4 Name the polled breeds of cattle.
- 5 Which breed(s) were developed from Indian cattle?
- 6 Identify the breeds used by the CSIRO to develop the Belmont Red.

- 7 List the main types of beef enterprises.
- 8 List three factors that affect the growth of an animal.

The carcasse

The **carcasse** consists of three major components – bone, muscle and fat – as well as small amounts of nervous tissue, blood vessels and connective tissue (tendons and ligaments). Different types of tissue develop at different stages of growth. Nerve tissue develops first, then bone, then muscle, and finally fat. Once an animal has reached its maximum muscle production it will convert any extra feed eaten into

- 9 List the order of tissue development.
- 10 Describe the type of carcasses that farmers try to produce.

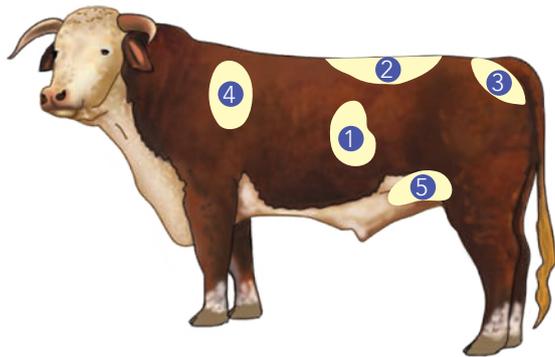


Figure 28.5 Main areas of fat build up on an animal

fat. It is important that the farmer sells the animal for slaughter before too much fat is laid down. A farmer can assess the amount of fat cover by feeling the five main areas where fat is produced, as shown in Figure 28.5.

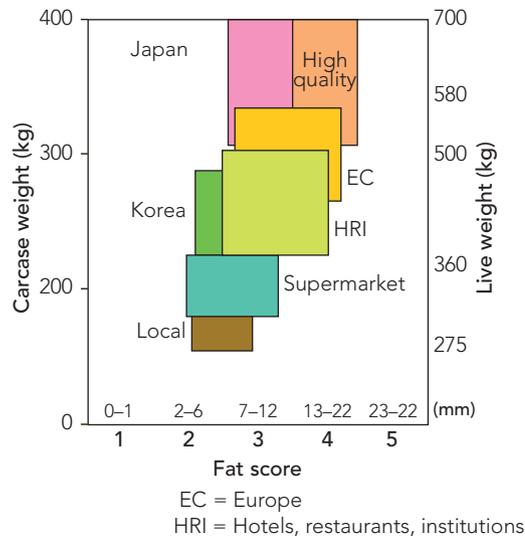


Figure 28.6 Broad market specifications for Australian beef cattle products

Farmers generally want to produce animals that have a high proportion of muscle (red meat), a minimum amount of bone and whatever level of fat the consumer desires.

Market specifications for beef cattle are expressed in measurable or objective terms, and include:

- carcass weight
- sex
- age (by dentition)
- meat quality relating to meat colour, fat colour, **marbling**
- levels of hormonal growth promotants (HGPs)
- chemical residue levels.

Factors affecting meat quality

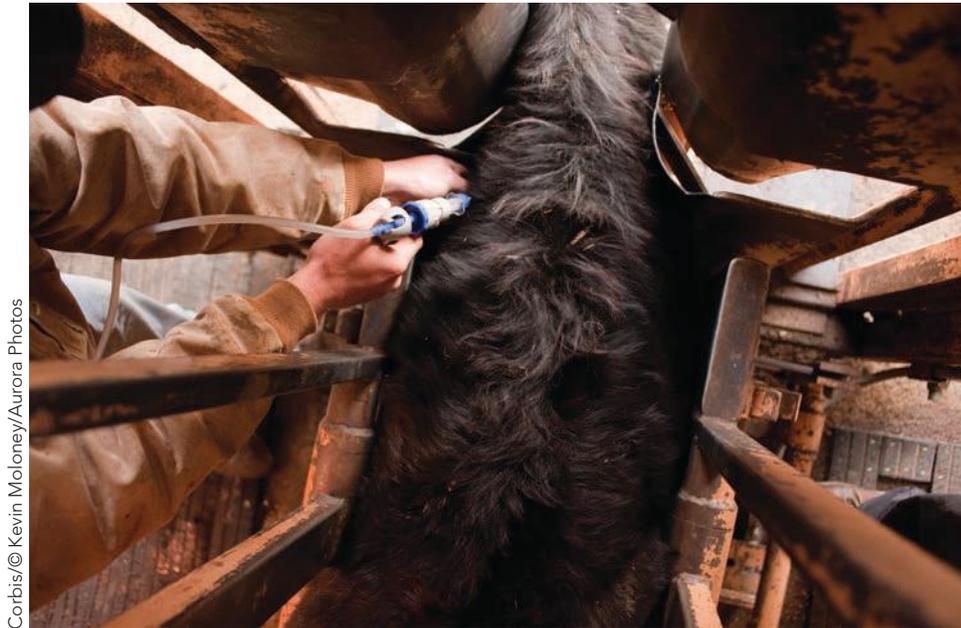
The main aim throughout the production and marketing process is to maximise meat quality. It can take months or even years to produce an animal for a specific market. Poor management can easily damage or downgrade beef. ‘Quality’ includes the colour, texture and distribution of the muscle and fat, the smell, pH, tenderness and flavour of the meat. Meat quality can be affected by the following factors.

- 11 List four factors that can cause bruising in cattle.
- 12 How does stress in an animal affect its meat quality?

- **Breed.** The farmer selects a breed based on markets, tradition, suitability to climate and personal preference. In some areas, buyers will pay more for Herefords. In other areas, tick-resistant Brahman crossbreeds are more popular. Feedlot farmers prefer cattle without horns.
- **Diseases and pests.** Cattle should be protected from disease by vaccinating against clostridial diseases (diseases caused by clostridium bacteria) and tick fever. They should be free of ticks, lice and worms.
- **Condition.** Animals should be the right age and weight and have the correct fat cover for the target market. Over-fattening is expensive because it wastes feed by laying down unwanted fat and it lowers the price.
- **Bruising.** Horns are a major cause of bruising. It is better not to yard, truck or move hornless cattle mixed with horned cattle. Other causes of bruising include rough handling, yards in disrepair and damage during transport (trucking).
- **Stress.** Beef from an animal killed in a stressed condition will be darker in colour and tougher to eat. Stress can be caused by many factors, including rough

handling, cold weather and exhaustion. Well-designed, well-built yards will encourage the flow of cattle. Weaner cattle can be trained to move quietly and without fear through the yards and onto a truck; this will help to reduce stress.

- *Weight loss.* Losses in live weight and carcase weight occur when cattle do not have access to food and/or water during handling and transport. It is important to make water available to cattle from when they leave the property until they are slaughtered.
- *Feed.* Meat quality is affected by the type of feed eaten (e.g. grain or pasture), quality of the feed eaten and the quantity or amount of feed given.



Corbis/© Kevin Moloney/Aurora Photos

Figure 28.7
Vaccination

Assessing meat quality

Two factors influencing the price of beef are meat quality and consumer demand. The farmer/producer must ensure that the quality and composition of the meat produced matches what the consumer desires. Meat quality can be assessed using the following criteria.

- *Safety and purity.* Australian beef has one of the lowest rates of chemical residue and other contamination in the world. Low rates of contamination are achieved by having very high hygiene standards at our abattoirs.
- *Tenderness.* This cannot be easily measured at the abattoirs, but is associated with younger animals, good nutrition, good handling and processing techniques. Meat from older animals is less tender. Certain methods of cooking and processing and the use of enzymes can tenderise meat.
- *Marbling.* Marbling (fine flecks of fat within the meat itself) is desired by Japanese and American consumers because it keeps the meat juicy when cooked as very thin cuts.
- *Colour.* Australians prefer the pinkish-red colour of a well-fed animal, while Japanese prefer their beef to be darker red.
- *Fat colour.* All consumers seem to prefer whiter fat and tend to avoid yellow fat.

connect

Meat and livestock Australia

Outline the functions of this organisation.

Managing the farm

Farm operations include all the management practices or activities that are carried out by the farmer, both routine cattle management and other activities done on a seasonal basis. Routine cattle management includes:

- grazing management
- feeding

- mating (the time of which is determined by the desired time for calving or weaning)
 - calving
 - **marking** of calves
 - weaning
 - culling
 - pest and disease control
 - selling.
- Seasonal activities include:
- pasture management
 - haymaking
 - fencing
 - maintaining machinery
 - supplementary feeding of cattle.



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Figure 28.8 Cattle grazing

Managing pastures and grazing

Year-round grazing of pastures, with little supplementary feeding, is the cheapest method of production. In most cattle regions of Australia there is a seasonal pattern of pasture growth, where there is an abundance of feed for some months of the year and not enough during other months. Arranging for calving to occur at the start of the expected flush in feed supply is beneficial. In most closely settled beef areas in Australia the seasonal flush occurs in spring and the extra feed available during this time can be used by the new calves.

Some animals are finished off in a feedlot. Here cattle are fed a high protein grain-based diet to maximise weight gain prior to selling. Cattle can spend 60–100 days in a feedlot depending on their intended market.

Feeding

One way to improve carcase quality is by providing better nutrition. In southern areas of Australia, pasture improvement and fattening steers on grain can achieve this. A pasture's nutritive value depends on seasonal conditions such as drought. Feed shortages can be overcome by hand feeding hay or grain.

Many suitable rations can be fed to cattle and can be home mixed. Additionally, a number of feed manufacturers prepare commercial rations in the form of meals or pellets. These have the advantage of saving the labour involved in home mixing. There are two parts to a suitable ration: roughage and concentrate. At the beginning of feeding it is usual to start with roughage only and then gradually increase the amount of concentrate. The best type of roughage is hay (e.g. grassy or pasture hay or wheaten hay). Suitable concentrate mixtures vary, usually depending on the grains available and their relative costs. An example of the composition of a suitable mixture is grain sorghum, oats and linseed meal.

Lot feeding of cattle is used to produce animals for specific markets. For example, the Japanese market requires marbled beef (fat is laid down within the muscles). This is more likely to be achieved in feedlots where the diet is strictly controlled. It is cheaper and more environmentally sustainable to produce beef on pasture.

Breeding

A bull can be used for breeding from about 18 months, but preferably he should be over 2 years old. He must be disease free, fit and keen to work. One bull is usually run with about 60 cows. The size of the bull in relation to the cow or **heifer** is

13 Briefly explain how feed shortages can be overcome.

14 Name the two parts of a ration.

important. A large bull will normally sire big calves and this can result in smaller females having calving difficulties.

Bulls should be kept separate from the rest of the herd so that mating time is controlled. This requires a separate bull paddock with good fencing.

Heifers should not calve until they are at least 2 or 3 years old. A cow will come on heat and can mate with the bull every 21 days until pregnant. The **oestrus** (heat) period lasts for approximately 1 day, and during this period a cow will stand to be mounted by the bull.

If successfully mated, the cow will be in calf for 9 months. This is called the **gestation period**. Many farmers have their cows pregnancy tested by a veterinarian. This can be done by manual palpation (feeling) or with an ultrasound machine. Often if a cow fails to become pregnant after two breeding cycles, she is sold.

Farmers are making greater use of artificial insemination (AI). Semen is used from superior bulls. Farmers may also use estimated breeding values (EBVs) to gain information on a range of genetic traits that a bull may pass on to his offspring (e.g. ease of calving, growth rate over 300 days and muscling). AI is more common in stud beef cattle. Embryo transfer is very costly and must be managed carefully, so it is limited to mainly stud cattle and a few commercial beef herds.

Calves

A number of operations are carried out at calf-marking time (generally before the animal is 6 months old).

- Calves are branded with the owner's registered brand.
- Male calves not required for breeding are castrated.
- Vaccination is given for enterotoxaemia, blackleg, tetanus, malignant oedema or blood poisoning and black disease (5-in-1 vaccine will cover all these diseases).
- Earmarking for age and identification is carried out using plastic ear tags.
- NLIS tags (National Livestock Identification Scheme) are placed in the right ear of calves that are likely to be sold and leave the property. These tags contain a micro-chip to identify the animal's property of origin.
- Horned breeds are usually dehorned.

At 8–9 months calves are usually separated from their mothers (weaned).

Selection and culling

Some selection is done at weaning time when calves of poor breed, type or performance or with major defects are culled and sold. The next selection and main classing takes place before mating. At this time the best grown cattle and those that conform best to the breed type are kept and placed in the breeding herd. The rest are sold to the butchers. **Bullocks** are sold when they reach suitable condition.

Older cows are also culled when it appears that they are not able to efficiently rear another calf.

Store cattle are not yet fat enough for slaughter for a good quality carcass.

Controlling pests and diseases

Bloat

Bloat is a build-up of gas produced by the breakdown of food in the rumen or paunch. It causes the rumen (or first stomach) to swell. The most common cause is cattle grazing legumes such as lucerne or white clover. Bloat is more likely to occur when the feed has high moisture content and when cattle first graze a paddock.

15 How old should a bull be when first used for breeding?

16 At what age should heifers calve?

17 List the main operations carried out at calf-marking time.

18 What is weaning, and when is it carried out?

19 On what basis is culling or selection done at weaning time?

20 Why are older cows culled?

21 What causes bloat?

The gas can be released by drenching the animal with a vegetable oil or by using a trocar and cannula (an instrument like a knife). The trocar and cannula should only be used as a last resort, because it requires puncturing the rumen.

Lice

22 How are lice controlled?

Several species of lice affect cattle, but the two main types are biting lice and sucking lice. They both irritate the skin, causing cattle to rub against trees and fences. The sucking type cause blood loss and reduced weight gain. To control lice, all cattle should be treated at the same time with a pour-on insecticide.

Roundworms

23 Describe the symptoms of roundworm infection.

There are many species of roundworms (e.g. barber’s pole worms). Cattle, especially those in higher rainfall areas, are likely to have a mixed infection. Some of the symptoms include anaemia, rough coat, stunted growth and weight loss. Control can be achieved by spelling (or resting) paddocks, to allow the worm larvae to die, and by drenching cattle with drenches like Ivomec or Q-drench.

Ticks

24 How are ticks controlled?

Tick infestation is limited to the higher rainfall areas. The three main ticks are the cattle tick, paralysis tick and bush tick. Ticks cause cattle to become weak because they suck blood. The paralysis tick also injects a poison that attacks the nervous system. They can also spread disease. Control can be based on dipping cattle and spelling paddocks.

Animal welfare

Careful handling of cattle will result in higher quality carcasses and less weight loss through stress. Cattle should be taught to move through yards quietly at an early age. Starting at weaning they can be put through the yards and fed as they come out of the crush. This results in less damage and stress when they later have to be handled for drenching, ear-tagging, pregnancy testing, weighing and other operations.

Bruising and marking of carcasses is caused when cattle horn one another, and by rough handling during operations such as branding and culling. Carcase damage can be reduced by dehorning and the use of polled bulls, as well as devices that hold the animal without damaging it, such as branding cradles. Special care must be taken when transporting animals to saleyards to avoid stress and physical damage. At saleyard locations various welfare requirements governing the yarding and handling of animals must be adhered to. These include avoiding problems associated with exposure, adequate provision of food and water, avoidance of overcrowding or inappropriate mixing of animals and the need to be vigilant against disease outbreaks.

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and Forestry

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Animal welfare

Keeping records

Farm records tell the farmer what is happening on the farm; they help with running the farm enterprise efficiently. Many records are now kept electronically, on computers, tablets or iPads. The important records on a beef property are livestock records, paddock records, financial records, chemical records and climate information.



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Figure 28.9 Farmers can keep records on tablets.

Livestock records

Livestock physical records include records of each cow, breeding records, heifer selection records and a herd-management planner, which shows management operations during the year.

Paddock records

Paddock history records show what has happened in each paddock on the farm. Records may include the name or number of each paddock, area, soil type, grazing history, pasture improvement activities (including fertiliser history) and fodder production.

Financial records

It is important for the farmer to be aware of what is happening to the farm business financially, to answer the important question: is it making a profit?

Calculating the gross margin of an activity on the farm provides an indication of its profitability. The gross margin includes only variable costs (i.e. the costs that change during production) and does not include fixed or overhead costs. Gross margins are worked out per cow or per hectare. The formula for a gross margin is:

$$\text{Gross margin} = \text{total income} - \text{variable costs.}$$

Marketing

Australians consume on average 33 kg of beef and veal product per person per year. The beef and veal export market was worth \$4.5 billion in 2010–11. Beef and veal are exported primarily to Japan, United States and Korea. Australia is the world's second largest exporter of beef.

Live cattle exports were worth \$660 million in 2010–11 – the major markets being Indonesia, Turkey and Israel.

Beef can be marketed according to the method of production, resulting in several strategies as follows.

- *Grass fed.* Beef cattle raised on pasture are referred to as 'grass fed'.
- *Feedlot or grain fed.* Some steers remain in a feedlot for 60 days and heifers for 70 days to be sold as 'grain fed'.
- *Organic.* To be classed as organic, beef cattle must only eat feed that has been certified 100 per cent organic. An extension on this where the farmer seeks to maintain natural systems in the soil so the environment leads to production of 'biodynamic beef'.
- *Hormone free.* Cattle not injected with slow-release hormone growth promotants (HGP) are called 'hormone free'. (Some supermarket chains have stopped selling beef with HPGs altogether.) Injection of HPGs into animals is permitted in Australia, as is marketing the resulting product as fit for human consumption. In the European Union, it is not permitted.

Farmers can use any of the following five methods to sell their cattle.

- 1 *Live weight sales.* Sales are held weekly or fortnightly in all major centres. Producers send cattle into the saleyards and they are sold by auction. This is the preferred method of selling cattle in many districts because it allows for good competition. Lots (i.e. groups of animals) of any size can be sent to the saleyards.

25 Name four pieces of information usually found in livestock physical records.

26 Name four pieces of information found in an individual paddock history record.

connect

Farm budgets

Examine specific market-focused gross margins for beef cattle, and look at 'Farm business and trade', then 'Livestock gross margins'.

- 2 *Over the hook.* Cattle are sold directly to abattoirs in sales ‘over the hook’. This cuts out the extra handling of cattle, because they are transported directly from the farm to the processor. Cattle sold directly to the processor are less likely to suffer from bruising. The price the farmer receives is determined by the **dressed weight** and quality of the carcases.
- 3 *Price grids.* When cattle are sold directly to the abattoir, the price the farmer receives may also be determined by a price grid. The ideal specifications for a particular market category are determined, and a price offered for cattle meeting these specifications. A price grid specifies different prices per kilogram for individual carcasses based on weight, muscle score, fat cover, fat and meat colours, age and sex. Less money is paid for animals that do not completely meet the specifications.
- 4 *Private sales.* Specialist lines of cattle can be sold in the paddock by negotiation, usually through a stock and station agent. The agreed price can be calculated by dollars per head, or cents per kilogram dressed weight at the abattoir (after slaughter and processing).
- 5 *Online sales.* Selling online combines the advantages of strong competition (as with saleyard auctions) and reduced handling (as with direct selling offers). Cattle sold through the **AuctionsPlus** website are assessed in the paddock. Their description is catalogued and distributed to buyers. The buyers then bid for groups of animals through a computer network or by telephone at weekly sales.

connect

AuctionsPlus

View the cattle auctions listed on the ‘Upcoming Auctions’ page.

27 Outline the five methods farmers can use to sell cattle.



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Figure 28.10 A cattle saleyard auction

Chapter review

Things to do

- 1 Collect pictures of the different breeds of cattle and make a wall chart. Describe the main differences between British, Zebu and European breeds.
- 2 Draw the outline of a beef animal in your notebook and label the areas from which the various cuts of beef come. Find out from a butcher the different prices per kilogram of each cut and account for the differences.
- 3 Carry out the following cattle husbandry practices.
 - a Safely and quietly move cattle into a set of handling yards.
 - b Move cattle through a race and operate the crush to restrain an animal.
- 4 Use a weight tape or scales to weigh a growing calf regularly. Record the weight each week. Calculate the average daily weight gain (expressed as kg/day). Graph your results.
- 5 Observe vaccination and/or drench cows or heifers.
- 6 Examine labels from drenches and vaccines to determine dosages, withholding periods and safety precautions.
- 7 Visit a beef cattle property and observe:
 - a artificial insemination.
 - b pregnancy testing.
 - c calf marking (ear tagging, vaccination and **castration** of bull calves).
- 8 Fat is scored 1–6 by measuring the fat over the 12th and 13th ribs, where 1 = 0–1 mm fat and 6 = >19 mm fat. Muscle is scored A–E, where A = very heavily muscled and E = lightly muscled.
 - a For a steer or cow in a crush, determine the fat score and the muscle score.
 - b Combine the fat and muscle scores to give a **condition score** (e.g. C3) for the animal (Table 28.1).

Table 28.1 Condition scores

FAT SCORE		1	2	3	4	5	6	
12/13th rib fat depth (mm)		Light 0–1	2–3	Medium 4–7	8–12	13–18	Extreme 19+	
MUSCLE SCORE	Very heavy muscle	A	A1	A2	A3	A4	A5	A6
	Heavy muscle	B	B1	B2	B3	B4	B5	B6
	Medium muscle	C	C1	C2	C3	C4	C5	C6
	Moderate muscle	D	D1	D2	D3	D4	D5	D6
	Light muscle	E	E1	E2	E3	E4	E5	E6

Things to find out

- 1 Compare the following breeds of beef cattle by copying and completing the table.

Breed	Country of origin	Characteristics of the breed (commercial and physical)
Angus		
Braford		
Brahman		
Hereford		
Murray Grey		
Santa Gertrudis		
Square Meater		

- 2 For a major regional centre where cattle are sold, examine market reports in a rural newspaper as shown in Table 28.2 (or on the internet) and record the price in cents per kilogram (c/kg) of live weight for vealers, steers and cows.

Table 28.2 Market report

PRIME BEEF								
Major centres	TYPE	LIVE WEIGHT KG	* GS	LIVEWEIGHT (c/kg)			DWT* c/kg	
				PRICE RANGE	MOST SALES	CHNG*		
Toowoomba	YARDED: 900, April 6. LAST SALE: 2200. Bullocks off grain sold to 133.8 c/kg while those off grass reached 129.6 c/kg. Heavy steers averaged 122 c/kg and medium-weights 119 c/kg. Cows also improved in value with score 3 types making 96–98 c/kg. Trade cattle rose 3–4 c/kg. The Queensland Cattle Market Index rose 0.4 to settle on 121.2 points.	VEALERS	131.1–210	C1	119.2–119.2	119	n/q	2
				C2	125.0–139.8	136	+5	26
				C3				
	YEARLING STEERS	281.1–370	B2					
			C2	104.2–104.2	104	n/q	8	
			C3	119.2–129.2	123	n/q	5	
	YEARLING HEIFERS	281.1–370	C2	97.6–97.6	98	n/q	1	
			C3	106.6–119.2	113	+2	52	
			D2					
	STEERS	501.1–550	C2					
			C3	115.0–115.0	115	n/q	4	
			C4	116.4–131.4	122	+1	49	
COWS	421.1–520	D3	90.2–99.6	96	n/c	50		
		D4	99.2–105.8	102	n/c	124		
		D5	83.2–83.2	83	n/q	1		

PRIME BEEF								
Major centres	TYPE	LIVE WEIGHT KG	* GS	LIVEWEIGHT (c/kg)			DWT* c/kg	
				PRICE RANGE	MOST SALES	CHNG*		
Casino	YARDED: 1900, April 7. LAST SALE: 765. The heavier yarding contained 1450 young cattle. Quality was mixed and the market easier with the best light veal 5–7 c/kg cheaper. Heavier vealers were back by 1–2 c/kg while yearlings met a firm market. Export cattle sold firm with some cows slightly dearer. Sale still in progress at time of publication.	VEALERS	UNDER 200	C2	128.6–136.6	134.2	-5	258
				C3	119.2–123.2	121.6	n/q	243
				D2				
	YEARLING STEERS	330.1–400	C2	107.6–112.6	111.3	n/q	214	
			C3	123.6–125.0	124.1	n/q	230	
			D3					
	YEARLING HEIFERS	UNDER 330	C2	114.2–118.0	115.5	n/q	231	
			C3	116.6–120.2	117.9	n/q	227	
			D3					
	STEERS	400.1–500	C2					
			C3					
			C4					
COWS	400.1–520	C3	94.6–94.6	94.6	-2	189		
		D3	83.2–90.6	86.5	n/c	192		
		D4	95.2–100.6	97.5	+2	203		

* CHNG = price variations from previous sale – n/c = no change, n/q = no change in price (but does not reflect any change in meat quality); DWT = dressed weight (also called carcass weight)

GS = Grade Score (combined muscle and fat score)

Courtesy of Meat and Livestock Australia Market Information

- 3 Find out why embryo transfer is not widely used in commercial cows, but is used in some stud herds.

+ Extension activities

- 1 Breedplan® has been producing estimated breeding values (EBVs) on growth for several years.
- What is Breedplan®?
 - What are Breedplan® EBVs?
 - Describe two ways that a farmer could use EBVs in herd management.
- 2 Find out the carcass type (age, carcass weight and fatness) required by the following markets.
- Local and supermarket
 - Hotel and restaurant trade
 - Japan
- 3 In Europe, foot-and-mouth disease has been a serious problem. Discover what causes this disease and how it has been kept out of Australia.

✓ Test yourself

- 1 Go to the 'Cattle appraisal' page on the [DPI Agriculture](#) website. Define 'shape assessment and muscle score in beef cattle' using information from the page.
- 2 Give a 3-minute PowerPoint presentation on the characteristics of one breed of beef cattle (mention commercial and physical characteristics).

connect

DPI Agriculture

- 3 Copy out the following statements and indicate if each is true or false.
- a Castration is the removal of the penis from a male.
 - b Dressed weight is the live weight of an animal.
 - c Gestation is the period from conception to maturity.
 - d Marbling is fine flecks of fat within meat.
 - e Supplementary feeding is additional feeding given to an animal in times of need to maintain sufficient nutrient level.

CHAPTER 29

SHEEP

Words to know

crutching shearing wool from the breech area

dipping applying chemicals to sheep to control external parasites

drafting separating sheep into different groups based on such aspects as age, body condition and sex

drenching administering medicine to treat internal parasites

ewe a sexually mature female sheep

flushing increasing the level of nutrition to ewes prior to joining

hogget a shorn or unshorn sheep 12–15 months of age

joining putting together male and female livestock for the purpose of breeding (e.g. the ram with the ewes)

lamb a young sheep from birth until weaning

mulesing surgically removing skin from the breech area of the sheep

mustering gathering sheep together into a mob so they can be moved to different places around the farm

ram an entire male sheep (not castrated)

seminal fluid secretions produced by glands in the male reproductive system

sperm male sex cells

tail docking removing the tail from a young lamb

wether a male animal castrated while still immature

Introduction

Since the early years of the sheep industry, overseas demand for the quality Merino wool produced by Australian farmers has resulted in a very successful wool industry in Australia. The development of the industry reflects both the suitability of the climate and the nature of overseas markets.

The highest recorded population of sheep in Australia was in 1970 – 174 million head. After this period a combination of drought and poor markets saw a decline in numbers. During the 1980s, sheep numbers in Australia increased, largely because of favourable climatic conditions and farmers shifting to producing wool when other markets such as grain offered lower returns. Sheep numbers reached 173 million in the early 1990s and declined again; wool markets had collapsed as result of industry deregulation and government incentives to cull sheep numbers. By 2002 the sheep population of Australia was 106 million. Drought and poor markets forced this figure down to 68 million in 2010.

Most sheep farms are mixed farms, combining activities such as prime **lamb** production, wool, wheat and/or beef enterprises.

Australia’s sheep-meat industry has developed alongside the wool industry. Prime lamb production is confined to areas of good pasture growth and high rainfall, such as the tablelands of New South Wales, parts of eastern and southern Victoria, south-east South Australia and south-west Western Australia. Lambs produced include first cross (e.g. Merino crossed with another breed such as Border Leicester) and second cross (e.g. a first cross ewe crossed with a Poll Dorset or Suffolk **ram**). A combination of changing market and climatic conditions has caused sheep numbers in the industry to fluctuate.

1 Why is prime lamb production restricted to areas of higher rainfall?

2 List the main products obtained from sheep.

3 Why is the distribution of Australia’s pastoral lands included on the map in Figure 29.1?

Distribution of sheep in Australia

Figure 29.1 illustrates the distribution of sheep in Australia. The western wheat belt of New South Wales, which has an annual rainfall of 350–450mm, is a marginal area for farming. Wheat grown in this area has a growing season of approximately 170–180 days. Subterranean clover has been the main pasture species used in rotation with wheat and in the pasture phase of the rotation, sheep are kept for wool production. Pastures provide a cheap source of feed for the animals.

A number of products are obtained from sheep, including wool, meat, milk and skin.

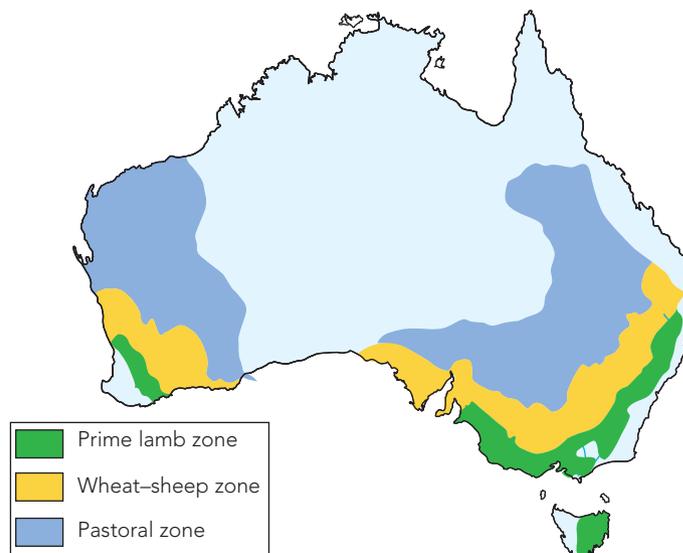


Figure 29.1 The distribution of sheep in Australia

There are four main groups of sheep breeds in Australia.

- 1 Purebred Merinos are used for wool production.
- 2 First cross ewes (Merino crossed with Border Leicester) are used to mother high-quality prime lambs.
- 3 Merino-based dual-purpose breeds are developed in high rainfall areas for wool and meat production.
- 4 British breeds:
 - a long wool breeds are used to breed prime lamb mothers
 - b short wool breeds are used as sires for prime lamb production.

Other breeds are emerging, such as Texel, East Friesian, Ryeland and Damara. Figure 29.2 shows the parts of a ewe.

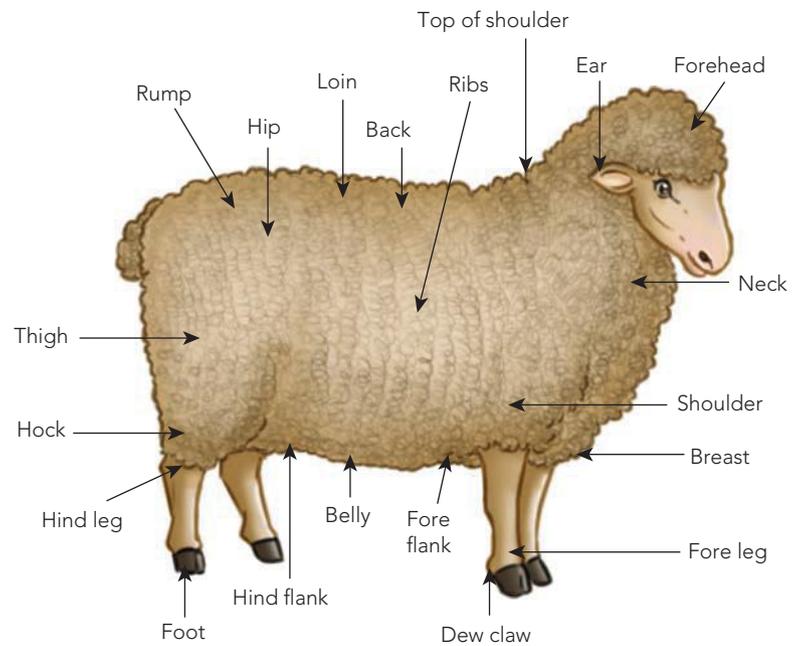


Figure 29.2 Parts of a ewe

Breeds of sheep

Figure 29.3 Breeds of sheep in Australia



Alamy© Nigel Cattlin

Border Leicester

The Border Leicester is a very popular British breed in Australia. It plays a major role in the Australian prime lamb industry, being mated with Merino ewes to produce a first cross prime lamb mother. The breed is polled and carries no wool on the head or legs. It has a distinctive 'Roman' nose.



Billigaboo Corriedales, Goulburn NSW

Corriedale

The Corriedale was developed in New Zealand by crossing Lincoln rams with Merino ewes. It is one of the most versatile breeds, producing quality wool or meat (i.e. dual purpose). The breed is large-framed, polled and produces good carcasses as lamb, **hogget** or mutton.

Superior Selections Photography/Ian & Wendy Turner



Dohnes

The Dohnes was developed in South Africa by crossing Peppin Merino ewes with a German mutton Merino sire. It was introduced into Australia in 1998, produces fine to medium white wool and is naturally polled. The carcass is heavy. The breed has high fertility and is resistant to fleece rot and fly strike. It is suited to a range of environmental conditions.



© Oceanwideimages.com

Dorset Horn

The Dorset Horn is one of the oldest breeds to come from England. It is the earliest maturing of all sheep breeds. Dorset Horn rams are mated with crossbred ewes to produce prime lambs. Both sexes have horns and the face and legs are white. This is an important short wool breed.

Kaya Dorper and White Dorper Stud



Dorper

The Dorper was developed in South Africa by crossing Dorset Horn rams with Blackhead Persian ewes. The Dorper is a hardy, fast-growing breed that is white bodied with black colouring on the head and neck area. It is mainly used for meat. The fleece is a wool and hair type of fleece that is shed in late spring.



Shutterstock/John Carnemolla

Merino

The Merino originated in Spain, but the present Merino was bred and developed in Australia. It is very hardy and is more tolerant of heat, cold, hunger and thirst than other breeds. It is the only breed used solely for its wool and has distinctive folds of neck wool. The rams have curled horns and the ewes are polled.

Animals Animals/© Claire Selby



Polwarth

The Polwarth was developed in Australia by crossing Lincoln rams with Merino ewes and mating the progeny back to a Merino ram. It is a dual-purpose breed. The Polwarth contains both polled and horned sheep, and is large framed and robust, producing a high-quality fleece.

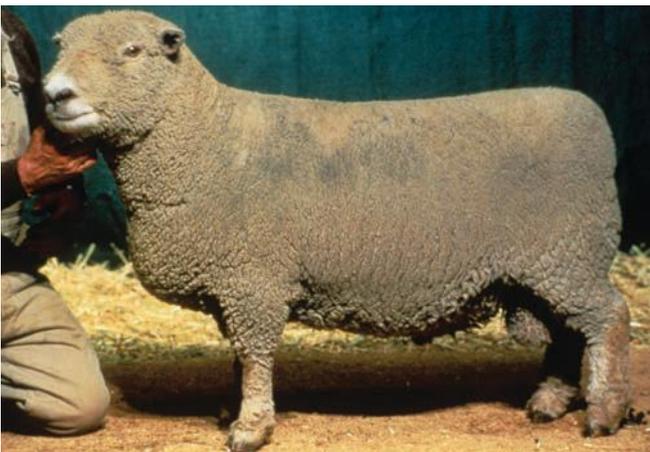
Wikimedia Commons/CattleGirl



Romney Marsh

The Romney Marsh originated in England and is well adapted to cold and wet conditions. It is resistant to footrot. The Romney Marsh is a polled breed with a large frame and, when crossed with British short wool breeds, produces high quality prime lambs.

NSW Department of Primary Industries



Southdown

The Southdown was developed in England. It is an important short wool breed and is used as a sire over other breeds to produce quality lambs. It is a hornless, thick set and short-legged breed.



Alamy/© Marilyn Shenton

Suffolk

The Suffolk was developed in England and is well known for its hardiness and is an important short wool breed. The Suffolk sheep is popular in cooler areas and is used as a prime lamb sire. It is a hornless breed with a black face, legs and feet.



Alamy/© Wayne Hutchinson

Texel

The Texel originated in the North Holland province of the Netherlands and was first imported to Australia in 1993. The Texel is a heavily muscled meat sheep and is used as a terminal sire for prime lamb production.

- 4 For what purpose is the Merino sheep used?
- 5 Which breeds of sheep are 'dual purpose'?
- 6 Describe the nose of a Border Leicester.
- 7 Which breed of sheep has a black face?
- 8 What are two important short wool breeds of sheep?

Production

The production cycle for sheep comprises a series of interlocking tasks that, when arranged correctly, allow for an efficient use of time and labour over the year. Many activities require **mustering** (moving large numbers of sheep around the farm). When sheep are gathered into yards they may need to be separated (**drafted**) to allow activities such as vaccination or drenching to occur.

Depending on the location of a sheep farm, the months indicated for various operations will vary due to climate and market influences. Figure 29.4 illustrates the main periods involved in the management of sheep.

Birth

Lambs are born in October and November. The first main management routine for these lambs occurs in January when they are tail-docked, vaccinated, earmarked and, if male, castrated to promote the development of a better carcase and make handling easier. Castrated male lambs are called **wethers**.

Weaning

By early March the lambs are weaned and placed on good quality pasture. During the weaning process all sheep are crutched to reduce fly strike problems. Worms can be a particular problem for young weaned lambs and special care must be taken to avoid a disease problem at this stage.

Joining

During May–June the sheep are joined; that is, the rams are allowed to run with the ewes so mating can occur. The **joining** period lasts for 6 weeks on average, and across the whole farm, approximately 2–3 rams per 100 ewes are used. For 2–3 weeks prior to joining, the farmer may place the ewes onto good-quality feed in a practice called **flushing**, which increases the percentage of twinning in sheep flocks.

Shearing

There is a gap in the operation until September when all the sheep are shorn. Shearers are usually contractors who remain on the property until shearing is finished (about 3 weeks). In the gap other complementary activities can occur on the farm such as the sowing of wheat.

Dipping

Sheep are **dipped** in October to control external parasites. **Drenching** occurs at various times throughout the year to

- 9 Copy the management calendar for the production of wool into your notebook. Mark on this calendar time periods when farm labour can be used to do other tasks.

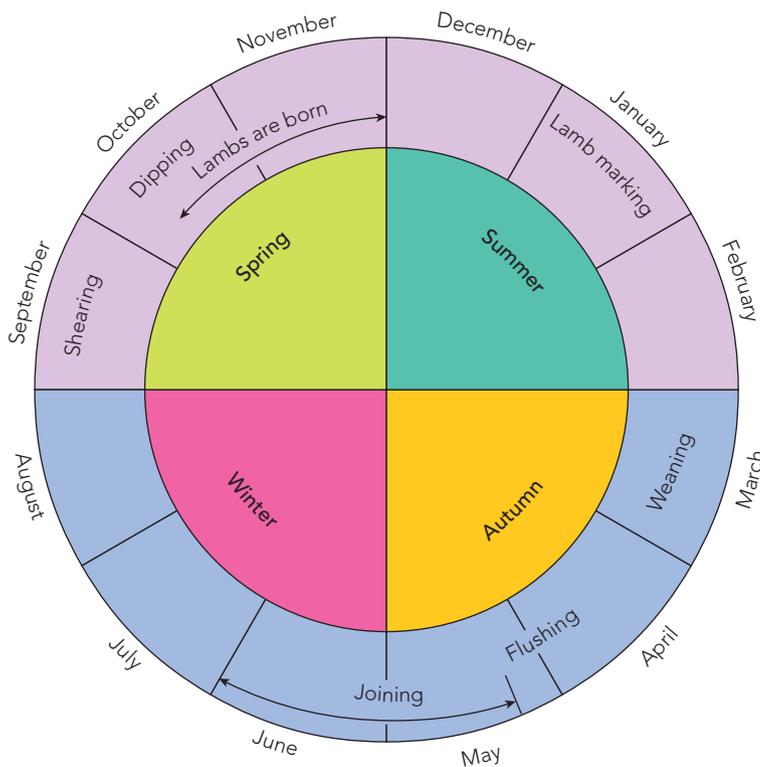


Figure 29.4 A management calendar for wool production

Science Photo Library/ David Aubrey

**Figure 29.5** Drenching

Alamy© Wildlight Photo Agency

**Figure 29.7** Wool skirting**Figure 29.6** Shearing

Fotolia© Juice Images

control internal parasites. Many farmers still link drenching to shearing times, crutching and joining periods when the farmer is managing all the animals at one time.

Husbandry

Husbandry tasks must be carried out on sheep farms. The main sheep husbandry tasks are as follows.

- **Drenching.** In some areas sheep must be drenched to protect against internal parasites (worms and liver fluke). The sheep are penned firmly in a long narrow pen or race and drenched using a drenching gun fed from a container carried on the back of the operator. The gun must be carefully adjusted to deliver the correct dose for age and weight of sheep. (Fig. 29.5)
- **Jetting.** It is sometimes necessary to jet sheep to prevent or treat blowfly strike. Jetting is the application of chemical liquids as a spray through the wool and on the skin. The chemical is applied to the sheep using a wand with several spray nozzles.
- **Shearing.** This is the removal of fleece from a sheep. Shearing is carried out in four runs per day, each of 2 hours duration. After the sheep is shorn, the fleece is picked up and thrown on the wool table, tip upwards. It is then 'skirted' (i.e. coloured or uneven wool, or wool with burr in it, is removed and kept separate). The fleece is then rolled up and classed (Figs 29.6 and 29.7).
- **Dipping.** This is the treatment of sheep for the prevention of external parasites (ked, lice, itch mite). It involves soaking the wool all over the sheep with an insecticide solution. Sheep can be either forced into a plunge dip or 'bath', or put through a shower or spray dip. The most recent development in controlling external parasites is backlining – the farmer pours a special chemical in a line along the sheep's back.



Alamy© cbstockfoto

Figure 29.8 Australian sheep blowfly (*Lucilia cuprina*)**Figure 29.9** Tail docking (knife method)

- 10 Why are sheep drenched?
- 11 What is 'skirting' and why is it carried out?
- 12 Describe the main methods used to dip sheep.
- 13 Why is crutching carried out?
- 14 List the four main operations carried out at lamb marking.

Shutterstock/Chris Turner



Figure 29.10 Vaccination

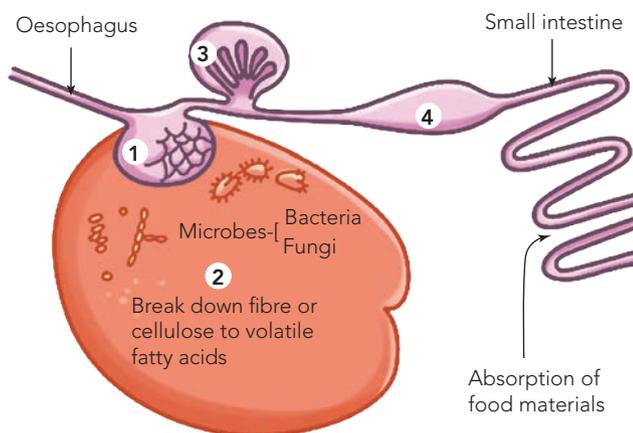
- *Crutching.* This is the removal of wool from the back of the sheep's legs, crutch or breech, and over the tail because the most common place for blowfly (Fig. 29.8) to lay their eggs in the skin (blowfly strike) is the sheep's breech region. Sheep can be crutched by either using hand shears or a shearing machine.
- *Lamb marking.* Lambs should be marked 3–6 weeks after birth. Four operations are carried out. Ear marking is the cutting of the registered mark in the right ear of ewe lambs and the left ear of ram lambs, using ear marking pliers. Tail docking is carried out by removing the tail at the second or third joint, using a knife or rubber ring (Fig. 29.9). Ram lambs that are not needed for breeding are then castrated using a knife or rubber ring (applied around the scrotum). Vaccination involves a small injection of a vaccine to protect the lamb against a variety of diseases such as tetanus (Fig. 29.10). The vaccine is given by syringe, usually inside the lamb's back leg or behind the ear.
- *Weaning.* Lambs are weaned (separated from their mothers) at 3–4 months of age. Weaning paddocks should have the best feed and a good supply of water.

Feeding and digestion

Sheep are ruminant animals, feeding mainly on bulky fibrous food such as grass. Digestion is a slow process in a ruminant, as discussed in Chapter 25. The animal needs to store and ferment the food within its digestive tract, then further soften it by regurgitating and re-chewing. Figure 29.11 illustrates the main stomachs

of a sheep, while Figure 29.12 outlines the entire digestive system.

What is unique about ruminant animals is their ability to digest cellulose – the main substance that makes up the walls of cells in plants forming what is termed plant fibre. The protozoa, bacteria and fungi that do this release high energy compounds which are absorbed through the rumen wall for the sheep to use. These micro-organisms also make better quality protein from plants. The microbes from the rumen eventually travel to the abomasum or true stomach where they are digested and their protein broken down into essential amino acids. All ruminant animals obtain their protein by the digestion of micro-organisms. It is the microbes that determine the quality of protein available to the animal, regardless of the quality of food consumed by the animal. The microbes also supply the animals with various vitamins.



The four stomachs are:

- 1 Reticulum
- 2 Rumen
- 3 Omasum
- 4 Abomasum

Figure 29.11 The four stomachs of a sheep

Pastures and grazing

Sown pasture is the cheapest feed for sheep. Sheep eat a wide variety of pasture species, and prefer plants when they are short and succulent. An ideal pasture mix for sheep would consist of grass and legume species. Ryegrass and phalaris are suitable grass species, while subterranean clover and lucerne are suitable legumes.

Pastures need top dressing with superphosphate each year to keep them producing at their best and to allow them to carry a reasonable number of sheep per hectare. Breeding ewes need more feed than wethers, so the stocking rate must be lower than for wethers.

In times of shortage such as drought one of the cheapest and best supplementary fodders for sheep is pasture hay. Its feed value depends on the stage at which it was cut, the clover content and the weather conditions at the time of haymaking. Some farmers prefer to feed concentrates such as wheat, oats, barley or sheep nuts instead of roughages – less labour is required in feeding these out, and there is less waste.

-
- 15 What is the cheapest feed for sheep?
 - 16 Name two legumes that can be grown for sheep feed.
 - 17 Which fertiliser is applied to pastures each year to keep them producing at their best?
 - 18 What factors affect the feed value of hay?

Digestive tract of a sheep

1 Oesophagus
2 Rumen
3 Reticulum
4 Omasum
5 Abomasum
6 Pancreas
7 Duodenum
8 Small intestine
9 Blood vessels to the liver
10 Gall bladder
11 Liver
12 Caecum
13 Large intestine
14 Rectum
15 Anus



Figure 29.12 The digestive system of a sheep

Reproduction

The main reproductive organs of the ram are the testes (singular 'testis'), in which the male sex cells or **sperm** are made. The testes are outside the body in a sac called the scrotum. The scrotum maintains the testes at slightly less than body temperature and allows sperm production to occur. The sperm when made are collected and stored to mature in the epididymis. The sperm ducts carry sperm to glands that secrete various fluids, collectively termed **seminal fluid**. Semen, which is sperm plus the seminal fluid, passes to the outside through the penis. Figure 29.13 illustrates the main reproductive structures of the ram.

- 19 Draw the structure of the reproductive system of the ram and label the main parts.
- 20 Draw the female reproductive system and label the main parts.
- 21 Distinguish between sperm and semen.
- 22 Distinguish between ovulation and fertilisation.
- 23 Define 'gestation period'.
- 24 What is the function of the umbilical cord?
- 25 Refer to Figure 29.15 and determine which breed of sheep has the longest seasonal breeding pattern.

The main organs of reproduction of the ewe are the ovaries, which make egg cells or ova. When an egg is released from an ovary the process is called ovulation. The egg cell moves down the Fallopian tubes toward the uterus. If a sperm cell fuses with the egg cell during this journey, the egg cell becomes fertilised and will embed itself on the uterine wall to develop into an embryo. If fertilisation does not occur the egg cell will degenerate. Figure 29.14 shows the main reproductive structures of a ewe.

If a ewe becomes pregnant, the foetus is protected by a fluid-filled sac called the amnion and is attached to the uterine wall by a cord called the umbilical cord. The foetus obtains its nourishment through this cord. It takes 5 months (150 days) for the foetus to develop in the uterus before birth. This is called the gestation period. Figure 29.16 illustrates the main steps in the reproductive process for sheep.

Most sheep breeds are seasonal breeders, responding to decreasing hours of sunlight. Figure 29.15 illustrates the seasonal breeding pattern for three common breeds of sheep. Notice that the most popular breed has an extended breeding period due to selective breeding.

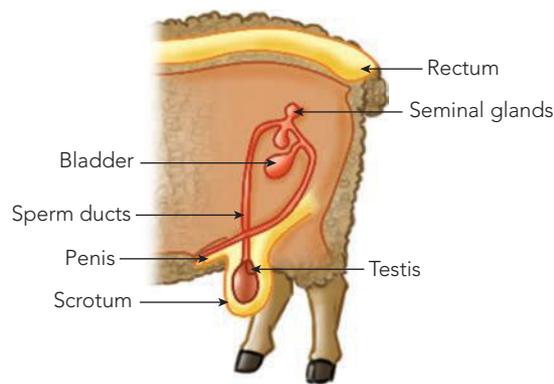


Figure 29.13 The reproductive structures of a ram

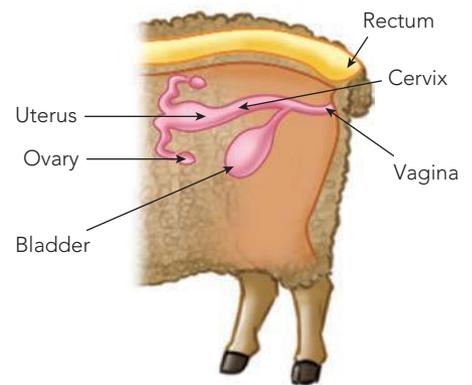


Figure 29.14 The reproductive structures of a ewe

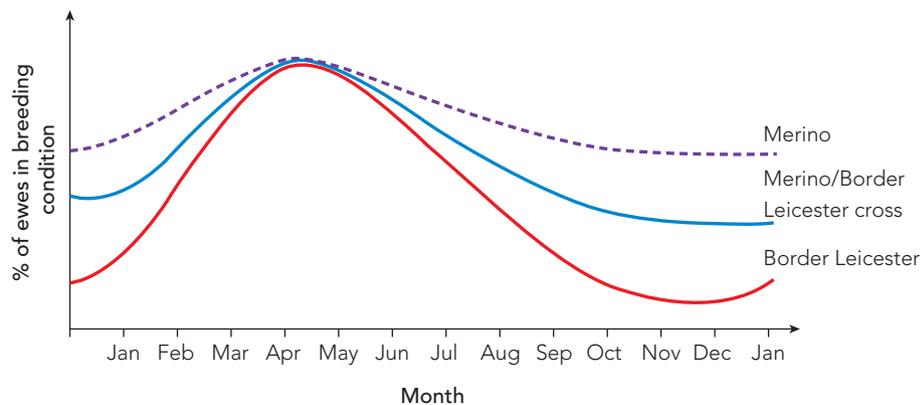


Figure 29.15 Breeding patterns for three sheep breeds

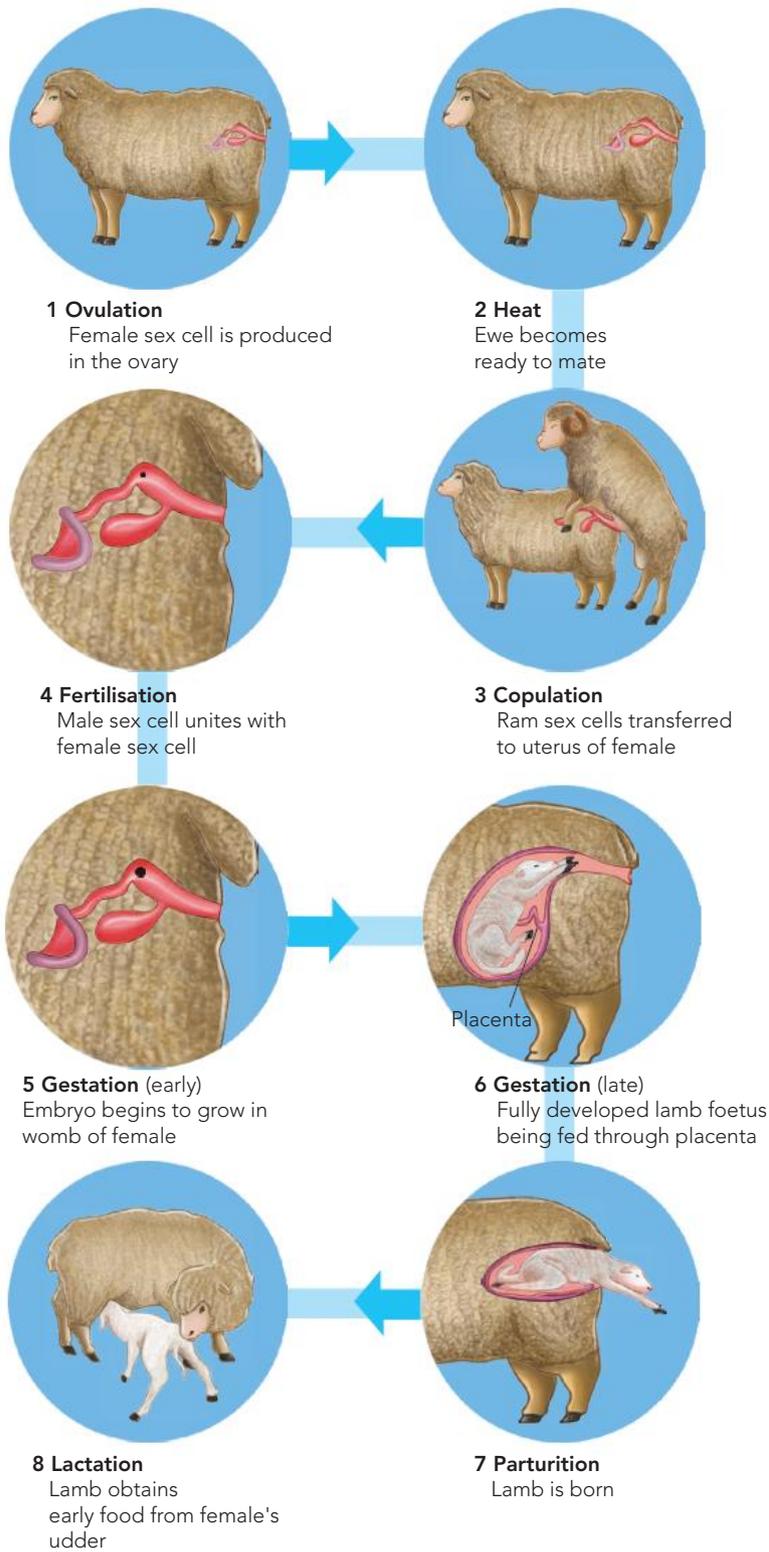


Figure 29.16 The main steps in the reproductive process for sheep

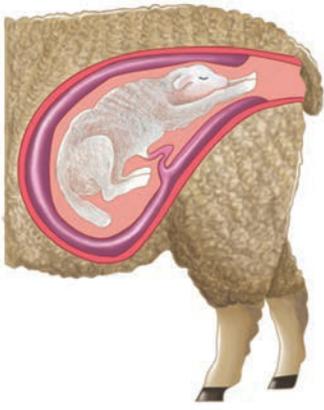


Figure 29.17 Normal birthing position

-
- 26** How long are rams left with the ewes in mating?
 - 27** How many rams would be run with 200 ewes at mating?
 - 28** What is the gestation period for a sheep?
 - 29** What is the purpose of the ram harness or raddle?

-
- 30** What is the main disease-causing organism for the clostridial diseases?
 - 31** What method is used to control infections caused by clostridium in sheep?

Breeding

Ewes come on heat about every 17–18 days and stay on heat for 1–3 days. During this time they will receive the ram. Rams are usually left with ewes for at least 6 weeks, giving the ewes at least two chances to conceive. One ram is run with approximately 50 ewes. The rams are sometimes fitted with a raddle harness that carries a crayon, to help the farmer identify the ewes that have been mated.

Ewes should be in good condition at mating to get high lambing percentages. If successfully mated, the ewe will lamb in about 5 months. It is important that ewes are on good feed for the last 6 weeks of pregnancy, as the foetus grows rapidly during this time. This is called flushing. Lambs are usually born front feet and head first (Fig. 29.17).

Controlling pests and diseases

Several types of micro-organisms cause serious diseases in sheep. Nutrient deficiencies and parasites can also cause serious economic loss and even death to the animal.

Clostridial diseases

This major group of sheep diseases is caused by related species of *Clostridium* bacteria. The main diseases are tetanus, black disease, pulpy kidney or enterotoxaemia and blackleg.

Tetanus mainly affects young animals; the bacteria live in the soil and enter the sheep through wounds particularly after shearing, lamb marking and **mulesing**. Tetanus is fatal to sheep. There is no suitable treatment for sheep once they are infected. It begins with the animal developing stiffness coupled with muscle spasms. These symptoms may appear 7–24 days after wounding. A vaccine to prevent tetanus exists and the animals become immune to the disease 14 days after vaccination. Two injections are given 3–4 weeks apart and a booster injection is given every 12 months.

Black disease is fatal to sheep of all ages. The sheep pick up the bacteria from the soil as they graze. Once inside an animal, the bacteria lie dormant until the sheep become infected with a parasite called liver fluke. The damage to the liver caused by the parasite activates the bacteria to produce a poison. The skin of an infected animal is black underneath the wool, which pulls away easily. The disease can be prevented by the use of a vaccine.

Blackleg is a type of blood poisoning that is caused by soil-borne bacteria entering the animal through a wound, or during grazing. Animals up to 18 months of age are particularly vulnerable. The animals die rapidly; their skin is discoloured, the wool pulls away easily from the carcass, and there is often blood around the nostril region. Prevention is by vaccination.

Because these diseases are related, the 5-in-1 vaccine is used to control all of the clostridial diseases. The easiest way to vaccinate a sheep is to inject it under the skin. Usually ewes are vaccinated before lambing. Lambs are vaccinated at marking and once a year for the rest of their lives.

Footrot

This is a highly contagious disease in sheep that can also affect goats, deer and cattle. Bacteria infecting the damaged hooves of an animal cause the disease. This is particularly the case in wet conditions where the foot area has been softened. The infection causes the skin between the hooves to separate from the hard part of the hoof. The animal eventually goes lame, is unable to graze properly and

will consequently lose weight and condition. Annual trimming of sheep feet and regular checking of the flock for lame animals is a common way of controlling the disease. If footrot is detected, severe trimming of the hoof should take place with an application of a dressing or antiseptic solution.

Parasitic pests and diseases

A parasite is an organism that lives on or in, and obtains its food from, another living organism. Sheep blowflies are the worst parasitic pests of sheep in Australia (see Fig. 29.8). The female blowfly lays its eggs on moist patches of wool. This commonly occurs in the crutch area (where the wool has been dirtied by droppings and urine) or where they have wounds such as shearing cuts. The eggs hatch into larvae called maggots, which live on the flesh until fully grown. They then fall to the ground and hide, where they pupate and emerge as flies. The weather is usually hot and humid to favour fly reproduction.

There are five methods of reducing the incidence of blowfly strike in sheep.

- 1 Crutching** is necessary once a year to stop the wool around the tail and back legs getting soiled and becoming attractive to flies. Wool is clipped away from the crutch in this operation.
- 2 Mulesing** removes the top layer of skin from the breech area of the sheep. The chance of fly strike is reduced by this method of management because it removes the wrinkles in the crutch area.
- 3 Tail docking** is the removal of the tail of a lamb, 5 cm from the base, at approximately 2–8 weeks of age. This operation is part of what farmers refer to as ‘lamb marking’. The tails are removed so that the crutch area may be kept dry and be less likely to be struck by flies.
- 4** To reduce the incidence of this damage sheep are being bred to have fewer wrinkles in the breech area to reduce blowfly strike.
- 5 Jetting** offers short-term protection. This consists of placing an insecticide into the wool to repel or kill flies and destroy live maggots.

Other external parasites of sheep include lice and ked (sheep tick). Both cause irritation and loss of condition for infected animals. The wool is also damaged by sheep rubbing against fences, which reduces its value. Control is by dipping.

Important internal parasites of sheep include the liver fluke, barber’s pole worm, roundworms and tapeworms. Farmers control the outbreaks of worms by strategic drenching of the flock, especially after periods of rain. The main concern is the development of resistance by the worms to the chemicals used in the drenches. For this reason farmers must regularly change the type of drench given to the animals and strictly adhere to the directions for use of the drench. Figure 29.18 illustrates some common internal parasites of sheep.

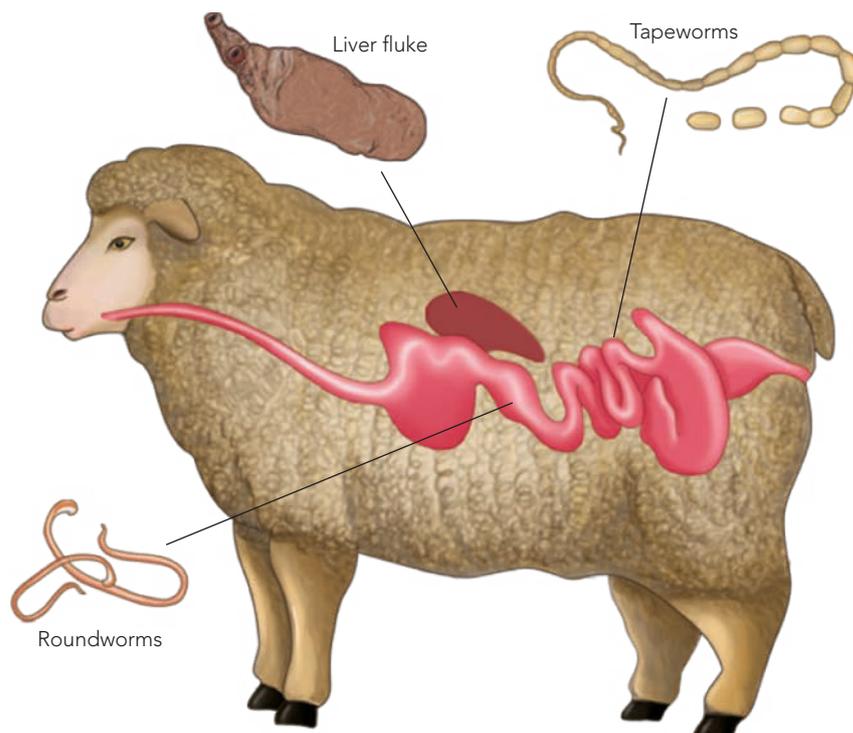


Figure 29.18 Internal parasites of sheep

- 32** What is a parasite?
- 33** Identify two examples of internal parasites.
- 34** How are internal parasites controlled?
- 35** Outline the control measures a farmer can use to reduce the risk of fly strike.
- 36** What environmental conditions favour fly strike?

connect

Agriculture

Further information on animal welfare

Animal welfare

The basic requirements for the welfare of sheep are:

- safe handling facilities
- adequate disaster protection (e.g. fodder and water reserves)
- protection from harsh environmental conditions
- adequate disease control strategies
- adequate protection from predators
- sufficient space to stand, lie down and follow normal behaviour patterns
- access to clean and fresh water and feed.

The degree of supervision depends on the intensity of the management system. However, sheep in extensive conditions require a manager to sight their condition at regular intervals depending on food and water availability, age, physiological state and climatic conditions.

Because sheep husbandry involves a number of management procedures, farm hands need to be competent or under the direct supervision of an experienced operator. In all situations sheep must be handled gently and calmly to avoid panic or injury in crowded yards. Stock handlers need to be trained in all surgical handling procedures or employ a suitably trained person.

Working safely

Farm safety is also an important consideration in farm management. Workers need to be trained in many aspects of sheep husbandry to meet animal welfare requirements and to ensure their own safety.

- Working in crowded yards, farm hands need to be aware of natural behavioural patterns so animals are not stampeded into corners. Sheep can also jump, especially on leaving races, so injury to workers can be minimised through an understanding of this behaviour.
- Working with breeds such as Dorset Horn, farm hands can avoid leg and knee damage by careful and calm movement of animals.
- Correct lifting procedures are needed. Lifting is often carried out by workers in yards in the course of a day's work.
- When applying chemicals or using vaccination guns extreme care is required. Correct clothing is needed and workers should have a clear understanding of the directions, concentrations of chemical to be used and safety precautions prior to any activity.

Marketing wool

Average Australian wool production is around 368 330 tonnes of greasy wool. Wool is exported mainly to China, India, Italy and Japan.

After shearing, the raw wool is graded according to fibre diameter and checked for cleanliness. This includes freedom from weed seed contamination as well as damage caused by disease and nutritional factors. Colour can also be an important factor. The fleece is skirted to remove belly wool and stained fibres. The total number of bales of wool that a farmer is able to produce each year is called the woolclip.

The raw wool is then delivered to a wool collection centre where core samples are taken from each bale, both for inspection by buyers and for analysis. Most wool is

sold overseas as greasy wool, although some value adding occurs to about 20 per cent of the wool by cleaning or scouring to remove dirt and grease prior to export.

Two systems are used to process wool. Woollen fabric is made from yarn in which the fibres lie in all directions, giving a furry surface. This process is used to make jumpers and cardigans. Worsted fabrics are woven from combed wool in which all the fibres lie in the one direction. It also has fewer short fibres. This gives a smooth surface. This process is used to make suits and dresses. Most fine Merino wool is used to produce worsted products.

Once wool enters the mill it is washed and then dried by warm air. This process is called scouring and removes dirt, vegetable matter and grease from the wool. One useful product obtained after scouring is lanolin, used in cosmetics. After scouring the wool is tangled and has to be carded to straighten the fibres. Carding further removes vegetable matter such as seeds. At this point the wool may be drawn into strands. Worsted fabrics are also combed to allow the fibres of wool to lay parallel to each other.

Once strands of wool are formed from the fleece they are drawn out and spun. Spinning reduces the thickness of the strand to a size required by the yarn manufacturers. A twist is put in to increase strength; extra strength can also be gained by twisting several yarns together.

In the weaving process cloth is made from interlacing two sets of threads at right angles to each other. The cloth is then set to a certain width or finished. Dyeing can take place at various stages to enhance further the value of the final product. All of these steps add value to wool as a raw product and enhance its market price.

The majority of wool is sold at auctions. The Australian Wool Exchange (AWEX), based in Sydney, conducts sales at several national centres. On arrival at the broker's store wool is sampled and this sample tested in a laboratory. The physical characteristics of the wool are determined and the wool catalogued for auction – a process termed 'objective clip preparation'. These characteristics are:

- fibre diameter
- fibre quality
- length of staple
- strength and colour of staple
- the amount of vegetable material such as grass seeds in the sample
- fibre curvature.

AWEX carries out many of the functions of the previous Australian Wool Corporation, including selling wool, quality assurance and providing pre- and post-auction information systems. A wool levy is currently set at 2 per cent and applies to the initial gross value of shorn greasy wool.

A further change to the way wool is sold includes sale by description, where the measured characteristics of wool are presented to buyers. This means the buyers no longer inspect samples of the wool on sale. An example of this is shown in Table 29.1.

Table 29.1 Description of Merino wool

	Greasy fleece weight (kg)	Fibre diameter (micrometres)	Adult body weight (kg)
Superfine	3–4	≤19.5	35–40
Fine	3–5	19.6–20.5	35–40
Medium	4–6	20.6–22.5	40–50
Strong	5–7	≥22.6	45–55

connect

Australian wool testing authority

Information on sale by description and wool testing

- 37** What are the main types of cloth produced from wool?
- 38** Outline the steps in the processing of wool from the raw material to the final product.

Marketing meat

Meat from sheep is sold as either lamb or mutton. Lamb comes from young sheep aged up to 10 months with no adult teeth showing. Mutton is obtained from older sheep and is tougher, requiring slower cooking compared to lamb. Consumers now prefer low fat meat, so today lamb carcasses have less fat and are larger sized to enable a variety of meat cuts to be marketed to consumers. Average mutton and lamb consumption in Australia is 11.2 kg per person per year. The export trade is quite large with 50 per cent of all sheep meat produced in Australia exported. The main markets for Australian lamb are the United States, China, and United Arab Emirates, and for mutton the main export markets are China, Saudi Arabia and United States. Live sheep are exported to Kuwait, Bahrain and Qatar. Australia produces 7 per cent of the world's lamb and mutton.

Lambplan is the Australian lamb industry genetic information system. It supplies information on the value of an animal's genes for a range of commercially viable characteristics. This information is provided as estimated breeding values (EBVs) of a particular production trait such as growth, carcass fat, wool weight and disease resistance.

There are several ways to market sheep meat products.

- *Saleyard auction.* Farmers deliver their lambs to regional saleyards where buyers bid for the sheep at auction. These sales are conducted by stock and station agents on a pen by pen basis. At some saleyards sheep are auctioned on their live weight. Care must be taken for the welfare of the animals with this system as bruising, stress and disease will lead to carcass damage and lower prices.
- *Private sales.* Buyers inspect the sheep on the farm and a price is negotiated with the farmer. This is also termed paddock sale.
- *Online sales.* A system based on sale by description, [AuctionsPlus](#) allows setting of a reserve price and provides a legal means of changing ownership without people or product having to come together physically at the time of sale. Auctions may be conducted as:
 - 1 simultaneous electronic auctions controlled by computer, where all listed lots are sold at once. Bidding can be on any lot at any time within the sale period and the response from other bidders is immediately available on screen. When the auction time is up, all lots are deemed sold at the same time.
 - 2 interfaced electronic auctions, where an online bid is interfaced in real time to a person sitting at the actual auction wearing a wireless device interfaced to a computer. As the auctioneer runs the physical auction the bidders place their bid on their computer and this is transferred to the person at auction who will raise the bid with the auctioneer. In this system only one lot at a time is auctioned.
- *Contract selling.* A farmer negotiates a contract with a processor. The lambs must meet the processor's requirements in terms of fat score and carcass weight, but the farmer will have negotiated a set price should these specifications be met.
- *Over the hook.* Here sheep are sold to the processor on the basis of the dressed carcass. The lambs are delivered directly to an abattoir where the carcasses are dressed according to the [Ausmeat](#) standards. Fat depth and the weight of the carcass immediately after slaughter and dressing are recorded and used to determine the price paid. This information is also supplied to the farmer to assist with future management decisions.

connect

AuctionsPlus

connect

Ausmeat

39 Outline how lamb and mutton are sold.

Chapter review

Things to do

- 1 Discuss a method of determining worm infestation in sheep.
- 2 Construct a management calendar for a sheep farm in your local area for the year.
- 3 Learn how to throw a sheep, a necessary skill to safely restrain the animal while examining it for disease and determining body condition, and for shearing.
- 4 Draw in your notebook the floor plan of a shearing shed in your district. Label the main features.
- 5 Draw a plan of a set of sheep yards. Label the receiving yards, holding yards and drafting race. Use arrows to indicate the movement of sheep in the yards.
- 6 Skirt a fleece.
- 7 Look at a sheep fleece. Measure the number of crimps (i.e. the waviness of the wool fibre) per centimetre.

Things to find out

- 1 How is the percentage of vegetable matter in a sample of wool determined?
- 2 Discover the storage conditions necessary for a vaccine.
- 3 Describe the lifecycle of the sheep blowfly. How does it affect sheep, and how can blowfly strike be controlled?
- 4 What are the advantages of using rubber rings instead of a knife when tail-docking a lamb?
- 5 Determine the most common diseases of sheep in your local area. Make up a table, indicating the type of disease, symptoms and control measures. Talk to various farmers about control methods used on their farms.
- 6 Determine the current marketing arrangements for wool. Various marketing procedures are evolving; which is most favoured by local farmers and why?
- 7 Visit the [Sirolan Fleecescan](https://www.sirolan.com.au) website and describe how laser technology is used when classing wool at shearing time.

connect

Sirolan Fleecescan

Extension activities

- 1 A newborn lamb must receive colostrum. What is colostrum, why is it necessary and how can it be made artificially?
- 2 Using local papers, magazines, the internet or television, determine the main products from sheep that are produced in your local area. Track their market price for 1 month. Determine the factors that are affecting the market price for these products over this time period.
- 3 Evaluate robotic shearing as a method of removing fleece from sheep.

connect

Robot sheep shearing

✓ Test yourself

1 For one named pest or disease of sheep evaluate the strategies being used to control it.

2 In your notebook, write each of these words with the correct definition from the list below.

crutching, sperm, mulesing, joining, dipping, drenching

- surgically removing skin from the breech area of the sheep
- male sex cell
- shearing wool from the breech area
- administering medicine to treat internal parasites
- applying chemicals to sheep to control external parasites
- putting the ram with the ewe

CHAPTER 30

PIGS

Words to know

backfatter a fat pig too heavy for the bacon trade; more than 90kg, dressed weight

baconer a pig ready for market, usually 60–75kg dressed weight

boar a male pig older than 6 months of age

farrowing the production of a litter of one or more piglets

finisher a pig in its last 4–6 weeks before slaughter

gilt an unmated sow

grower a pig between weaning and finishing

hybrid vigour the increased vigour (e.g. growth, litter size, milk production) of crossbred animals

porker a pig ready for market, usually 45–60kg dressed weight

sow a female pig used for breeding

weaner a young animal that has been weaned from its mother

weaning the permanent separation of a female from her young

Introduction

Pig producers are found in every state of Australia, with the greatest numbers in New South Wales and Queensland. Larger operators are found in grain-producing areas, so that feed costs are reduced. Factors that help to determine where pig farms should be located include:

- proximity to major markets
- land availability
- access to a good water supply
- community acceptance.

A unit of 120 **sows** can be successfully run by one farmer, but there seems to be no upper limit to farm sizes. Many of the larger units range from 400 to more than 20000 sows and employ workers.

The majority of Australian pigs are housed indoors; such systems are comfortable and efficient for both the sow and the worker. In cold conditions, heating systems are installed and in hot conditions the whole environment can be cooled. The **Australian pork** and **Aussie pig farming** websites contain information on many aspects of the pork industry.

Pigs produce pork (fresh pig meat), bacon and ham (factory-processed and cured pig meat) and pig skin (used for leather).

connect

Australian pork

connect

Aussie pig farming

- 1 Why are pigs produced close to grain-growing areas?
- 2 Name three products obtained from pigs.
- 3 Identify the three main breeds used in Australian piggeries.

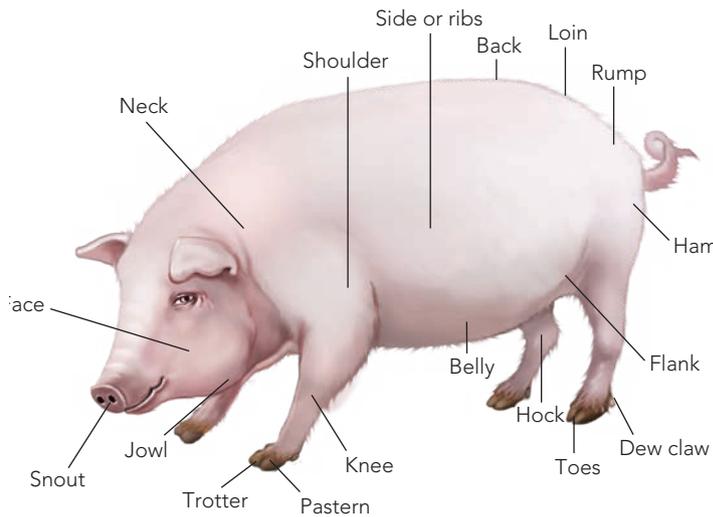


Figure 30.1 Parts of a pig



Figure 30.2 Pigs require husbandry

Australian pig farmers mainly use three breeds of pigs: the Large White, the Landrace and the Duroc. Generally two of these breeds are crossed to produce a first-cross gilt. This female shows **hybrid vigour** and therefore can produce extra piglets per litter. A purebred or crossbred **boar** is then mated with this female to produce pigs for market (slaughter). Figure 30.1 shows the parts of a pig.

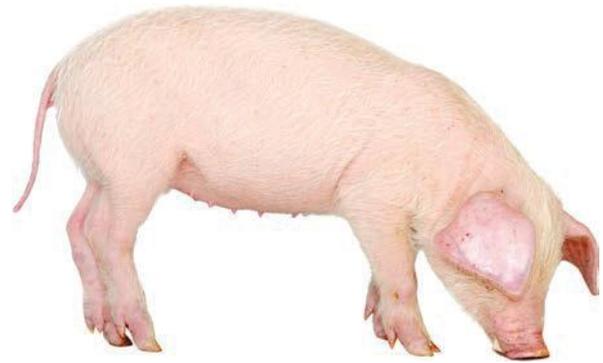
Breeds of pigs



Corbis/© Robert Dowling

Berkshire

The Berkshire was developed in England. It is a black pig with a white face, feet and tip of tail. Sows are good mothers, good milkers and rear their young well to weaning age.



Shutterstock/Steashkin Yevgeniy

Landrace

The Landrace was developed in Denmark. It is all white with ears that hang forward over the eyes. The Landrace is popular for its high proportion of lean meat and excellent growth rate. It makes an ideal bacon pig.



Alamy/© Nigel Cattlin

Duroc

The Duroc was developed in the United States using pigs brought from England. It is a red pig and is very popular.



Alamy/© Alun John

Large Black

The Large Black pig is all black with long thin ears that flop in front of its eyes. It is a hardy, early maturing pig and is used for crossing with other breeds.



Corbis/© Yann Arthus-Bertrand

Large White

The Large White was developed in England. It is a large pig, all white in colour and is an excellent bacon type. It is also the world's most popular pig.

Figure 30.3 Breeds of pig. Seven main breeds of pig are produced in Australia.

Stockphoto/© Julian40



Tamworth

The Tamworth was also developed in England. It is a red pig with erect ears. The breed is very hardy. The sows are prolific and the carcass carries lean flesh suitable for bacon.

Alamy/© FLPA



Wessex Saddleback

The Wessex Saddleback was developed in England from three crosses. It is a black pig with a characteristic white saddle running from one foot up over the shoulder to the other foot. It is crossed with any breed to produce pork and bacon breeds. The sows make excellent mothers and can cope successfully with large litters.

connect

Pig breeds 1

connect

Pig breeds 2

- 4 Which pig breed was developed in Denmark?
- 5 Which breeds are black in colour?
- 6 Which breeds have ears that flop or hang over their eyes?

connect

Industry change

Summarise the main changes being undertaken within the pig industry.

- 7 How long is the gestation period of a sow?
- 8 At what age are piglets weaned?

Sustainable pig farming

A sustainable pig farm is one that remains profitable, producing pig meat of acceptable quality and quantity. The farmer should also conserve soil and water resources and protect the environment. Sustainability issues especially relevant to pig farming include:

- keeping chemical residues out of the carcasses, because consumers want 'pure' foods free of chemical residues. Of concern are chemicals used for grain treatment, drugs used for the control and treatment of diseases, and pesticides used for the control of insect pests around the piggery.
- carefully collecting and disposing of effluent to avoid polluting rivers and creeks
- maintaining strict quarantine measures to ensure that Australia is kept free from many major pig diseases, such as foot-and-mouth disease, which is widespread throughout the world.

Many changes are occurring within the pig industry.

Production cycle

Young mature female pigs, called **gilts**, are first mated at 7–9 months when they weigh approximately 100kg (from about 28 weeks). If successfully mated, the sow will give birth to piglets in approximately 114 days. The average litter size is 11 piglets weaned. The piglets suckle milk from their mother and at 1–3 weeks they start to eat dry feed as well. Generally, piglets are weaned at about 4 weeks of age, when they weigh around 12kg. The sow is re-mated 7–10 days after her piglets are weaned (Fig. 30.4).

A pig enterprise is performing well if it has a 90 per cent conception rate, a 4-week **weaning** age, 10 piglets weaned per sow, and the sow pregnant again within 7 days of weaning.

After weaning, the aim is to maximise growth, which is measured in terms of live weight gain. Growth follows an S-shaped curve, as shown in Figure 30.5, and is affected by diet, sex and breed.

Meat quality

The price of pig meat is influenced by meat quality and consumer demand. The farmer/producer must make sure that the quality and composition of the meat produced matches consumer requirements.

Meat quality can be assessed for:

- **Safety and purity.** Chemical residues need to be kept at a very low level. Low rates of contamination are achieved by having very high hygiene standards at our abattoirs.
- **Fat content.** Consumers prefer meat from leaner carcasses (carcasses that have less fat). Carcass fatness is determined by carcass weight – the carcass becomes fatter as the weight increases. At a given carcass weight, variation in fatness can be due to animal factors (breed, sex) and nutritional factors. Therefore producers are able to change carcass fatness at a particular weight by their choice of breeding stock and by feeding particular rations to avoid excess fat being deposited.

Factors affecting meat quality

The main aim throughout the production and marketing process is to maximise meat quality. It can take months to produce an animal for a specific market. Poor management can easily damage or downgrade pig meat. Meat quality can be affected by the following factors.

- **Fat content.** The fat content of meat cuts affects the consumer's choice. Consumers prefer meat with less fat. Some fat can be removed by trimming.
- **Pests and diseases.** Pigs should be protected from disease with vaccinations and they should be free of lice and worms.
- **Condition.** Pigs should be the right age and weight, and have the correct fat cover for the target market. Table 30.1 indicates the market categories for pigs: porker, baconer and **backfatter**.
- **Stress.** Changes to a pig's normal routine or environment can be stressful. The extent and length of these changes, and the pig's ability to adapt to them, will determine whether meat quality is reduced. Stress can be caused by many factors, including prolonged handling and transport, fighting and extreme weather conditions before slaughter. If it is hot, pigs should be transported at night.
- **Weight loss.** Losses in live weight and carcass weight occur when pigs do not have access to food or water during handling and transport.
- **Feed.** Meat quality is affected by the quality of the feed and the quantity or amount of feed.

Table 30.1 Pig markets

Market	Dressed or carcass weight (kg)	Fat score	Fat depth (mm)
Porker	45–60	1–2	8–14
Baconer	60–75	1–2	8–14
Backfatter	90 and above	3–4	22–29

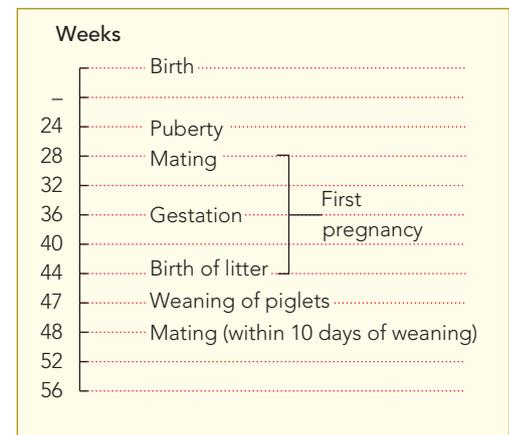


Figure 30.4 Reproductive cycle of a sow

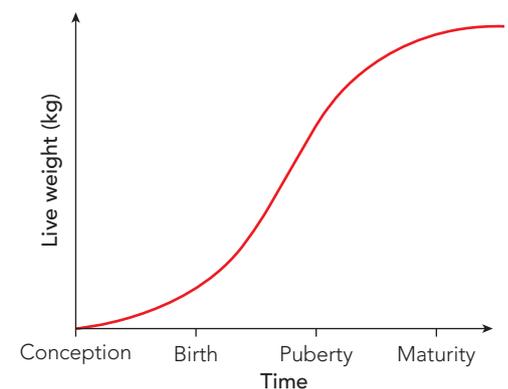


Figure 30.5 Growth curve in pigs

connect

AusMeat

For more information on consumer requirements relating to cuts of meat

- 9 What determines the price of pig meat?
- 10 How can producers change the fatness of a carcass?

- 11 How does stress affect meat quality?
- 12 What factors can cause stress in pigs?

Managing the farm

There are three main types of farming systems for pigs: intensive, outdoor and free range. Visit the [Types of farming](#) website for more information.

Pig farm operations include all the management activities that are carried out by the farmer, including feeding, mating, **farrowing**, marking of piglets, weaning, culling, disease control and selling.

connect

Types of farming

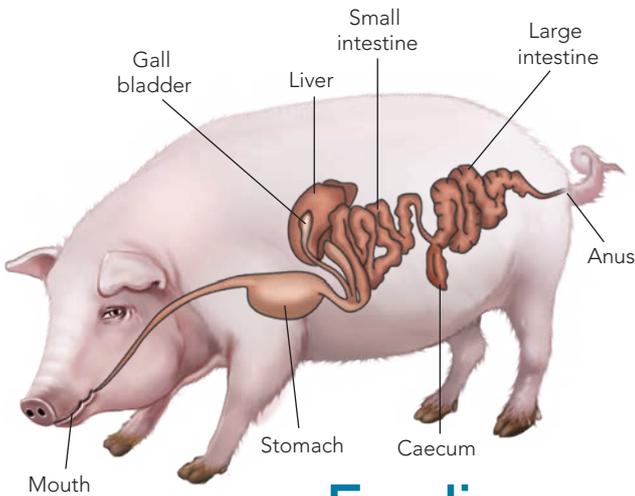


Figure 30.6 Digestive tract of a pig

- 13 What type of digestive system does a pig have?
- 14 Briefly describe where digestion occurs in a pig.
- 15 List four grains fed to pigs.
- 16 Why do pigs need protein in their diet?
- 17 What is the general rule about feeding protein to pigs?
- 18 What do premixes contain?

connect

Ultrasound

Using ultrasound to check pig pregnancy

Digestion

The pig is a monogastric animal as discussed in Chapter 25. Digestion in the pig takes place in the stomach and small intestine, but starts immediately once the food enters the mouth because of an enzyme in the saliva. Because bacteria only play a small role in the pig's digestion, its food must always consist largely of starch, sugar, fat and protein that can be made soluble by the enzymes secreted in the stomach and intestines. Pigs also need to be fed all the vitamins in their feed because they are not able to make any themselves.

Feeding

Grains such as wheat, barley, sorghum and maize may form up to 80 per cent of a pig feed mixture. They are the main energy source for pigs. Protein, which is essential for growth, is supplied by protein-rich feeds such as meat meal, soybean meal, fishmeal and lupins. These feeds form about 20 per cent of a ration. The general rule about protein in pig diets is that the younger the pig, the higher the protein content required in their feed.

Pig feed mixtures can be prepared on the farm by the producer or the farmer can elect to purchase ready-mixed feeds from specialised stockfeed manufacturers. Premixed feeds may contain certain amino acids as well as the required vitamins and minerals. Commercially prepared feeds are often conveyed direct from the manufacturer to the producer's silos. Virtually all feed is fed in a dry form, as mash or pellets. Pigs may be fed once or twice a day, although in some larger piggeries feeding may be automated.

Feed accounts for approximately 70 per cent of the cost of pig meat production. It takes approximately 3 kg of feed to produce 1 kg of pig meat.

Breeding

A **boar** may be used for breeding from about 9 months of age. Gilts may also be mated at about 9 months. Mating gilts at a younger age would result in smaller litters.

A female will come on heat and will mate with the boar every 21 days until she is in pig. The signs of a **sow** or gilt on heat include a reddened vulva, and behaviour such as mounting other sows, calling to the boar, pacing a fence, and standing when the farmer applies pressure to the back and shoulder.

The heat period lasts 2–3 days and mating should be carried out on the second or third day. If successfully mated the sow will farrow or give birth to piglets in about 3 months, 3 weeks and 3 days (approximately 114 days) (see Fig. 30.4). The piglets are weaned at 3–8 weeks, depending on the management system used. The sow is

then mated again. It is possible to get two litters per year with careful management, while three litters of 11–13 piglets can be achieved by the top performers in the industry.

In commercial piggeries crossbreeding is used. The resulting hybrid pigs show more vigour – increased litter size, increased milk production and increased growth in the piglets. These pigs can also be used as **porkers** or **baconers**. Many modern commercial herds are based on stock drawn from specialist breeding companies that develop genetically superior lines of boars and sows.

Performance testing is used to identify and select the best possible breeding stock in terms of rapid growth, feed conversion and meat quality. Ultrasonic equipment is used to measure the carcass quality of the live animal without slaughtering the pig. In recent years, farmers have made greater use of artificial insemination, using semen from boars that have been performance tested. Pregnancy testing in sows is used to confirm pregnancy in a mated sow. Ultrasound is the most common and accurate system in use in commercial piggeries. Portable machines have made this task much easier.

Farrowing

Farrowing is the production of a litter of piglets. With intensive housing of the sow and her litter, the general temperature within the farrowing shed should be 15–20°C with adequate ventilation. One way to help prevent the sow from lying on top of her piglets is by using a farrowing crate. The crate has a gap below the bottom rail to allow the piglets to move from suckling their mother into the surrounding creep area. There is a general move away from the use of both farrowing crates and sow stalls (used to hold the sow after mating for up to 6 weeks). In 2010 the pig industry decided to phase out the use of sow stalls and economic alternatives to farrowing crates are still being assessed.

A heat source such as an infrared lamp is placed in the creep area to provide a temperature of 30°C when the piglets are born, decreasing to 24°C when they are 3 weeks old. Piglets are given feed in the creep area from about 7 days old.

Management practices carried out on the piglets from birth to weaning, which occurs at approximately 4 weeks, include teeth clipping, trimming the umbilical cords, iron injections and in some cases castration (for males). The trend is not to castrate male pigs.



Shutterstock/rnem

Figure 30.7 A farrowing crate

-
- 19** List three signs of a sow on heat.
 - 20** Why is crossbreeding used in commercial piggeries?
 - 21** Name three factors looked for in performance testing of a boar.

connect

Farrowing

Further information on alternatives to farrowing crates

-
- 22** What is the purpose of a farrowing crate?
 - 23** Name the management practices that are carried out on the piglets between birth and weaning.

Weaning

Piglets can be weaned as early as a few days old or up to 8 weeks of age. Early-weaned pigs require a high level of management and housing compared to pigs that are weaned when they are older.

At 1–3 weeks of age, piglets can be weaned into tiered cages with mesh floors and housed in a separate shed or area. Cages are suitable for 10–12 piglets. A temperature of 26°C is required.

Growing and finishing

A **grower** is the term used for any pig between weaning and finishing. A **finisher** is a pig in the last 4–6 weeks before slaughter. Pigs slaughtered for pork are younger and a lighter weight than pigs slaughtered for bacon.

The housing requirements for growers and finishers vary according to the size of the animals. The temperature should be 15–20°C and pigs of widely varying weights should not be run together to prevent bullying. Feeding occurs once or twice per day. Young pigs are fed ad lib (i.e. they have access to feed

at all times) and older pigs are on restricted feeding. Vaccinations for leptospirosis should be given at 6 weeks and erysipelas at 10 weeks of age.

Selection and culling

Gilts are selected for breeding on the basis of their growth rate and back-fat depth. This is done when the gilts weigh about 80–90 kg. Some gilts are culled and sold at this time if they are of poor type or performance, or have major defects.

Breeding females are also culled if they have low productivity. The productivity of the breeding female will depend on the time interval from being weaned to mating, the number of piglets weaned and the number of farrowings per year. Sows are usually culled after their fifth litter due to decreased productivity.

Controlling pests and diseases

The following pests and diseases are common in pigs.

- *Salmonellosis (paratyphoid)*. This is an infectious disease caused by a bacterium that causes reddening of the pig's skin and eventual death. Affected pigs are treated with broad-spectrum antibiotics. Care must be taken not to overuse antibiotic treatments because of the development of drug resistance by disease-causing organisms.
- *Erysipelas*. This is an infectious disease caused by a bacterium. It can cause arthritis and death. Affected pigs can be treated with penicillin.
- *Piglet anaemia*. This is caused by iron deficiency occurring in piglets confined to pens with concrete floors where the only diet is sow's milk. Piglets develop pale skin, respiratory problems and, in many cases, diarrhoea. The disease can be overcome by an iron injection within the first 24 hours of life. Piglets that have access to soil do not need an iron injection.
- *Leptospirosis*. One of the more common diseases that can affect pigs in Australia, leptospirosis is caused by a bacterium. The infected pregnant sow may abort, deliver stillborn piglets, or deliver very weak piglets that die soon after birth. The source of infection is usually a chronically infected animal that contaminates



Figure 30.8 Weaned piglets



Figure 30.9 Grower pigs

24 Which factors affect the age at which piglets are weaned?

25 What temperature range do pigs require between the growing and finishing stages?

26 How often are pigs fed?

27 On what basis are gilts selected for breeding?

28 Why would a breeding female be culled?

drinking water or feed by infected urine. Pigs with leptospirosis can be treated with antibiotics. Control of the disease involves the detection and elimination of carrier pigs and the vaccination of susceptible animals.

- *APP pleuropneumonia*. An economically significant disease of the respiratory system, APP pleuropneumonia affects pigs of all ages. It is a bacterial disease spread through the air. Symptoms include coughing followed by death. Post-mortems indicate damage to the lungs. The disease is more frequent where pigs are overstocked and where there is poor management of temperature and ventilation. It can be controlled by vaccination, purchase of pigs from a known healthy source and good temperature and ventilation control.
- *Lice*. The pig louse is easy to see and is 2–6 mm in length. Lice can cause weight loss in boars and sows and poor growth rate in **weaners**. To control lice, pigs should be treated with an insecticide.

Animal welfare

Dust, humidity and air quality are common issues that require monitoring and good design to prevent health and safety issues from arising. Husbandry practices often involve the use of vaccinations, chemicals and medicated foods. The labels for these products must always be read. Manufacturer instructions and safety directions in particular must be followed. Farmers must observe the recommended withholding period for chemicals before sending pigs to the abattoir.

An awareness of behavioural traits is also important. Boars are very aggressive at times and need to be handled with care. Sows, if not carefully restrained when giving birth, may kill many of the piglets as they move around in a confined space.

Working safely

When working in an intensive piggery, care needs to be taken to prevent health and safety issues from arising.

Safe lifting practices must be adopted because there is a considerable amount of lifting involved with pigs.

Pigs may carry diseases that can be transferred to humans. Farm workers need to be familiar with the symptoms of these diseases and seek early medical attention. Leptospirosis can be transferred by urine, blood or saliva and can be passed to humans via cuts or other wounds. High levels of personal hygiene and the use of protective clothing are essential.

Keeping records

Record keeping provides a continuous and accurate check on pig performance. Farm records tell the farmer what is happening in the piggery. An analysis of pig performance will help identify any production problems. Important records in a pig enterprise are herd records (a production plan for the herd), production records and financial records. These records are increasingly computerised.

Herd records

Farmers can prepare a production plan based on the number of pigs to be sold each week. This plan will include the number of sows required to farrow each week and the number of sows required to be mated each week (allowing for return matings). Daily, weekly and monthly routines can then be noted; for example, daily health check of piglets, weaning of piglets from sows, placing new sows into farrowing crates and sorting of pigs for market.

-
- 29 What type of organism causes erysipelas?
 - 30 List the symptoms of piglet anaemia.
 - 31 How is leptospirosis treated and controlled?

connect

Current welfare practices

Concisely summarise current approved welfare practices.

-
- 32 Name two pieces of information used to prepare a production plan.

connect

Examples of records

- 33 Name four events found in a daily/monthly production record.

Production records

Production records include sow records, mating or breeding records and daily/monthly records of events such as sows mated, sows farrowed, total piglets born, piglets weaned and pigs sold.

Financial records

The farmer needs to know what is happening to the pig enterprise from a business or financial point of view. Is the enterprise making a profit?

Calculating the gross margin of an activity on the farm provides an indication of its profitability. The gross margin includes only variable costs (i.e. the costs that change during production) and does not include fixed or overhead costs.

Gross margins are worked out per sow. The formula for a gross margin is:

$$\text{Gross margin} = \text{total income} - \text{variable costs.}$$

Marketing

There are three methods of selling pigs.

- 34 List the methods a farmer may use to sell pigs.
- 35 Why is consignment selling so popular?

- 1 *Saleyard auctions.* This was once the main method of selling pigs. Producers are required to transport pigs to the saleyards, where they are divided into uniform lots and auctioned. In most cases, a selling agent is involved and represents the producer at the auction. Buyers inspect the pigs and bid up to what they think the animals are worth. Price is usually on a cents-per-kilogram (c/kg) live weight or dollar-per-head basis.
- 2 *Consignment selling (direct selling).* Consignment selling now covers 85 per cent of all pig marketing. Pigs go direct from the farm gate to the abattoir with minimal losses from handling. After slaughter the carcasses are classified according to weight and back-fat depth. Payment, usually on a c/kg carcass weight basis, is directly related to these measurements. A feature of this selling method is feedback to producers.

connect

AuctionsPlus

- 3 *Online auctions.* Classification auctions allow pigs to be sold while still on a farm. Producers are required to measure or estimate carcass details before the sale. The description and lot details are then put in a sale catalogue. Once a lot is sold, through for example the [AuctionsPlus](#) website, transport is organised. Successful sellers are charged a commission fee and there are price penalties for inaccurate descriptions. The main advantages of this system are that there is open competition, costs are minimised, and payment is based on objective measurement. Some producers are reluctant to use this system because of the cost of commissions and the possibility of price reductions if inaccurate descriptions are given.



Shutterstock/Eric Isselele

Figure 30.10 Husbandry processes are needed before these pigs can be sent to market.

Chapter review

Things to do

- 1 Visit a piggery and complete the following tasks.
 - a Draw a plan of the layout and label the main features.
 - b Describe the environmental conditions, such as ventilation and temperature control.
 - c Describe the methods of effluent disposal.
 - d Observe management practices such as trimming umbilical cords, giving iron injections, teeth clipping and castration.
- 2
 - a Weigh piglets or pigs each week and record their weight.
 - b Graph weight gain against time from the collected data.
- 3
 - a Examine a pellet of pig feed and attempt to identify the main components.
 - b Look at pig feed labels (starter, weaner and grower feed) and compare protein percentages.
- 4
 - a Observe a dissection of a pig's digestive system.
 - b Label a diagram showing the main parts of the digestive system.
- 5 Visit your local pig saleyards, or look at the information in *The Land* newspaper's Pig Marketing Report. List three pieces of information that determine the price per kilogram paid for a pig.
- 6
 - a Visit a butcher shop or supermarket and label a diagram of a pig carcass with the price (in \$/kg) for different pork cuts.
 - b Suggest reasons for the variations in price for the different pork cuts.

Things to find out

- 1 Describe some breeds of pigs that have been used in crossbreeding to produce pigs with characteristics suitable for meat production (porkers and baconers).
- 2 What is the ideal body conformation for a breeding sow?
- 3 Identify products from porkers and baconers. List any value-added products.
- 4 Is there any vertical integration in the pig industry?
- 5 How is carcass quality determined?
- 6
 - a Investigate the change (if any) in pig meat consumption over the past 40 years.
 - b How is pig meat being marketed or advertised to try to increase consumption?

Extension activities

- 1 Describe computer software that is used to assist with pig management.
- 2 Design an experiment investigating the effect of a single variable (e.g. feed supplement) on the growth of piglets.

connect

Types of farming

- 3 Genetic improvement in pigs is based on a number of factors. List these factors and assess their importance in the breeding program for pigs.
- 4 Examine the graphs of sale prices in *The Land* (or other newspapers) and describe the trends. Try to account for price fluctuations.
- 5 Visit the [Types of farming](#) website and compare and contrast the following types of pig farming systems: indoor intensive housing, outdoor bred and free range.
- 6 Develop an environmental monitoring survey for an intensive piggery. List reasons for monitoring the variables you identify.

✓ Test yourself

- 1 Define 'hybrid vigour'. How does this concept apply to the breeding of pigs?
- 2 In table form outline the functions of a pig's major digestive organs.
- 3 In your notebook, write each of these words with the correct definition from the list below.

gilt, baconer, sow, weaner, boar, farrowing

- a pig ready for market, usually 50–80 kg dressed weight
 - a male pig over 6 months of age
 - an unmated sow
 - a female pig used for breeding
 - a young pig newly weaned
 - the production of a litter of one or more piglets
- 4 Outline a calendar of operations for one production cycle of a sow. Indicate the main management practices that are carried out.

CHAPTER 31

GOATS

Words to know

buck a male goat

cashmere any type of goat with the ability to grow a downy undercoat; technically there is no cashmere goat breed

cashmere fibre very fine, soft and warm fibre from the downy undercoat of a goat; used in light to heavy fabrics

chevon goat meat

doe a female goat

feral goat a wild goat

kid a young goat aged up to approximately 1 year

mohair a long and lustrous fibre produced by Angora goats

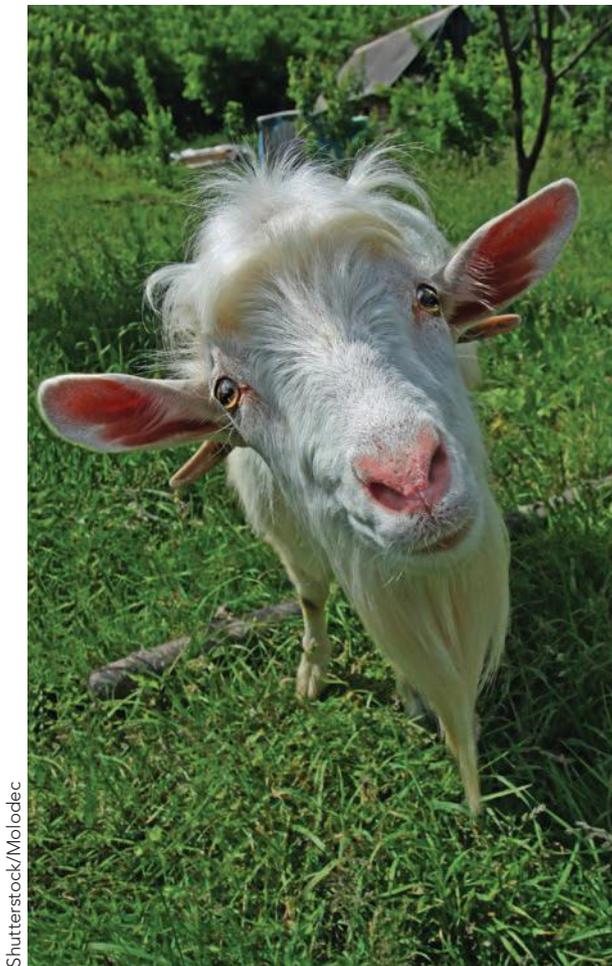
wether a male animal castrated while still immature

Introduction

The goat industry produces five types of products, as follows.

- 1 **Mohair.** This is the long and lustrous fibre produced by Angora goats and used for making suits, drapes, blankets and upholstery. **Mohair** grows at the rate of 30 cm per year and shearing is necessary twice yearly.
- 2 **Cashmere.** Technically there is no such thing as a **cashmere** goat. It is not a breed, but a type of downy undercoat that can be grown on any breed of goat. **Cashmere fibres** are very fine, soft and warm, and are used in light to heavy fabrics.
- 3 **Milk.** The fat and protein in goat's milk is more easily digestible than cow's milk. Goat's milk is therefore suitable for infants, invalids and people with an allergy to cow's milk. An average goat produces 2–3 litres (L) per day during a 7–10 month lactation.
- 4 **Meat.** Goat meat is called **chevon**. It is less fatty and less tender than sheep meat. In Australia there are no breeds developed specifically for meat production, but thousands of **feral goats** are used for this purpose. Consumers are still slow to accept goats as an alternative meat source, though in major cities there is increasing demand from the restaurant trade and from communities of Asian, Mediterranean, Middle eastern and African origin. There is often an irregular supply of goats for slaughter.
- 5 **Skins.** A market for **kid** skins exists in international fashion houses.

Figure 31.2 shows the parts of a doe.



Shutterstock/Molodec

Figure 31.1 Goats are curious animals.

- 1 For what is mohair used?
- 2 How much milk does a dairy goat produce per day?
- 3 For what are feral goats used?

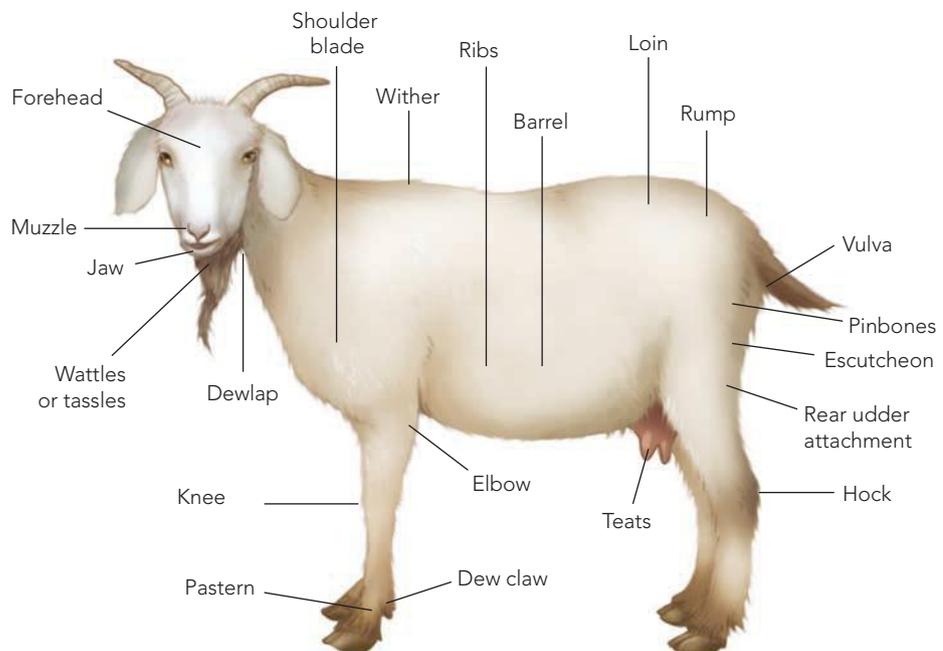


Figure 31.2 Parts of a doe

Breeds of goat

There are other breeds, as well as feral animals. For further information on breeds of goat, visit the [Breeds of livestock](#) and [Goats](#) websites.

Anglo-Nubian

The Anglo-Nubian is a large-framed, well-fleshed breed, producing milk with high fat and protein content. It has a 'Roman' nose, long drooping ears and can be any colour or combination of colours. The Anglo-Nubian is probably the most vocal of all breeds and can be recognised by its loud bleat.



Shutterstock/Eric Isselee

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Breeds of livestock

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Goats

Figure 31.3 Some of the goat breeds recognised in Australia.

Angora

The Angora originated in Turkey and is a smaller breed of goat. It is known for its coat of long, curling ringlets of lustrous white mohair.



Shutterstock/EcoPrint

Boer

The Boer originated in South Africa and is a goat grown for its meat. Rapid weight gains, an extended breeding season and a 200 per cent kidding rate are characteristics of the breed that have ensured its popularity.



Alamy/© Krys Bailey

- 4 Which goat breeds originated in Switzerland?
- 5 Which breed has a 'Roman' nose?
- 6 Explain how the Australian cashmere goat has been developed.

Corbis/© Ocean



British Alpine

The British Alpine is a dairy breed that was developed by English breeders. It is suited to milk production when feed conditions may be less favourable. It is black in colour, with white markings on its face and legs.

Cashmere types

The Australian cashmere goat is not a breed; rather, it is any type of goat that carries cashmere. It can originate from feral herds, or be the result of selective breeding from many strains of goat: feral, dairy and Angora cross. A cashmere goat produces small quantities of very soft, fine hair (white or coloured), grown under a coarse hairy outer coat.



Alamy/© Richard Tadmam

Shutterstock/Angela Luchianiu



Saanen

The Saanen originated in Switzerland. It is the most common dairy breed, and possibly the most prolific milk producer under good feeding conditions. It has pricked ears and is generally pure white, but can also be cream or a pale biscuit colour.

Toggenburg

The Toggenburg, a hardy dairy breed, also originated in Switzerland. It is a prolific producer, but its milk is low in butterfat. It is fawn to dark brown in colour, with white facial lines and white legs from the knees and hocks downwards.



Shutterstock/Eric Isselee

Production cycle

Angora goats must be shorn twice yearly because mohair grows approximately 2.5 cm every month. Because a goat's fleece is less dense and carries less grease than wool, the shearing handpiece is geared down to about half speed to prevent overheating of combs and cutters.

Dairy goats are milked twice daily (Fig. 31.4) and usually with an interval of 12 hours between morning and afternoon milking. The udder is washed with running water before milking and a teat dip is applied after milking to seal the end of the teats and help protect them from cracking and from mastitis infection.

If surplus male kids are to be raised for eating purposes, they should be castrated. The two most common methods are elastrator rings and surgical removal using a sharp knife (Fig. 31.5). A male goat castrated while still immature is referred to as a **wether**.



Shutterstock/Eugene Chernetsov

Figure 31.4 Goat milking



Marking ring applicator



Marking knife

Figure 31.5 Marking equipment

Managing the farm

Fencing must be of a high standard, as goats will go through or crawl under fences rather than go over them. The cheapest effective fencing for goats is an electrified plain wire fence. Netting fences are expensive and must be heavy gauge to prevent animals breaking through.

Goats should be handled quietly during mustering and yarding. Excessive noise and activity may cause them to become over-excited and to go through fences.

Goats, and particularly kids, require sheds in hot weather (Fig. 31.6). Goats are thinner-skinned than sheep and have less body fat, so they are also more likely to suffer stress in cold, wet and windy weather. Simple shelter sheds or windbreaks should be provided.

Every stud kid should be tattooed after birth to give it lifelong identification.

Goats may be either polled or horned. Kids with horn growth should be disbudded at 6–14 days. In disbudding the horn buds are destroyed either by using a red-hot disbudding iron, or by applying caustic paste. The hot iron is the preferred method as it is bloodless and quick.

Goats' feet require regular trimming to remove any excess growth.

Goats need to be tagged with a National Livestock Identification Scheme (NLIS) breeder tag before they are sent to a sale yard, abattoir or another property.

-
- 7 How often are goats shorn?
 - 8 What are the most common methods of castrating male goats?
-
- 9 What is the cheapest effective fencing for goats?
 - 10 Why should goats be handled quietly during mustering and yarding?
 - 11 How are goats disbudded?



Shutterstock/val lawless

Figure 31.6
Goat housing

Feeding

The goat is a naturally browsing animal (Fig. 31.7); that is, it prefers to eat bushes and shrubs rather than pasture. A goat can survive on sparse, harsh vegetation that will not support sheep or cattle. Goats can also be run successfully in the absence of trees and shrubs, provided that hay or similar roughage is available when pasture is short. A goat may need supplementary feeding when paddock feed is insufficient, such as during a drought or in the late stages of pregnancy. Vitamin and mineral supplements may also be provided.

- 12** Goats are referred to as 'browsing' animals. What does this mean?
- 13** Why would goats need supplementary feeding?



Shutterstock/FomaA

Figure 31.7 Browsing

Breeding

Goats have an annual breeding season extending from January to August. During this time the **does** come into season about every 21 days unless they are pregnant. Most farmers tend to join their does in March–April, and they kid (give birth) in August–September.

Angora does and **bucks** are run together, with a ratio of 2–3 bucks per 100 does. The mating period is usually 6–9 weeks. Bucks are not run with the milking dairy does, because the odour of the buck may contaminate the milk.

Does are usually first mated at 15–18 months; they often have a single kid at their first kidding, but in later years usually have twins or triplets. If successfully mated, the doe will be in kid for 5 months.

With both Angora and cashmere goats, most farmers buy one or two purebred bucks from established studs and buy feral does from elsewhere. They then upgrade the flock by using the stud buck over the doe progeny until the offspring can be registered as pure after passing a breed society inspection. Strict culling of animals is carried out during this upgrading program.

Controlling pests and disease

Diseases are often spread with animal and people movements. Managing the common farm diseases involves understanding the risks associated with stock and vehicle movement and carefully managing what comes onto your property. The goat industry, governments and agents have agreed on a National Goat Health Statement (GHS) that identifies the health status of the goat herd on a particular property. It is useful to producers buying goats for their farm from that property. The National GHS declaration has information about the lice, footrot, Johnne's disease and resistant worms of the herd on that property as well as drenching and vaccination history.

Goats suffer from the following diseases and pests.

Plant poisoning

Several plant species are poisonous to goats, though the toxicity can depend on the part of the plant eaten or the stage of growth of the plant. Some common examples of toxic plants are oleander, deadly nightshade, cape weed, castor oil plant and fireweed.

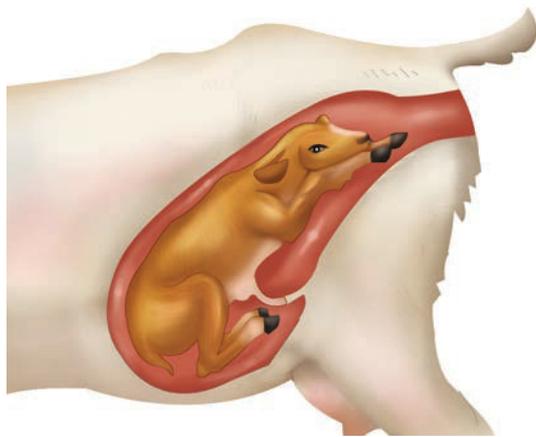


Figure 31.8 In the normal birthing position the kid's front legs and head should emerge first.

- 14** How old is a doe when she is first mated?
- 15** How long is the gestation period for a doe?

connect

National Goat Health Statement

Pregnancy toxaemia

This condition occurs during the last month of pregnancy if the doe is unable to meet her own feed requirements as well as that of the developing foetus. An affected goat will have a reduced appetite and become lazy. She will also develop swollen legs and have difficulty walking. Treatment involves drenching with glycerine twice daily until the doe starts eating again.

Pulpy kidney

Goats with pulpy kidney (a bacterial disease also called enterotoxaemia) suffer abdominal pain, scour and appear very stressed. Without treatment they may die within a few hours. Pulpy kidney can be prevented by annual vaccinations. Kids should be vaccinated at 1 month and a booster given 6 weeks later.

Tetanus

Tetanus may appear within days or possibly weeks after severe hoof trimming, kidding, castrating or the wounding of a goat. Animals walk stiffly, go into spasm if startled, and go down on their sides with legs stiffened out. Prevention is by vaccination. Kids may be vaccinated at 1 month and a booster given 4 weeks later. Another booster at 1 year will provide protection for many years. Both tetanus and pulpy kidney vaccines could be given simultaneously in a 5-in-1 vaccine.

Worm infestation

Moderate to heavy worm infestations will lower the condition and production of goats. Harsh coat and frequent scouring are signs of worm infestation. Worms are controlled by drenching and pasture rotation.

Animal welfare

Goats are kept in various farm conditions ranging from extensive grazing systems to intensive systems with animals kept in sheds.

The provision of adequate food and water to maintain good health is essential. Food must be supplied in sufficient amounts to maintain the growth, production and reproductive phases of a goat's life. Water must be clean and available to meet the needs of goats; for example, a lactating goat requires at least 10 L of water per day in average temperature conditions.

Goats must be able to comfortably move around, stand up and sit down. The design of sheds, pens, loading ramps and dips must provide for both ease of movement and protection from injury.

Predators may be controlled by use of electric fences and routine but constant supervision of the animals is required.

Frequent supervision and competent management skills also lessen the likelihood of stress-induced problems arising from changes in the weather, such as cold snaps after shearing.

Prompt treatment of diseases and the maintenance of hygienic operations are essential management practices in promoting goat welfare. Welfare guidelines are available for the following management practices: castration, dehorning, milking, shearing, animal identification and animal movement.

-
- 16** Describe the symptoms of pregnancy toxaemia.
 - 17** How is pulpy kidney prevented in goats?
 - 18** When may tetanus occur in goats?
 - 19** How are worms controlled in goats?

-
- 20** List the basic welfare requirements for raising goats.

Keeping records

Farm records tell the farmer what is occurring on the farm, helping to run the farm efficiently. Most of this information is computerised.

Important records to keep include:

- feeding
- chemical use records
- breeding
- production records
- paddock records
- animal sales and purchase
- health records
- income and expenditure.

Marketing

connect

WA tackles gourmet cheese market

Australia is a small producer of goat meat, but leads the world in the export of goat meat and live goats. Boer goats and rangeland (feral) goats are the most used for meat. Goat meat is the most consumed meat in the world. China, India and Pakistan are the largest producers and consumers of goat meat.

Mohair production is worth approximately \$1.9 million to the Australian economy. Goat milk can be made into cheese and marketed locally and internationally to a niche market.

NLIS sheep and goats is Australia's system for identifying and tracing sheep, lambs and farmed goats. It is a mob-based system that links animals with the properties on which they have run. The mob-based movement system is based on:

- visual ear tags printed with the property identification code (PIC) of the property of birth (breeder tag), or the PIC of the property of consignment (pink post-breeder tag)
- movement documents; either a national vendor declaration (NVD) or a transported stock statement (TSS)
- all sheep and goat movements being recorded on the NLIS database.

The NLIS is a way to maintain access to key export markets and helps to quickly contain a major food safety or disease incident. It is implemented by industry in partnership with governments across Australia.

The products of goats and their marketing arrangements include the following.

- *Mohair* is mainly sold through brokers in a pooling system. Mohair can be classed in the shed or sent unclassified as individual fleeces to a broker.
- *Cashmere* is classed and sold through a pooling system.
- *Goat's milk* is used by people who are allergic to cow's milk and by people who are from countries that traditionally consume goat milk products. Goat's milk can be purchased from health food shops, supermarkets, farmer's markets and online.
- *Goat meat* is in strong demand among people from Mediterranean and Middle Eastern communities for whom goat meat is a traditional part of the diet.
- *Goat skins* are in demand in other countries for goat leather products such as belts, wallets, handbags and hats.

connect

National Livestock Identification System – NLIS sheep and goats

21 Describe the common marketing arrangements for goat products.

Chapter review

Things to do

- 1 If possible, keep a goat at school. Keep records of the amounts of food given, and the milk yield.
- 2 Sketch the tattoo that appears in the ear of a stud goat.
- 3 Draw plans of a raised milking platform for a single goat (Fig. 31.9).
- 4 Look at a mohair fleece and measure the length of mohair at different places. Does the length vary over the fleece?
- 5 Place equal quantities of goat milk and cow milk into similar glass containers and allow them to stand. Compare the depth of cream on each.



Cengage Learning

Figure 31.9 Goat milking platform

Things to find out

- 1 How do you know when a goat is ready for mating?
- 2 What is kemp?
- 3 What are the benefits of a National GHS declaration scheme to farmers?
- 4 Find out the composition of a suitable milk substitute for feeding an orphan kid.
- 5 Find out what diseases are prevented by vaccination in goats. What are the major symptoms of each of these diseases?
- 6 What are the advantages and disadvantages of using permanent electric fencing for goats?
- 7 Why do goats need to be tagged with an NLIS breeder tag?

connect

National Livestock Identification System – NLIS sheep and goats

Extension activities

- 1 Observe a mob of goats in the paddock and describe the plants that the goats eat first (or most of) and indicate whether they ignore any plant types.
- 2 Describe the physical features of a Boer goat. Why has this breed of goat become very popular? (For further information, visit the [Boer](#) website.)
- 3 Define 'feral goat'. How did they become feral and what economic benefits may have arisen from this group of goats?
- 4 Design a poster that will convince people to use more goat products such as mohair, cashmere, goat milk and goat meat. Your poster must be less than 20 per cent writing, yet be informative and interesting.
- 5 For the types of farm records listed in the text, outline the information that would be required for each of these records.

connect

Boer

Test yourself

- 1 Describe the production cycle for a goat raising enterprise.
- 2 List the products that can be produced from goat enterprises and assess the market for each.
- 3 Define the following terms.
a Buck b Chevon c Doe d Mohair e Wether
- 4 Discuss the factors that limit the productivity of a goat enterprise.

CHAPTER 32

POULTRY

Words to know

broiler a young chicken of either sex, raised for meat; usually up to 8 weeks old

brooder a device designed to give young chickens the best environment for growth

chicken a young bird, from hatching to approximately 4 months; also used as a general term referring to poultry

cockerel a male bird younger than 12 months

culling removing an animal because of age, disease, low production or physical deformity or abnormality

hen a female bird older than 12 months and after the first adult moult

incubator a heated structure used for hatching eggs

pullet a female bird younger than 12 months

rooster a male bird older than 12 months

Introduction

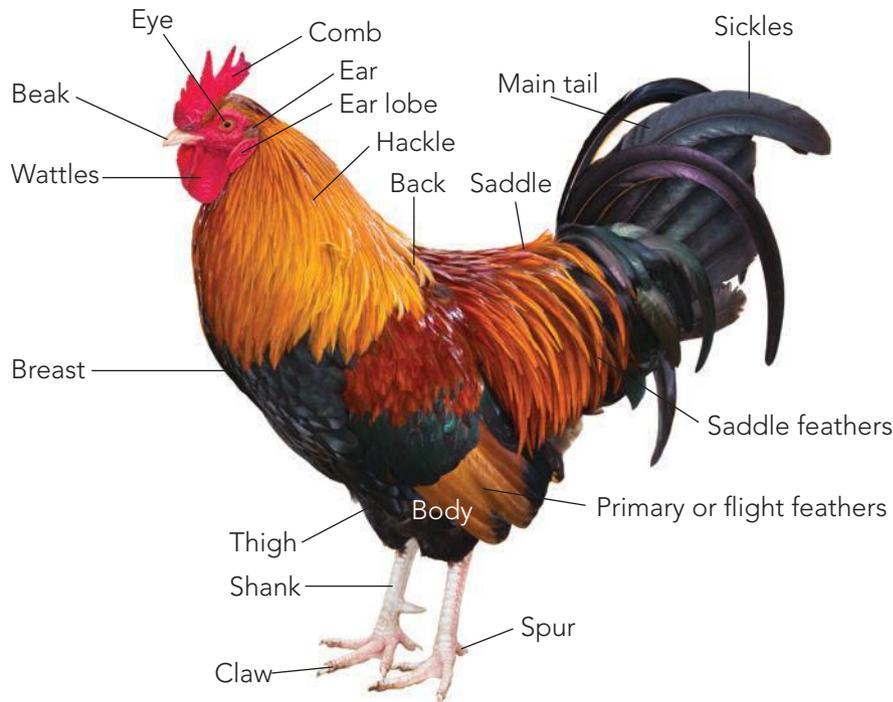
The term 'poultry' refers to domestic fowls, which includes **chickens** and other birds such as turkeys, guinea fowls, quails, ducks and geese.

In this chapter, however, we will consider the production of chickens.

There are two types of birds in chicken production:

- layers, which produce eggs
- **broilers**, which are grown to produce a meat carcase.

Figure 32.1 shows the anatomy of a **rooster**.



Shutterstock/Olgysa

Figure 32.1 Parts of a rooster

As the chicken production industry has developed it has become specialised, and now includes egg producers, broiler growers, breeders, hatcheries, poultry-feed companies and marketing companies. Poultry farms are located close to large cities, which are areas of high egg and meat consumption. They are intensive, highly mechanised farms occupying small areas. Birds are kept at high stocking rates. Extensive poultry production is becoming more popular (Fig. 32.2).



Shutterstock/Pack-Shot

Figure 32.2 Extensive poultry farming

Breeds of chicken

The four main breeds of chicken used in Australian egg production – the Lohmann Brown, ISA Brown, Hisex Brown and Hy-line – account for 98 per cent of all egg layers in Australia and are all brown-egg layers. All are imported breeds. Other chicken breeds are shown in Figure 32.3; some are dual purpose.

- 3 Which breed(s) lay(s) brown eggs?
- 4 Which breed(s) are dual purpose?

Figure 32.3 Other breeds of chicken

Shutterstock/Andrea J Smith



Australorp

The Australorp is a heavy pure black bird. It is quiet and lays well. Eggs are large and creamy-to-brown in colour. Broodiness can be expected in some strains. They are often crossed with White Leghorns to produce very successful commercial egg-laying flocks.



iStockphoto/© Rinelle

Rhode Island Red

The Rhode Island Red is a medium sized reddish-black bird with yellow legs. It lays brown eggs. The birds are quiet and lay less than other breeds. This breed has played a major part in the development of meat strains. It is a dual-purpose breed, used for both egg laying and meat production.

Shutterstock/Lena Pan



Light Sussex

The Light Sussex's tail is black-tipped and the neck covered with black lacing; the rest of the feathers are white. The flesh is also white, which makes it popular as a table or meat bird. It has played a major part in the development of meat strains.



Shutterstock/clarence s lewis

White Leghorn

The White Leghorn is a small-bodied, all white and rather flighty bird. It is a good egg-producing breed, and produces white eggs. It is not likely to go broody.

Production cycle

Eggs

Hens lay eggs in clutches. A hen may have a clutch length of six. This means she will lay an egg on each of 6 successive days and then miss a day. After this break she will start laying her next clutch of eggs. Hens vary greatly in their clutch laying.

Meat

The majority of the eggs used to produce broilers come from two integrated companies: Inghams and Steggles. Both companies maintain genetically selected lines for breeding. Fertile eggs are collected from breeder farms and placed in an **incubator** in hatchery farms for 21 days. Once hatched the chickens are graded, vaccinated and sexed then sold or, in an integrated industry, on-sold to grower farms. Farmers are contracted to produce broilers to specific quality standards within a period of 40–50 days with a negotiated mortality rate, often using feed and medicines supplied by specific companies. Once mature the birds go to processing plants.

Managing farm conditions

Well-planned farms have the sheds arranged so that feeding, cleaning and egg collection can occur in the least amount of time. On commercial farms, feeders and waterers are automatic (Fig. 32.4).

In cold weather a metal guard should be used around the **brooder** to keep young chicks from straying, and to prevent draughts. The guard should be moved gradually outwards and removed completely at the end of 1 week. Approximately 5 cm of suitable litter (e.g. wood shavings) should be used. Caked and damp litter should be replaced if necessary and henhouse hygiene maintained (Fig. 32.5). If the chickens are silent they are comfortable; a high-pitched chirping sound, on the other hand, usually means they are cold.

Laying birds

Layers can be housed on deep litter or in laying cages. Artificial lighting is used to increase winter egg production. The lighting simulates longer days, which encourage the birds to continue producing eggs by delaying moulting during the autumn and winter period.

Meat birds

These are usually housed on deep litter. Lighting is often reduced so that chickens only move to obtain food and water.

Culling

Any inferior or unprofitable bird should be **culled** or removed from the flock. This may be necessary because of poor laying, poor weight gain or the age of the bird.

5 What does 'a clutch length of four' mean?

6 What is a 'broiler'?



Figure 32.4 Automatic waterer

connect

DPI poultry

Information about the management of poultry

-
- 7** What is the purpose of a metal guard (or surround) around a brooder?
 - 8** What is usually indicated when chickens chirp in a continuous, high-pitched sound?
 - 9** Why is artificial lighting used in layer sheds?
 - 10** Why would a poultry farmer buy only day-old chickens, and not older birds?

Deworming

Birds may become infested with several types of worm, which may retard the growth of young birds. Routine deworming, by additives in the feed or water, is effective.

Vaccination

Vaccination is necessary to protect the birds against a number of major diseases such as Marek's disease.

Hygiene

The following rules will help to minimise diseases in a flock.

- 1 Keep visitors to sheds to a minimum.
- 2 Clean out sheds between each batch of birds.
- 3 Keep internal and external bird parasites to a minimum.
- 4 When purchasing, buy only day-old chickens from well-known hatcheries. Older birds may bring in infections.



Shutterstock/B747

Figure 32.5 Henhouse hygiene

Managing production systems

Several systems are used in the production of eggs.

connect

Victorian DPI: eggs

Victorian Department of Primary Industry provides more information on the egg industry.

Barn layer

This is a deep litter system. This form of farming accounts for 9 per cent of Australia's supermarket shell egg sales. Conditions are as follows.

- Hens are kept in a shed that has a deep litter floor.
- Hens are provided with nest boxes to lay eggs.
- A code of practice allows at least 800 cm² per hen (commonly 1428 cm² per hen).
- Typically, eggs are collected by hand.

In this system birds are able to move around freely, engaging in typical behaviours. They are protected from predators. Food and water systems are usually automated, allowing for some economies of scale and lower labour costs.

Commercial cage system

This is the major production system in Australia, accounting for 55 per cent of shell egg sales in Australian supermarkets. Keeping laying hens in cages is an emotive issue that attracts considerable debate about animal welfare. Conditions are as follows.

- Hens are kept in a shed in small groups in cages.
- From 2002 a code of practice allows at least 550 cm² per hen for new cages.
- Typically, eggs are collected automatically.

This system is subject to stringent standards relating to animal welfare and is regarded as the most efficient system for the production of shell eggs.

Free range

The free range system accounts for about 34 per cent of Australian supermarket shell egg sales. The average flock size is 1000–2000 hens. Conditions are as follows.

- Hens are kept in a shed that has a deep litter floor and are allowed outside access.
- Hens are provided with nest boxes to lay eggs.
- A code of practice allows at least 800 cm² per hen (commonly 1428 cm² per hen).
- Typically, eggs are collected by hand.

- Stock density recommendations vary across organisations and range from 750 hens per hectare to 20 000 hens per hectare.

The advantages of this system are that hens can perform natural behaviours such as dustbathing and perching, and can move around freely. It is a more expensive system to operate, in part because a greater area of land is required to house the hens, a higher level of manual labour is required to manage the production system, and economies of scale are lacking. Consequently product prices are higher at the supermarket. Parasites are more of a problem to manage, especially lice and mites, and exposure to predators is much higher so there are higher mortality rates with this enterprise management system.

Organic and specialty

This farming system relies on feeding poultry only organically produced certified food. Operations are based on free range systems. This farming enterprise accounts for 2 per cent of shell egg sales in Australian supermarkets.

Feeding

Feed cost amounts to about 70 per cent of the total cost of production. Poultry rations are usually fed as pellets (Fig. 32.6), crumbles or a mash. Nutrient requirements vary with the age of the bird (e.g. chickens or **pullets**), type of production and the stage of the production cycle. During the early brooding and rearing period there is a high demand for protein for body growth and development. As the chickens increase in age, there is also an increased demand for energy for warmth and activity. During the laying period the requirement for protein is smaller.

The main nutrients required by poultry are protein, fats, carbohydrates, minerals, vitamins and water. Protein is usually supplied in the feed by including fishmeal, sunflower meal, soybean meal or meat meal. Young chickens need 20 per cent protein in their diet and layers need approximately 16 per cent. Carbohydrates provide energy and are usually supplied by grains such as wheat, barley, maize or sorghum. Fats are not usually added to chicken diets except with meat chickens, where a high-energy ration is fed.

Minerals are needed for growth and egg production. Laying hens need large amounts of calcium for making egg shells. This is usually supplied in the form of lime or shell grit. Vitamins are required if the birds are housed away from sunlight, or if they do not have access to green feed. The most important vitamins for poultry are vitamins A, B₂ (riboflavin) and D₃ (cholecalciferol). These are readily available as synthetic supplements and can be added in the feed or mixed daily in the drinking water.

- 11 Identify the percentage that feed accounts for in the total cost of production.
- 12 Why is there a high requirement for protein in the ration of a young chicken?
- 13 Name three feeds that supply protein.
- 14 Why is calcium fed in a ration?
- 15 If birds are housed, how can vitamin deficiencies be prevented?



Shutterstock/Nuiko



Shutterstock/Kharkhan Oleg

Figure 32.6 Poultry feeding on pellets

Breeding

The pure breeds of birds are not as efficient as the special strains or hybrids that are produced by the big breeding companies. These companies specialise in producing meat or egg-laying hybrids.

For eggs

It is desirable to breed hens with long clutch lengths.

The shedding of the egg is called ovulation. The egg spends approximately 26 hours in the oviduct. As the egg moves down the oviduct it first develops the chalazae (cords that fasten the yolk to the shell membranes). This is followed by the albumen or egg white, the shell membranes, and finally the shell. The egg is then laid. If fertile eggs are required for hatching, **cockerels** are necessary. One cockerel is run with every 10 hens. The sperm unites with the egg (yolk) in the oviduct before the chalazae, albumen, membranes and shell are formed.

To breed for egg production, producers measure the production of hens and their female offspring and breed only from those families where the production of 'daughters' is high.

For meat

The breeding of hybrid meat birds (or 'broilers') has two aspects. First, in the male line only the fast-growing hens and cockerels are bred from. Second, in the female line birds are chosen for rapid growth and egg production, early maturity and food conversion ratios (the efficiency of turning food into meat).

Controlling pests and disease

- *Chronic respiratory disease (CRD)*. CRD is caused by bacteria. Affected birds show cold symptoms such as watery eyes, blocked nostrils and coughing. The disease causes birds to be inefficient producers. Affected birds can be treated with antibiotics. Overuse of antibiotics can lead to the antibiotic being ineffective because of antibiotic resistance in the bacteria. Antibiotic-resistant bacteria can have implications in the treatment of human diseases.
- *Coccidiosis*. This disease is caused by a protozoan parasite that enters the bird during feeding. The parasite multiplies in the intestine and burrows into the wall of the intestine and caeca. Infected birds close their eyes, do not eat and have dirty, ruffled feathers. This disease can be controlled by including a drug, coccidiostat, in the feed.
- *Lice*. There are several kinds of lice (e.g. Fig. 32.7), which are insects that infect humans, animals and plants. Body lice are the most common. Lice are active at night and irritate the bird when it should be resting. Lousy birds scratch and pick at their feathers, refuse to eat, and stop laying eggs. To control lice, birds should be sprayed or dusted with, or be dipped in, an insecticide.
- *Newcastle disease*. This is a viral disease of poultry and a wide range of other birds. It is very contagious and can be passed from bird to bird by direct contact or through contaminated food. It is usually fatal. The signs that a bird has contracted this disease are variable, ranging from no visible signs to respiratory distress, diarrhoea, nervous tremors and paralysis of the legs or wings coupled with an inability to hold the head up. Although the disease can infect people, it does not cause these symptoms. Mild conjunctivitis can occur in humans. All birds with this disease or suspected of having this disease must be destroyed and affected farms quarantined.
- *Avian influenza (bird flu)*. This is an infectious disease of birds that can occasionally infect humans. It is caused by a virus, but the avian influenza virus is not the same

connect

Eggs

Outline the steps to incubate eggs.

16 Define 'ovulation'.

17 Recount what happens to an egg as it passes down the oviduct.

connect

Victorian DPI: chicken meat

Alamy/© Phototake / Dennis Kunkel Microscopy



Figure 32.7 Poultry lice, *Menacanthus stramineus*, adult (left) and juvenile (right)

18 What causes chronic respiratory disease?

19 What are the symptoms of coccidiosis in poultry?

20 How are lice controlled in poultry?

as the human influenza virus. Infected farms are destocked and decontaminated. In Australia outbreaks have been only the strain of influenza virus that affects poultry alone, and not the dangerous strain found in some Asian and European countries that kills people. At the time of writing, there is no vaccine available.

Animal welfare

It is important to evaluate management systems using proven welfare indicators or standards rather than perception or observation alone. Welfare groups promote the free range and litter-based management systems, but codes of practice for commercial cage systems determine floor space and housing density, cage design and cage life. Management practices such as the management of moulting times and cannibalism are also prescribed in a code of practice.

Litter is removed at the end of lay (about 60 weeks) and standards prescribe depth of litter, but eggs that are laid in the litter or on the ground (as can happen in barn or free range systems) can be easily contaminated with faeces. Eggs that have contact with faeces have a much greater risk of becoming contaminated with microorganisms such as *Escherichia coli* or *Salmonella*. Procedures for the handling and cleaning of eggs are also outlined in an industry code of practice.

Marketing

Chicken meat

Chicken meat is marketed throughout Australia by large companies under various brand names. Smaller processors also market chicken.

Chicken meat is sold through supermarkets, specialty chicken shops, butchers, delicatessens, department stores and other outlets. Large supermarkets market fresh and frozen chickens, whole and in pieces, and they also sell rotisserie chickens (Fig. 32.8).

Eggs

Eggs are collected and taken to a central egg-handling area on the farm. Here the eggs are checked for cleanliness and cracks.

At the grading and distribution facility, eggs are washed prior to packing to remove any dirt or faeces. Washing removes the film around the egg that is produced during lay and makes the shells more porous. The eggs are then coated with food grade oil to reduce their shell porosity. Eggs are graded on weight. Regular samples of all eggs are taken to determine yolk colour and quality.

The egg market accounts for 87 per cent of all eggs consumed in Australia (Fig. 32.9). The remaining eggs are sold as egg pulp, liquid white and liquid yolk, egg powder and egg products such as scrambled egg mix.

Packed eggs are kept in cool storage before distribution to retail outlets in refrigerated trucks. In 1989 the New South Wales Government deregulated egg marketing arrangements in the state. Consequently egg producers can consist of co-operatives, family farms and partnerships.

The Australian Egg Corporation Limited represents the commercial interests of egg producers, processors and marketing organisations.

connect

Poultry diseases

connect

Biosecurity guidelines for egg producers

connect

FAQs

Frequently asked questions about layer hen cages



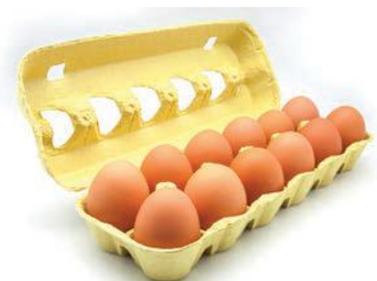
Shutterstock/Evgeniya Uvarova

Figure 32.8 The meat of a chicken can be sold as a rotisserie chicken

connect

AEC

Australian Egg Corporation Limited
current information



Shutterstock/stable

Figure 32.9 Eggs ready for sale

Chapter review

Things to do

- 1 Visit a commercial poultry farm and:
 - a draw a plan of the layout and label the main features.
 - b describe the feeding method used there.
- 2 Weigh a chicken at regular intervals through its whole growth period. Graph its change in weight against time, and calculate its rate of growth.
- 3 Observe the process of incubation (in an incubator with a transparent top). Record your observations.
- 4 Dissect a hen to show the principal organs, especially those associated with the formation of the egg. Identify the digestive organs, and lay them out in order. Examine the contents of the crop, stomach and gizzard.
- 5 Visit a shop where chicken is sold and make a list of all the different ways chicken meat is presented for sale.

Things to find out

- 1 What is a 'broody hen'?
- 2 Under what conditions are free range hens reared?
- 3 Discover what antibiotics (if any) are used in poultry feeds, and why. Outline the precautions that need to be taken when using these antibiotics.
- 4 Find out what effect diet change has on yolk colour.
- 5 List the nutritional elements of an egg.
- 6 Find out if there is such a thing as a 'pecking order' in poultry.
- 7 Find out what is contained in a commercially prepared broiler-grower mix, and in a layer mix. What are the main differences in the two feeds, and why?

Extension activities

- 1 Why have welfare codes of practice been developed for the poultry industry?
- 2 Discuss reasons why the sale of free range eggs have increased over the past few years.
- 3 Compare and contrast the various types of egg production systems.
- 4 Write a play to describe the management of a poultry enterprise.
- 5 Design an egg carton for your school's organic eggs, which could be sold through the canteen.
- 6 Investigate the trend toward the vertical integration of the chicken meat market by supermarkets.

✓ Test yourself

- 1** Copy out the following and indicate if each is true or false.
 - a** A brooder is a heated structure used for hatching eggs.
 - b** A pullet is a male bird under 12 months of age.
 - c** Culling is the removal of sick or unproductive birds.
 - d** A rooster is a male bird under 12 months of age.
- 2** Explain the terms 'dual-purpose breed' and 'ovulation'.
- 3** Newcastle disease is a major poultry disease. Research and report on this disease. In your report include:
 - a** the cause of the disease.
 - b** common symptoms found in infected birds.
 - c** the impact on the industry.

CHAPTER 33

BEES

Words to know

apiary a place where beehives are located

apiarist a person who keeps bees

apiculture keeping bees on a commercial basis

brood the eggs, larvae and pupae that will become fully-grown bees; housed in cells in honeycomb

extraction removal of honey from frames kept in the supers of a commercial beehive; honey extraction occurs immediately after the removal of the beeswax cappings from all the cells on the frame

honey the sweet, sticky fluid made by bees using nectar from flowers

nucleus colony a colony comprising a queen bee and workers

swarm movement of a queen and bees from a hive

Introduction

The honey bee is an example of a very useful insect. Products from bees include **honey** (Fig. 33.1), royal jelly, beeswax and bee pollen (made from flower pollen). A farmer who keeps bees is called an **apiarist** and keeping bees on a commercial basis is known as **apiculture**. Nearly all available insecticides kill bees, so the farmer must take extreme care not to destroy bees when controlling insect pests.

The honey bee is needed to pollinate flowers. Without the help of bees, many plants would not set seed. Bees pollinate a vast number of food crops. Farmers growing certain crops, such as canola, hire hives of bees to pollinate them. Figure 33.2 outlines the process of pollination.

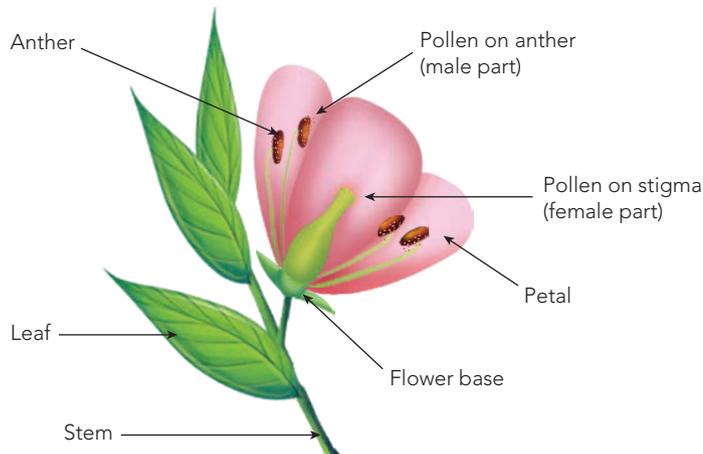


Figure 33.2 The pollination process: pollination is the transfer of pollen from anther to stigma

Pollen also provides the protein needed by bees to grow. Pollen, which is collected from the male part of flowers, is used to make royal jelly. Nectar from plants provides bees with sugars for energy. Nectar is very watery and will ferment quickly, so the worker bees fan the air in the hive to evaporate the water. The concentrated nectar is called honey. Honey is stored in the honeycomb cells (Fig. 33.3) and can last for many years.

More than 20 000 species of wild bees exist. Many are solitary in nature and do not form colonies. The honey bee found in commercial **apiaries** (bee farms) is native to Europe and Africa. Several types of bee are used in commercial production; two examples are the Caucasian bee and the Italian bee.

Bee-keeping for honey production is a very old human activity; evidence of hives dates back to 900 BCE. By the mid 19th century bee-keeping had evolved to a point where bee colonies could be raised in well-constructed artificial beehives that allowed for the **extraction** of honey without destroying the entire colony.

The production cycle

The common honey bee is a social insect. Its colonies contain 30 000 to 50 000 insects. In the wild, the colony builds a series of parallel combs, each comb containing thousands of small six-sided cells. In these cells the bees store honey and pollen for food, and house the **brood**, the eggs, larvae and pupae that will become fully-grown bees.



Figure 33.1 Honey products



Figure 33.3 Honey is stored in honeycomb cells

Types of bees in a colony

Each colony has three types of bee and each type has a special activity to perform. Figure 33.4 shows these bees (note the size differences between them).



The worker

The worker bee is the most populous bee in the colony; almost all the bees in a hive are worker bees. Worker bees are sterile females. They do all the routine jobs in the colony. From the time the worker bee emerges from the egg, it starts to work. As the worker bee gets older, its jobs change. The average worker lives for 6–10 weeks.

When young, the worker cleans the empty brood cells, then starts to feed the young larvae. At this stage it is called a nurse bee. When older, it repairs and builds new comb. As it matures it becomes a guard bee for the hive. In the final stages of life the worker goes out to collect the nectar and pollen from plants, and at this stage is called a field bee. As it ages, its wings tatter and tear until it can no longer fend for itself.

The drone

Drone is the name given to the male bees of a hive. The drone comes from unfertilised eggs laid by the queen. Its main purpose is to fertilise young queen bees, usually from other hives. During the spring–summer period, the number of drones in a hive increases dramatically. When food becomes hard to find, such as in winter, the drone is thrown out of the hive to die. Drones are fat bees with blunt abdomens and large eyes.

The queen

There is usually only one queen bee in a working hive. The queen is the only fertile female in the colony. She is the mother of all the bees in the colony. Without the queen, the colony would quickly die out. The queen mates in the first week of her adulthood and stores the sperm for the rest of her life.

If several queens hatch from eggs in a hive, only one of them will survive. She will sting all the other queens so that they die.

Figure 33.4 The three types of bees

- 1 Why are bees important?
- 2 Describe the roles of the three types of bee found in a hive.

The lifecycle of the bee

The honey bee has four stages in its lifecycle (Fig. 33.5).

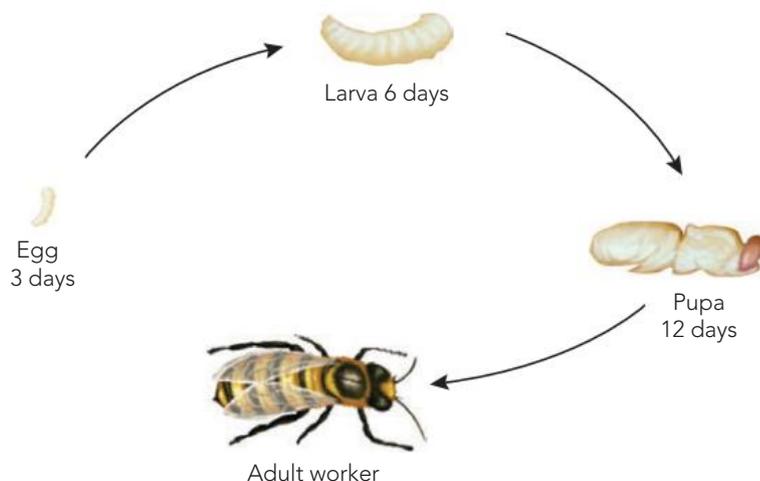


Figure 33.5 Lifecycle of a honey bee

- 1 **Egg.** All bees begin life as an egg. Eggs are laid by the queen in cells called brood cells. The drones are laid in special cells in the comb.
- 2 **Larva.** After 3 days, larvae hatch out of the eggs. The larvae are fed by nurse bees for 6 days on royal jelly and a mixture of honey and pollen. The larvae grow very quickly.
- 3 **Pupa.** The larvae spin cocoons and worker bees seal them in their cells using a wax capping. This is the pupal stage, where the adult body structures gradually form. It lasts approximately 12 days.
- 4 **Adult.** At 21 days after the eggs were laid, the adult bees bite their way out of their cells.

If the larva is to grow into a queen bee, it is fed large amounts of royal jelly during the larval stage. This allows for the full development of the reproductive organs. A new queen is raised when the queen dies or ages and becomes feeble.

The bees also start feeding larvae to produce new queens if the colony grows and overcrowding occurs. This produces a **swarm**. Swarming activity is usually confined to the spring and summer periods. Special swarm cells are produced in the hive, usually in groups of 15–20 cells located along the bottom and sides of the brood nest. The old queen leaves in the first swarm, along with a number of workers. Subsequent swarms contain virgin queens.

The commercial beehive

Figure 33.6 shows the basic parts of a beehive. The metal lid protects the bees in the hive from the extremes of weather. The entire structure rests on a hardwood base. It is important to have the base sitting on a clean area that can be easily maintained – many farmers place the hive on a cement slab.

The first box is called the brood box. It contains the queen and her eggs, along with nurse bees and other workers. The second and subsequent boxes are called ‘supers’ and contain frames into which the worker bees place surplus honey. To prevent the queen from leaving the lower box and laying eggs in the other boxes, a plastic screen is placed over the top of the brood box. The screen is called a queen excluder: it allows the worker bees to pass through but blocks the movement of the larger queen bee.

Inside each box there are frames, onto which foundation wax comb has been placed. Each box contains either eight or 10 frames, depending on its size. The foundation wax serves as a base pattern that the bees can use to construct the cells into which honey, pollen or eggs will be placed.

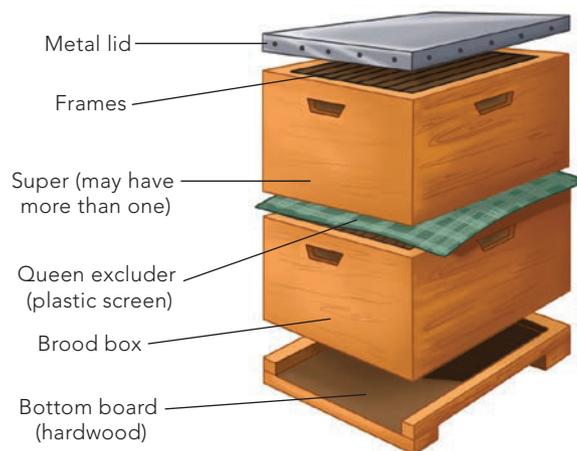


Figure 33.6 Structure of a beehive

Extracting honey

When the honeycomb in the hive is full of honey and capped with beeswax, it is ready for extraction (Fig. 33.7). The hive is opened after smoke has been gently placed into it. (The smoke sedates the bees – but too much smoke has the opposite effect!) The full frames are removed and replaced with empty ones. Some full frames are left in the brood box to feed the bees.

The frames are taken to an area where the honey can be removed and where ‘robber bees’ are unable to get to it. Robber bees do not belong to the hive and if honey or old comb is left unattended, they feed on it and may spread disease. It is illegal to leave honey or combs where robber bees can feed on it.

- 3 Draw the lifecycle of the honey bee.
- 4 How is a queen bee produced in a hive?
- 5 What is a ‘swarm’?

- 6 Describe the structure of a beehive.
- 7 What is a ‘queen excluder’?
- 8 What is the ‘brood box’?

Figure 33.7 How to open and inspect a beehive

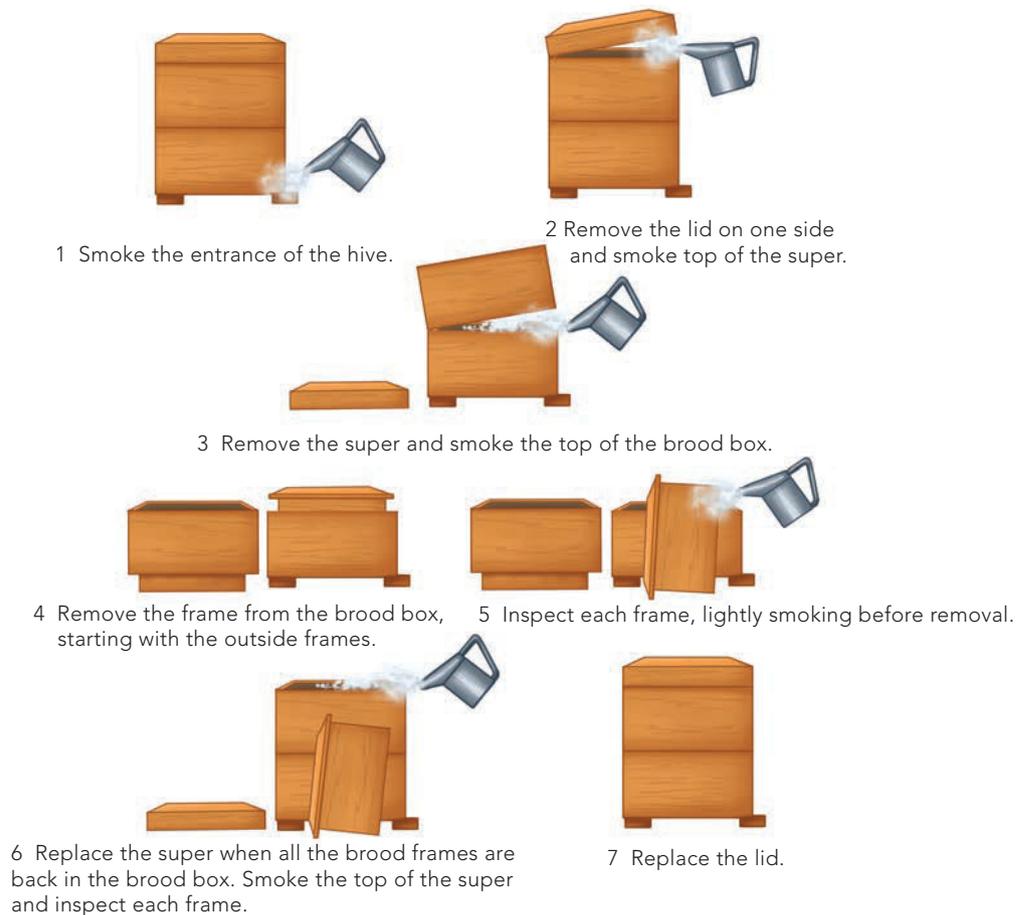
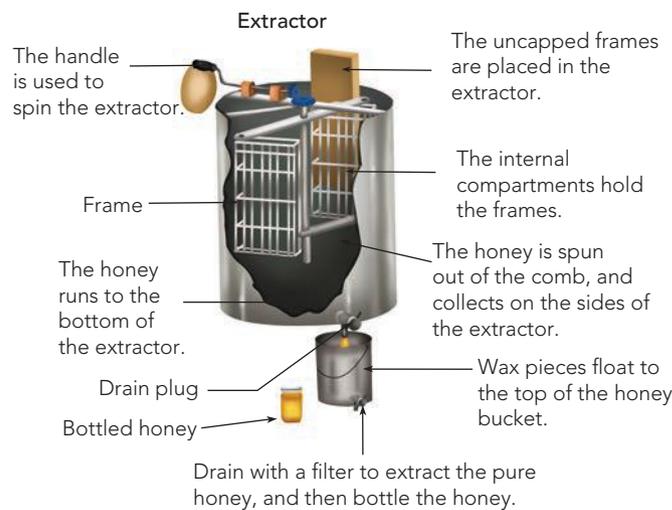


Figure 33.8 Extracting honey from the frames



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Beekeepers

After reviewing the information, describe the process of extracting honey.

- 9 Describe the process of extracting honey.

An uncapping knife is used to slice off the cappings, which are collected to have the honey squeezed out of them. Uncapping knives are either electric or steam-heated so that they can easily cut through the wax cappings.

Frames of similar weight are then placed into an extractor and gently spun. Centrifugal force removes the honey from the frames and it drains to the bottom of the extractor. From here it is drained into buckets, where it is left to stand so that air bubbles and wax pieces float to the top. This material is skimmed off and the honey is then bottled. Figure 33.8 illustrates the basic process.

Managing beehives

Hives should be placed in a warm, sunny position facing northeast (bees in wet shady areas are always sick). Initially, only two or three hives should be set up. These will very quickly build up and care must be taken to regularly inspect the hives. Bees need water, so containers of water should be placed in the general area of the hive. Bees also need a good food supply. Suitable options are gum trees, tea trees, various clovers, lucerne and canola crops.

All hives must be registered and identified. Farmers should take note of any signs of disease during hive inspections. It is a requirement that several types of bacterial disease in bees must be reported by law. These are known as notifiable diseases, and include American brood disease and European brood disease.

To obtain bees you can either buy an active hive, buy a **nucleus colony**, or capture a swarm of bees yourself to place into a hive.

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Keeping bees

Visit this website for more information on keeping bees.

-
- 10** List four things you must be aware of when keeping bees.

Controlling pests and diseases

American foulbrood (AFB)

AFB is caused by a bacterium that infects young bee larvae, causing death just prior to pupating. Visual signs include dark colouring and sunken areas of the capping and the larvae become darker in colour as death approaches. There is a smell associated with infected hives also.

AFB is a notifiable disease and contaminated hives are destroyed. To prevent infection, cleanliness in handling equipment and sterilisation of any secondhand equipment is recommended. Honey should be sealed in clean containers as it is collected and work areas should be thoroughly cleaned after use.

Colony collapse disorder

The cause of colony collapse disorder is not clear; it could be environmental or nutritional, or related to the effect of pesticides or parasites. The immune system of the bee becomes weak, allowing the bee to be attacked by fungi, bacteria or viruses. The bees become disorientated and lose their ability to return to the hive. In a few days the hive becomes empty. In response to this problem sections of the European community have restricted the use of nicotine-based chemicals in pesticides.

Small hive beetle

The larvae of the small hive beetle (native to Africa) contributes to hive death as well as damage to stored hive materials such as frames and combs. The larvae feed on live brood and honey and their faeces contaminate the product. To avoid or minimise infection, the bee colony must be kept in a healthy state so there is a high ratio of bees to available comb space. The humidity should be kept at less than 70 per cent. Good hygiene practice around the hive in removing debris and cleaning all equipment is essential, along with wrapping all stored materials.

Varroa mite

While the Asian honey bee is resistant to the varroa mite, the main species of honey bee in Australia is not. The mite attaches itself to the bee and sucks out its body fluids. In the process the bee can also be infected by viruses such as the virus

responsible for deformed wings. As mite numbers increase in a hive, so do mortality rates, eventually leading to the death of the bee colony. The varroa mite was first noticed in 1960 in Japan. By 1987 the mite was found in the United States; by 1992 it was in England and by 2006 it was found in New Zealand. Due to effective quarantine measures, at the time of writing this mite is not in Australia.

Wax moth

This greyish brown moth grows to about 2 cm long. The larvae cause damage by tunnelling into the comb, leaving a webbing trail and also chewing into hive and frame structures.

Healthy hives can survive an infestation but weak colonies could be displaced from the hive. The best preventative method is to maintain a healthy colony by regular re-queening and, if necessary, feeding. Hygienic storage of combs and frames is also required, such as the sealing of stored materials used in the construction of frames and boxes.

Animal welfare

As insects, bees are not covered by any legislation or guidelines covering animal welfare. Indeed, many people regard bees as a nuisance or even dangerous, and as an animal to be killed with pesticides. But entomologists, the scientists who work with insects, have observed that even insects feel pain. Like any farmer working with traditional animals, apiarists do not want their stock to suffer unnecessary trauma or pain. The obvious reason is that distressed bees will produce less honey, but apiarists can become fond of their bees and also wish them to live as free from harm as possible.

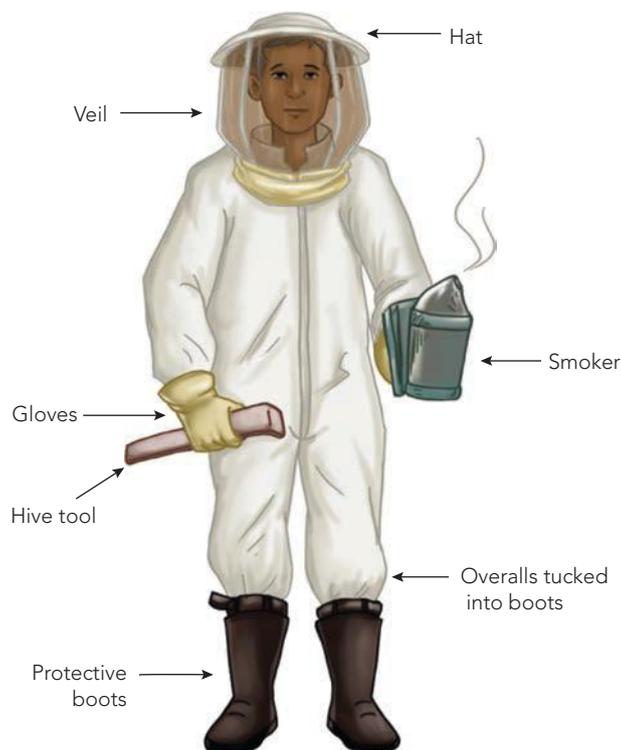


Figure 33.9 The complete beekeeper

Working safely

When handling bees you must be fully protected to avoid injury from bee stings. Figure 33.9 illustrates the type of clothing required.

Keeping records

As with all types of farming, apiarists benefit from keeping careful records. Climate records are particularly important, since climate influences flower production. Apiarists will also keep details of the amount of honey produced in different locations at particular times of the year, when hives are moved, and how many hives and bees are in different locations.

Chapter review

Things to do

- 1 Carefully approach a hive of bees and collect some of the dead ones thrown out of it. Use a hand lens to inspect and draw the following.
 - a The hind leg
 - b The sting
 - c The body hairs
- 2 Obtain some kits of bee boxes and frames. Assemble them under guidance from your teacher, wiring the frames if possible.
- 3 Help to extract, and bottle, some honey.
- 4 Look at some commercial foundation comb. Compare this with honeycomb taken from a hive. What differences do you see?

Things to find out

- 1 Why are bees important in orchards?
- 2 Bees are called 'social' insects.
 - a What does this mean, and why is this the case?
 - b What other insects are social insects?
 - c What is the importance of other types of social insects?
- 3 How do bees communicate in the hive to tell other bees where a food source is located?
- 4 How do bees differ from wasps?
- 5 Australia has native honey bees. Find out as much as you can about them.

Extension activities

- 1 Outline how a frame with a beeswax foundation is made.
- 2 Discuss the structure of a typical beehive, including 'supers', 8-, 10- and 12-framed boxes and queen excluders.
- 3 Discuss the seasonal management routines for a bee farmer.

Test yourself

- 1 Describe how bees assist the pollination process.
- 2 What types of bee are found in a beehive?
- 3 Describe two diseases that can affect bees.
- 4 List the main types of protective clothing that you need to wear when handling bees and explain the reason for each piece of clothing.

CHAPTER 34

ALPACAS

Words to know

cria (pronounced kree-ah) a newborn alpaca up to 6 months of age

dam or hembra a breeding female alpaca

macho or sire an entire male alpaca used for breeding

gestation period the length of pregnancy (from conception to birth)

weaner a young alpaca 6–12 months of age that has been weaned from its mother

wether a male animal castrated while still immature

Introduction

The alpaca industry is still in its early stages. Alpacas were first introduced into Australia in 1989. By 2001 there were approximately 40 000 alpacas in Australia. In Australia, 80 per cent of alpacas are in herds of less than ten animals. Initial investment is very high. Production goals and thorough researching of markets are essential so that farm outputs can be processed and marketed effectively. The alpaca requires other alpacas to survive and grow at ideal rates, so it is necessary to purchase several animals from the beginning when setting up an alpaca enterprise or farm.

Alpacas are South American camelids related to llamas and vicuna (Fig. 34.1). The wool harvested from the alpaca is very hard-wearing, fine textured and soft to touch. Its thermal properties make it ideal for producing clothing suited to very cold climates. Alpaca wool fibres are hollow and have a slippery feel. While alpacas in Australia are generally farmed for their fleeces, they are also used as guard animals for sheep flocks.



Shutterstock/meunierd

Figure 34.1 Alpacas

- 1 Describe the wool/fleece harvested from an alpaca.

Breeds of alpaca

Huacaya

Pronounced 'wa-ky-ya', the Huacaya is the most common type of alpaca in both South America and Australia. The Huacaya has soft fibres on its forehead, while its dense body fibres grow directly outwards; that is, perpendicular to the body (not unlike the Merino fleece) (Fig. 34.2). Ideally, the fleece coverage is even and extends down the legs.

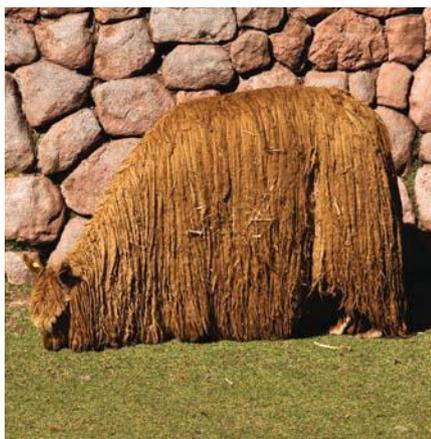


Shutterstock/Milosz_G

- 2 Name the most common breed of alpaca in Australia.
- 3 Describe the fleece of a Suri alpaca.

Suri

Pronounced 'soo-ree', only a small percentage of alpacas in Australia is Suri (Fig. 34.2). The Suri is covered in long, pencil-fine locks (not unlike dreadlocks) that hang straight down from the body. The fleece has lustre and its feel is more slippery and silky than that of the Huacaya. The main Suri colours are white or light fawn.



Shutterstock/S J Francis

Figure 34.2 There are two major breeds of alpaca in Australia: the Huacaya and the Suri.

Production cycle

Alpacas are shorn once a year, usually in spring. Shearing is the biggest maintenance task required and usually takes approximately 5–10 minutes per animal (for an experienced alpaca shearer). The preferred method is to lay the animals on their side, either on a shearing table or on the ground, and restrain or hold their legs with ropes at each end. The animals are often blindfolded to reduce stress. Electric sheep shearing equipment is usually used, but because alpaca fibre is not greasy, care needs to be taken so that the hand piece does not over-heat. Figure 34.3 shows alpaca shearing.



Alamy©/ adrian davies

-
- 4 Describe how alpacas are shorn.

Figure 34.3 Alpaca shearing

Managing the farm

Any fencing in broad acreage rural areas that keeps sheep contained is satisfactory for keeping alpacas, preferably without barbed wire. Alpacas do not tend to jump fences but are capable of clearing a standard fence if they are stressed. Electric fencing is not often used for alpacas.

Alpacas should be handled quietly during yarding and catching. The required group can be moved into a holding yard and the selected animal can be caught in the corner of the yard.

Alpacas can be ear tagged. A female (dam or hembra) has its brass International Alpaca Registry (IAR) ear tag placed in its right ear, while a male (**sire** or **macho**) has its IAR tag placed in its left ear.

A **weaner** is an alpaca that has been weaned from its mother at 6–12 months of age.

Alpaca toenails require regular trimming to remove any excess growth. Alpacas have soft padded feet with two toes and a soft leathery pad on each foot. In general, nails need to be clipped every 3–6 months depending on the softness or hardness of the grazing ground. Two people are required to carry out the task: one person to hold the alpaca still while the other person trims the toenails.

-
- 5 What is an IAR, and to which ear of female and male alpacas is it attached?

Castration is a necessary practice within any breeding herd. The very best young males are kept entire as stud **sires**, while the majority of the herd is castrated. Castration is carried out by a veterinarian when the young males are between 10 and 18 months old. A male alpaca castrated when it is young is referred to as a **wether**.

Use the information on the [Alpaca management](#) website to prepare a summary of the management of alpacas.

Feeding

Alpacas are mainly grazers (eat pasture), but sometimes they browse (eat bushes and shrubs). Alpacas are ruminant animals but only have three stomachs, not four like sheep, cattle or goats. They are fastidious food selectors and prefer to eat small amounts of a variety of plants. Although they can survive very harsh conditions, they do best on good quality pasture and benefit from having access to hay or similar roughage.

Alpacas are affected by the same poisonous plants as other livestock. Alpacas need ready access to good quality drinking water. Any changes to their diet should be introduced gradually over several weeks to allow microbes in their gut to adjust.

Breeding

Females become sexually mature at around 12–18 months of age and once they reach about 45–50kg. Males are not sexually active or fertile until around 18–36 months.

Alpacas do not have a breeding season and females can be mated at any time of the year. It is preferable to avoid mid- to late-summer matings. The average **gestation period** is 11.5 months, but it is not uncommon for pregnancies to last more than 1 year. This reduces the number of heavily pregnant females and new **cria** born in very hot weather. Most births occur before the middle of the day. Only single births occur.

If a female is not interested in mating (e.g. if she is already pregnant) she will not mate and will probably spit at the male.

Females are usually re-mated 2–6 weeks after giving birth.

Controlling pests and diseases

Compared with other livestock, alpacas are relatively disease and pest free. Because of their dry fleece and naturally clean breech, fly strike is not a problem and they do not require crutching or mulesing. Alpacas suffer from the following diseases and pests.

- *Johne's disease*. The owners/breeders of alpacas can participate in either one or both of the animal health/biosecurity programs that are conducted to provide assurance of their animals' health status.
- *Leptospirosis*. Alpacas are vaccinated with a 7-in-1 shot. This vaccine provides protection against two strains of Leptospirosis as well as the diseases covered by the 5-in-1 vaccine.
- *Tetanus, pulpy kidney, black leg, black disease* and *malignant oedema*. Alpacas are vaccinated twice yearly with the same 5-in-1 vaccine that is used on sheep and goats.
- *Worm infestation*. Alpacas are susceptible to the internal parasites of cattle and sheep if they graze in small paddocks at a high stocking rate or with other livestock. Worms are controlled by drenching and stock rotation.

connect

Alpaca management

- 6 Alpacas are described as grazers (or grazing animals). What does this mean?
- 7 Why should changes to an alpaca's diet be introduced gradually?
- 8 How old is a female alpaca (dam or hembra) when she is first mated?
- 9 How long is the gestation period for an alpaca?
- 10 How is pulpy kidney prevented in alpacas?
- 11 How are worms controlled in alpacas?

Animal welfare

The basic requirements for the welfare of alpacas are:

- safe handling facilities
- adequate disaster protection (e.g. fodder and water reserves)
- protection from harsh environmental conditions (e.g. cold, windy and wet conditions, which is particularly important after alpacas have been shorn)
- adequate disease control strategies
- adequate protection from predators
- sufficient space to stand, lie down and follow normal behaviour patterns
- access to clean and fresh water and feed.

The degree of supervision depends on the intensity of the management system.

However, alpacas in less intensive systems require a manager to sight their condition at regular intervals depending on food and water availability, age, physiological state and climatic conditions.

Alpaca husbandry involves a number of management procedures, so farm hands need to be competent or under the direct supervision of an experienced operator. In all situations alpacas must be handled gently and calmly to avoid panic or injury in crowded yards. Stock handlers need to be trained in all surgical management procedures, such as castration, or employ a suitably trained person.

12 Outline one example of environmental conditions from which alpacas need protection.

Marketing

The products and their marketing arrangements include the following.

- *Wool/fleece.* After shearing, the raw wool/fleece is sent to a collection point where a classer assesses the wool/fleece to grade it. The farmer receives payment based on the quality of the product. Most farmers produce only small amounts of wool. They sell to companies that combine these small amounts into larger lots that are reasonably uniform in colour and fibre diameter. These lots are then sold together to manufacturers or used by the purchasing company to make garments and other products for sale.
- *Alpaca meat.* High quality lean meat is produced from alpacas. It is an excellent source of protein with little saturated fat or cholesterol. This is a new market and most of the meat goes straight to restaurants. They represent a niche market.

13 How is alpaca wool/fleece marketed?

14 Describe alpaca meat and explain why it is sought after by consumers.

Chapter review

Things to do

- 1 Visit an alpaca farm and observe catching and holding an alpaca, halter training of an alpaca for showing or loading them into a float for transport, and shearing of an alpaca.
- 2 Examine labels from vaccine packets to determine dosage rates and safety precautions.
- 3 Sketch the ear tag that appears in the ear of a registered alpaca.
- 4 If possible, keep two alpacas at school (two because alpacas like a companion). Keep a record of the amounts of food given.
- 5 Look at an alpaca fleece and measure the length in different places. Does the length vary over the fleece?

Things to find out

- 1 How do you know when an alpaca is ready for mating?
- 2 Determine how alpacas' feet cause minimal soil disturbance and ecosystem damage – far less than Australia's traditional livestock.
- 3 Find out what diseases are prevented by vaccination in alpacas. What are the major symptoms of each of these diseases?
- 4 Why are alpacas free of problems with lice and fly strike?
- 5 Research the points to consider when purchasing alpacas.

Extension activities

- 1 Electric fencing is uncommon in the keeping of alpacas, but can be used. Obtain advice from an alpaca farmer with experience in electric fencing (or conduct internet research) on the correct height settings of the electrified wires.
- 2 Observe a herd of alpacas in the paddock and describe which plants the alpacas eat first (or the most of) and whether they ignore any plant types.
- 3 Are alpacas related to llamas?
- 4 Research the history of alpacas from the ancient Incan civilisation until today.
- 5 Design a poster that will convince people that they should eat alpaca meat or wear garments made from alpaca fleece. Your poster needs to be less than 20 per cent writing, but must be informative and interesting.
- 6 Use the information on the [Alpaca Q&A](#) website to prepare an information booklet of handy hints for people interested in raising alpacas.

connect

Alpaca Q&A

✓ Test yourself

- 1 List the products that can be produced from an alpaca enterprise/farm.
- 2 Define the terms cria, hembra, macho, gestation period and wether.
- 3 What is the average gestation period for an alpaca?
- 4 Discuss the factors that limit the productivity of an alpaca enterprise/farm.
- 5 Give a 3-minute PowerPoint presentation on the characteristics of one breed of alpaca (mention commercial and physical characteristics).

CHAPTER 35

AQUACULTURE: FARMED FISH

Words to know

angling quality the ease or difficulty of catching a fish

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

carnivorous meat-eating

carrying capacity the maximum weight of fish a dam can support

cold-blooded animals, such as fish, whose bodies do not stay at a constant temperature; instead, their body temperature matches that of the environment

extensive farming aquaculture systems with low stocking rates where fish feed on organisms that naturally live in their environment and there are low levels of environmental control

fingerling a fish older than 'fry' stage but not yet an adult

fry a young fish just after hatching

hatchery a place that produces fingerlings for sale to the public and for stocking public waters

intensive farming aquaculture systems with high stocking rates, where farmers provide the feed for the fish and there are a number of artificial controls on the environment for the fish

omnivorous eating both meat and plants

spawning the process of egg-laying by a fish

zooplankton microscopic animals living in the surface waters of dams, rivers and other water habitats

Introduction

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DPI Aquaculture

The latest information and research into fishing and aquaculture

Aquaculture is the farming of fish or other aquatic organisms – what is generally called ‘seafood’ – usually in farm dams, ponds or especially constructed tanks or floating cages. Aquaculture farming can be dated to around 500 BCE with the raising of carp in China. Fish farming can occur in freshwater, brackish (slightly salty) water or sea water. Like any other type of farming, there are standard management activities such as feeding, restocking and protecting stock from predators. These activities distinguish aquaculture from hunting and gathering methods of harvesting seafood, such as recreational fishing, shellfish collection on a beach or net casting by hand.

Aquaculture is a developing industry and, during the last 10 years, there has been a growing demand for freshwater fish to stock farm dams. In addition, farms have diversified to include the farming of molluscs (mussels, oysters), crustaceans (crayfish, crabs and lobsters) and aquatic plants (mainly seaweeds) for human consumption. Oyster production is the main aquaculture system in New South Wales with the Sydney rock oyster the main species grown in the state. The most economically significant fish in aquaculture today include Australian bass, barramundi, catfish, golden perch, Murray cod, salmon, silver perch, trout and tuna. Other farmed aquatic animals include edible and pearl oysters, mud crabs, mussels, prawns and yabbies.

Commercial aquaculture is a highly specialised field. It requires a lot of capital to set up and much technical knowledge to operate. There are several types of aquaculture enterprises:

- **hatcheries** that produce fertilised eggs, larvae or **fingerlings**
- nurseries that look after the fingerlings
- fish farms that grow the juvenile fish to a marketable size.

Farms may specialise in one of these production areas or feature aspects of all three elements of aquaculture, from **spawning** to marketing adult fish. The systems may range from **extensive farming** through to **intensive farming**, depending on stocking rates and the level of environmental control. In extensive systems, the water provides the medium in which organisms reproduce to become a source of food for the fish. In intensive systems, high-protein food is fed to the fish and many environmental variables are controlled allowing for high stocking numbers.

Land-based farms are divided into pond- or dam-based, or recirculating aquaculture systems. The distribution of aquaculture farms depends on the temperature requirements of fish species; for example, in New South Wales farms with silver perch are widely distributed, while trout farms are located on the cooler southern and western slopes of the Great Dividing Range.

A number of federal, state and local government regulations must be complied with, and a clear code of practice must be followed by aquaculture managers.

State and federal departments of agriculture and fisheries conduct aquaculture research.

In New South Wales, this department is trying to find out more information on stocking farm dams and is looking at nutrition, dam sizes, stocking rates, suitable species, growth rates and cultural practices.

By studying these factors, research scientists hope to improve the **carrying capacity** of a dam, thus leading to increased fish production. Aquaculture researchers are also trying to make sure that the industry develops in a sustainable way.

- 1 What is ‘aquaculture’?
- 2 List the economically significant fish in aquaculture today.
- 3 Why is it important to carry out research into aquaculture?
- 4 What aspects of aquaculture are being researched?

Species of fish

Fish can be divided into two groups – native species and introduced species – depending on whether or not they naturally occur in Australia. Native species grow well in warm waters and can be found on the coast, lower slopes and inland plains. Trout require cold waters and should be stocked only in dams on the upper slopes and highlands of the Great Dividing Range.

The group of animals known as fish includes many different species, as different from each other as goats, pigs and alpacas. With farmed animals, we think of only one species (e.g. cattle), which is divided into different breeds. With fish, different fish farms specialise in one species and it is helpful to know the scientific name of the fish. Common names can sometimes be confusing, because one species may have more than one common name, and sometimes common names may sound as though unrelated species are related (e.g. golden perch and silver perch). However, when different species are closely related, the first part of the scientific name will be the same (e.g. *Macquaria*, for Australian bass and golden perch).

- 5 On what basis are fish divided into their two groups?
- 6 List the native species suitable for farming in dams.
- 7 Which native species is omnivorous?
- 8 Which fish species were introduced into Australia?

Native fish species

Among native fish species, the following seven are suitable for farming (Fig. 35.1).

Australian bass (*Macquaria novemaculeata*)

The Australian bass is **carnivorous** and eats a variety of foods including insects, shrimps, yabbies and small fish. It has excellent **angling quality**, is a popular fish for eating and adapts well to farm dams.

Barramundi (*Lates calcarifer*)

The word ‘Barramundi’ probably comes from the Queensland Dharumbal language, meaning ‘eating fish with large scales’. The name has been used in Australia for this carnivorous freshwater fish species only from the 1980s; until then it was – and still is – known as Asian bass (the fish is also found in Asian countries). Barramundi is perhaps the best native fish for eating. For this reason, it fetches high prices. It also has excellent angling quality: these characteristics make it popular for recreational fishing. Barramundi is found in tropical and semi-tropical waters.

Catfish (*Tandanus tandanus*)

The catfish is carnivorous and feeds mainly on shrimp, yabbies, worms and insects. It is a very good angling and eating fish, although many recreational fishers reject it because of its repulsive appearance. Great care must be taken when landing and handling this fish because of the spines on its pelvic fins, which can pierce the skin and cause considerable pain.

Figure 35.1 Native fish species



NSW Department of Primary Industries



iStockphoto/George Clerk



NSW Department of Primary Industries



NSW Department of Primary Industries

Golden perch (*Macquaria ambigua*)

Golden perch is carnivorous and feeds mainly on yabbies, shrimps and small fish. It has excellent angling and eating qualities and can reach an acceptable size in 2 years. It is also commonly known as the ‘yellowbelly’.



NSW Department of Primary Industries

Murray cod (*Maccullochella peelii peelii*)

Murray cod is the largest Australian freshwater fish and it generally only lives inland of the Great Dividing Range. It requires more space than other species, because it is aggressive, carnivorous and territorial.



NSW Department of Primary Industries

Silver perch (*Bidyanus bidyanus*)

Silver perch is probably the best warm-water species for stocking in farm dams. It is **omnivorous** and feeds mainly on insects, shrimp, **zooplankton**, algae and aquatic plants. It does well in dams where weeds are growing. It has good angling and eating qualities, and can reach an acceptable eating size in 2 years. Because of the noise it makes when lifted from the water it is commonly known in many areas as the ‘grunter’.



Alamy/Michael Patrick O’Neill

Southern bluefin tuna (*Thunnus maccoyii*)

The southern bluefin tuna is a massive carnivorous fish that lives in the oceans of the southern hemisphere. The fish can reach weights of more than 200 kg, although under 100 kg is more common for tuna found near Australia. Southern bluefin tuna is very popular for eating, particularly in Japan. It is regarded as an endangered species, because of overfishing. It is the most important aquaculture species in South Australia.

Introduced fish species

Introduced fish species include the Atlantic salmon, rainbow trout, brown trout and brook trout.



Alamy/Design Pics Inc.

Figure 35.2 Atlantic salmon

Atlantic salmon (*Salmo salar*)

Salmon is regarded as freshwater fish, even though it will naturally spend part of its life in the oceans. Wild salmon generally grows to be 2–10 kg. Salmon has arguably the best angling quality and is a favourite for recreational fishing.

Trout



Dreamstime/Lukas Blazek

NSW Department of Primary Industries

NSW Department of Primary Industries

Figure 35.3 **a** Brook trout (*Salvelinus fontinalis*) **b** brown trout (*Salmo trutta*) **c** rainbow trout (*Oncorhynchus mykiss*)

Trout (Fig. 35.3) are cold-water fish and show good survival in dams on the highlands. The rainbow trout is probably the best for stocking in farm dams because it has the fastest growth rate. Its angling and eating qualities are excellent. It is carnivorous and its prey includes worms, grasshoppers, yabbies and frogs.

Sustainable aquaculture

Marine-based aquaculture systems are the most vulnerable to climate change effects. Changes in ocean currents, winds, nutrient availability, temperature ranges and natural events will affect the stability of fish populations.

Poor site selection and poor management of fish farms and other aquaculture ventures can have negative consequences for the environment. Concerns arise where natural habitats such as mangroves are cleared for intensive aquaculture systems. Discharge of untreated waste into surrounding water and overfeeding in fish farms can cause changes in the structure of surrounding natural communities. This can lead to algal blooms or excessive microbial activity, both of which result in lower oxygen levels, which can kill other fish and animals living in the water. These are examples of poor management outcomes.

Fish caught in the wild are often used as food sources for commercial aquaculture operations which in turn places pressure on the numbers of wild species as well as the diversity of life in natural situations. Similarly farmed fish that escape into the natural environment also place pressure on the natural population.

Where fish are farmed in sea cages, such as southern bluefin tuna, the cages are treated or painted with an antifouling agent to stop other marine life growing on or attaching to the cages (Fig. 35.4). Environmentalists are concerned about the use of these substances. Some people are also worried about the long-term environmental effects of the antibiotics used in salmon farming.

Producers and others who work in the aquaculture industry are of course interested in keeping it viable and are working with researchers and others to find ways to deal with these issues.

Production cycle

Introduced species are usually stocked as fingerlings (i.e. 75–100 mm long) while native fish are stocked at the advanced **fry** stage. Trout are usually reared in a **hatchery** on artificial food and are much easier to rear to the fingerling stage than the native warm-water fish such as perch, catfish, cod and bass. Stocking warm-water fry early in the summer allows them to take full advantage of the summer and autumn growing season.



Getty Images/Jason Edwards

Figure 35.4 A southern bluefin tuna sea cage in Port Lincoln, South Australia

Tuna are farmed differently; they are caught at sea when they are approximately 2 years old (or around 15 kg in weight) and are then grown out in sea cages until ready to harvest.

Survival after stocking will be reduced if predators are present. Predators can include larger fish. For this reason dams should not be restocked with fingerlings until most of the larger fish have been removed.

Growth rates depend on the conditions under which the fish are grown. Rates are usually greater at lower stocking rates.

Managing the farm

Animal welfare

Welfare concerns arise from issues due to stocking densities. Overcrowding can increase aggressive behaviours, competition for available food and increase levels of nitrogenous compounds and waste in the water, lowering oxygen levels and increasing water toxicity levels due to ammonia production.

These types of interaction cause stress and physical damage due to fighting, and increase the risk of disease. Management techniques that maintain stocking densities, keep as close as possible to the normal conditions for each fish species and that separate sizes according to the stage of growth have a positive effect on welfare.

While some people do not think **cold-blooded** animals such as fish deserve the same level of care in handling as warm-blooded land animals, fish still have a nervous system and are able to feel pain. An ethical approach to farming tries always to minimise pain in the lifecycle of animals. In some Australian states, fish are protected by laws prohibiting cruelty to animals.

- 9 What size dams give the best fish-producing results?
- 10 State the best-shaped dams for maximum food production.



Shutterstock/Melinda Fawyer

Figure 35.5 Suitable dams for aquaculture

Managing dams

Fish will survive and grow in very small dams provided adequate food is available. Dams of 0.1 hectares (100m²) or larger will yield the best results. In general, the larger the surface area of a dam or pond, the greater the amount of fish that can be produced. Most of the food for fish in a dam is produced on the dam walls. Dams with gently sloping sides get more sunlight and will produce more food than deep dams with steep, shaded sides. Figure 35.5 shows dams suitable for fish.

Care must be taken to prevent excessive bank erosion by other livestock, such as sheep and cattle. This can also turn the water muddy, which will reduce the light penetration: food production will then be reduced. Other animals can be limited to a part of

the dam by fencing it off or by putting in a water trough. This is an example of an extensive production system. Intensive systems use tanks, troughs or cages, where the farmer regularly changes the water, provides concentrated feed and constantly monitors the environment, especially temperatures, which more than anything else affect how quickly fish grow. The fish stocking density is higher in intensive systems.

The site for an aquaculture activity must have a regular supply of clean water. Trout and salmon also require high oxygen levels in the water. Native fish need water temperatures below 30°C. The water quality determines the stocking levels and, as a result, the productivity of the enterprise.

When managing fish in farm dams, consider the following factors:

- water quality
- excessive plant growth
- amount of oxygen in the water
- stocking rates.

Water quality

There are many environmental factors that determine acceptable levels for water quality. Major factors include:

- water acidity or alkalinity levels (pH)
- salinity levels
- amount of dissolved nutrients in the water
- presence of toxic nitrogenous waste materials
- turbidity (how muddy or clear the water is)
- contaminant concentrations, such as the presence of heavy metals or chemical contamination from crop spraying.

Excessive plant growth

While some plant growth is necessary in a dam to provide food and shelter for the insects and shrimp that the fish eat and to provide shelter for the fish, too much plant growth makes harvesting difficult.

Lack of oxygen

Low levels of oxygen are not usually a problem but can occur during summer, and also quite often after heavy rain (when dead grass and animal faeces may be washed into a dam).

The first sign of oxygen deficiency in water is the presence of dead fish or fish coming to the surface gasping for air. To replace the oxygen, the water must be circulated. This can be done by pumping water from the bottom and spraying it back onto the surface of the dam.

Stocking rates

The maximum weight of fish a dam can support is called its carrying capacity. This depends on factors such as the species of fish, the water quality, the amount of food provided and the size of the dam.

Feeding

The naturally occurring foods for fish in farm dams are insects, yabbies and zooplankton.

Fertiliser, provided it is not used in excess, will increase food production in a dam. It should be added in spring and autumn. The fertilisers used are superphosphate, sulfate of ammonia, potash and ground limestone.



Shutterstock/Ramon grosso dolarea

Figure 35.6 The carrying capacity of a dam depends on water quality, size of dam and availability of food.

11 What is the first sign of oxygen deficiency in a farm dam?

12 What is meant by 'carrying capacity' when referring to a dam?

13 What naturally occurring foods for fish are found in farm dams?

Controlling pests and diseases

FLPA/Biosphoto/Remi Masson



Figure 35.7 European carp (*Cyprinus carpio*) is an undesirable fish for a farm dam.

14 Name three undesirable fish that can be found in farm dams.

connect

European carp

View the video and answer the questions to gain an understanding about the impact of European carp in aquaculture.

connect

Murray cod

View the video and answer the questions relating to disease and how this has affected populations of the Murray cod.

Undesirable fish

Some of the undesirable fish that can be found in farm dams include the mosquito fish (*Gambusia holbrooki*), the redfin (*Perca fluviatilis*) and the European carp (*Cyprinus carpio*, a relative of goldfish; Fig. 35.7). These fish should be removed from a dam before starting to stock it with fingerlings.

Birds

The main predatory bird is the cormorant, which greatly affects the survival of fish. Once cormorants have found a dam containing fish, the birds will continue to work it until most of the fish have been taken.

Disease

Parasite infestation is a common problem often related to overcrowding. Sea lice are the main parasites of fish. They cause skin damage, gill congestion and lowered growth rates. Bacteria are a major cause of disease in salmon and trout farms while barramundi suffer problems associated with a number of viruses.

Marketing

Any species of fish commercially farmed must have market acceptance; that is, people wish to consume the product. Many producers cater for specialised or niche markets to gain an economic advantage. Australia has developed a reputation as a producer of quality seafood and aquaculture produce. Salmon and trout, tuna, silver perch and barramundi are currently the fish producing the most value in the farmed fish industry.

Demand is increasing for Australian native fish species and, coupled with the closeness to Asian markets, Australian aquaculture has become competitively positioned. Southern bluefin tuna is Australia's leading exported fish and the top four export markets for tuna are Hong Kong, Japan, the United States and China.

In time aquaculture will supply more than half of the fish consumed in the world. Australia exports approximately 75 per cent of its fish products and aquaculture production accounts for 40 per cent of Australian fisheries' gross value.

Shutterstock/Cameron Whitman



Figure 35.8 Fish market

Chapter review

Things to do

- 1 If you have a swimming pool, grow some trout during the winter or spring; they can be obtained from a hatchery. The trout will survive if the water temperature is kept below 20°C. Feed them twice a day and clean the pool every 3 days to remove uneaten food and faeces. Do not use chlorine, because this will kill the fish. Measure the length of the fish and work out their growth rate.
- 2 Silver perch and golden perch are active predators, ambushing or seeking out food items. When anglers fish for these species, worms, yabbies and shrimp are the most common baits. Go to a dam containing perch and find out for yourself which bait is the best.

Things to find out

- 1 Look up books or the internet to find out how Sydney rock oysters or yabbies are farmed. Make a list of the similarities and differences between how they are produced and how fish are farmed.
- 2 Some environmentalists claim that farmed salmon are the 'battery hens' of the sea. Discuss what they mean by this and whether you believe their concerns are valid.
- 3 When releasing fingerlings into a dam, why is it necessary to add small amounts of dam water into the bag for about 20 minutes before releasing the fish from it?
- 4 Why is it illegal to use English perch (redfin) or European carp for stocking dams in New South Wales?

Extension activities

- 1 Describe the freshwater farming techniques needed for barramundi or rainbow trout farming.
- 2 Compare and contrast extensive and intensive aquaculture systems. Indicate the advantages and disadvantages of each system.
- 3 Discuss the differences between aquaculture and fishery management.
- 4 Describe the farming techniques required for prawn farming.
- 5 Aquaponics is a food production system that combines aquaculture with hydroponic practices. Research how aquaponic systems are built and list the advantages of combining these two systems of food production.

Test yourself

- 1 Why is aquaculture an important industry?
- 2 What are the two forms of aquaculture farming?
- 3 Describe the common species of farmed fish.
- 4 What factors limit the level of productivity in an aquaculture enterprise?
- 5 Discuss the impact of climate change on aquaculture.
- 6 What welfare considerations must be taken into account when farming fish?

UNIT 6

FARMING TO MAKE A DIFFERENCE

CHAPTER 36

FARMING AS A BUSINESS

Words to know

business the organising and running of a farm so that money can be made

markets places where farm produce is sold

monitoring measuring what happens in a production process (e.g. how much feed is eaten by growing pigs and how much weight they put on as a result of eating this feed)

produce anything produced on the farm that is sold (e.g. wool, wheat, pigs, vegetables, milk or beef cattle)

resources things that are used in production (e.g. land, labour, fertiliser, money)



Shutterstock/Mojca Odar

Figure 36.1 Most Australian farms are family farms.

Introduction

Farming requires a **business** approach to maintain quality of life and conserve the environment. The farmer must be aware of how much money the farm is making because the costs of inputs rise much faster than the price received for **produce**. The farm has to provide for the needs of the family – farmers can no longer afford to be on the land just for the way of life.

Running the farm as a business

Most farms in Australia are family farms – they are owned and managed by farmers and their families. A business approach to running a farm requires care in planning, management, record keeping and **monitoring** of physical and financial progress. To run a farm as a business a farmer must:

- **Set goals.** The farmer decides how much money is needed to provide for the needs of the family. This then becomes one of the goals the farmer aims to achieve. Various things have to be considered here, including the education needs of the family, the cost of food, clothing, car, holidays, entertainment and anything else that is considered necessary for living (Fig. 36.2).
- **List all the resources of the farm.** These include:
 - a **physical resources** – the various kinds of land, buildings, fences, and water facilities for stock and irrigation
 - b **financial resources** – the amount of money invested in the farm, and any money in held banks, building societies, credit unions or invested elsewhere
 - c **labour resources** – usually the farmer is a full-time worker and other members of the family (spouse and children) (Figs. 36.2 and 36.3) are part-time workers.
- **List possible enterprises.** All the possible enterprises that could be undertaken on the farm must be listed. The available resources, the climate and the **markets** are important considerations in determining what can be achieved on the farm. The enterprises that neighbouring farms are running can be a good guide as to what might be achieved. Enterprises completely new to the district are also worth considering, and should be added to the list.
- **Choose enterprises.** From the list of possible enterprises, a few must be selected – it is a good idea to choose more than one enterprise. Then, if the prices drop for the product of one particular enterprise, the farmer will still be able to generate income from the other enterprises. The idea is avoid putting ‘all your eggs in the one basket’. If possible, the enterprises should be unrelated as far as the price received for the product is concerned. For example, wheat growing and wool production are often performed on a single farm. Because the prices of wheat and wool are unrelated, changes in the price of wheat have no effect on the price of wool, and it is rare for the prices of both to be low at the same time.
- **Finance the farm.** The farmer budgets to calculate how much money is required to finance the enterprises chosen. The amount of money the

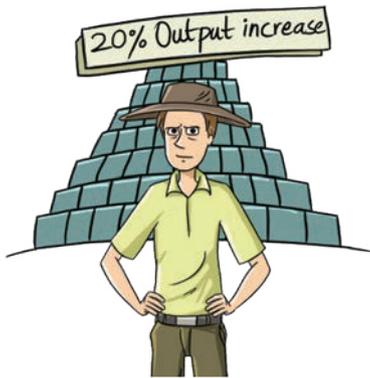


Figure 36.2 Set goals.



Figure 36.3 Make a list of the farm's resources.

farmer has on hand usually will not be enough, so money must be borrowed. The amount to be borrowed is calculated by subtracting the money on hand from the total amount required to set up and run the enterprises chosen.

	\$
Cost of producing 600 tonnes of wheat	120 000
Cash on hand	–31 800
Total amount to be borrowed	= 88 200

Financial institutions, banks and pastoral companies provide loans. Farmers can shop around to find the best deal for the money required (Fig. 36.4).

- *Put the plan into action.* When the money is available, production for the planned enterprises can begin, and livestock, equipment and other inputs can be obtained. The process of putting the plan into action may take several years, especially if it involves planting fruit and nut crops or establishing improved pastures.
- *Monitor progress.* While the enterprises are running, it is important to monitor progress. Good records enable the farmer to measure how efficiently the farm is running and how much money it is really making. The farmer will be able to determine if set goals are being achieved. Information from the monitoring process will identify areas in the enterprises that can be changed to improve performance. A farmer may also compare the performance of the farm enterprises with similar enterprises on other farms in the district. This is termed ‘benchmarking’ and provides the farmer with a standard to both monitor and evaluate progress.



Figure 36.4 Shop around for finance.

- 1 Why is it more important to run a farm as a business now than it was in the past?

Components of a farm business

Consider a farm business as being composed of eight major components, as shown in Figure 36.5. The farm business is the outermost circle and all of the eight components inside must be considered by the farm manager and be performing well if the farm business is to be healthy and bring in the returns it should. Note that actual production, ‘enterprise management’, is only one of the eight components. The components are described as follows.

- 1 *Mission objectives* provide the overall direction of the business.
- 2 *Natural resource management* considers the environment and the sustainability of the farm.
- 3 *Financial planning and control* manages the money aspects of the business, ensuring that money is invested wisely in the farm and consideration is given to things like taxation.
- 4 *Enterprise management* involves running the farm’s enterprises, ensuring that they are physically productive.
- 5 *Marketing management* involves advertising the farm’s product to promote sales, and adopting processes that ensure the best prices are received. A good farm manager will be aware of what the market wants with regard to the product and will use feedback from the market to adjust production to better meet market specifications. Marketing management also involves looking for better or new ways to market products, which may include finding niche markets and value adding.

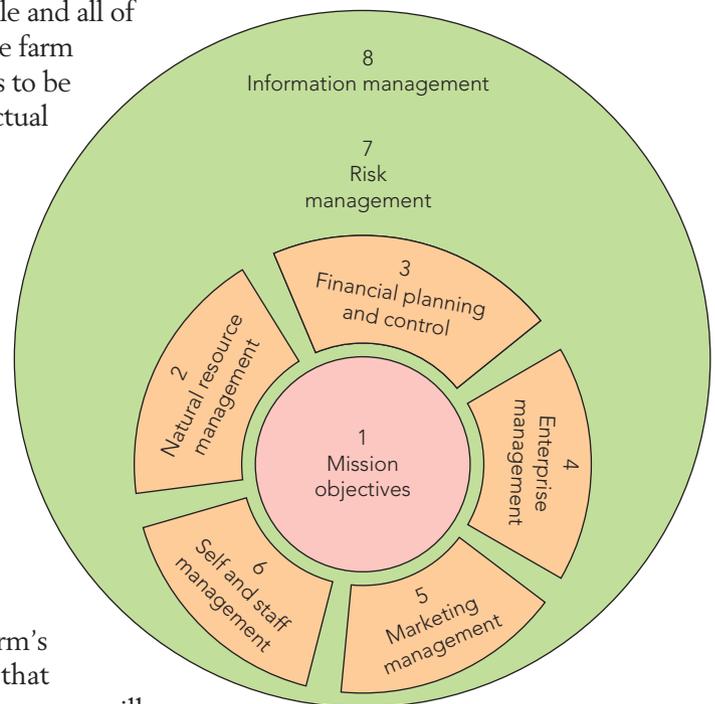


Figure 36.5 What to consider in managing a farm

2 Write down the list of processes that the farmer goes through in running the farm business.

- 6 *Self and staff management* attends to the needs and wellbeing of the human resources of the farm, which includes the farm manager.
- 7 *Risk management* reduces the possible adverse effects of factors partially outside of the manager's control. Risk arises from two sources:
 - the uncertainty of both the prices received for the farm products and the prices paid for the inputs to the farm
 - the uncertainty of the climate and weather and incidence of pests and disease, which can cause farm production to fluctuate.
- 8 *Information management* is one of the biggest challenges farm business managers face. Being able to sift through the vast amounts of information available and select what is most appropriate for a given situation is the key to success.

As the years go by

Running a farm requires ongoing monitoring and adjustment of processes over the years, and this is integral to a farm's success. Changes will occur in the wider environment of the agricultural industries. Government policies will change, affecting entire industries, while changes in the prices of agricultural products will affect what happens on individual farms. Some enterprises will become uneconomic and will be abandoned. Changes in the farmer's family will alter the farmer's goals. Changes in technology will improve the efficiency of production. Completely new enterprises will become possible and the farmer may adopt them. This means that the farmer must:

- 3 List the components of a farm business shown in Figure 36.5.
- 4 List three things that would make the farmer adjust or change the enterprises in a farm business.

- identify the goals to try to achieve
- assess how the farm is being managed to achieve these goals
- adjust enterprises as necessary to achieve these goals.

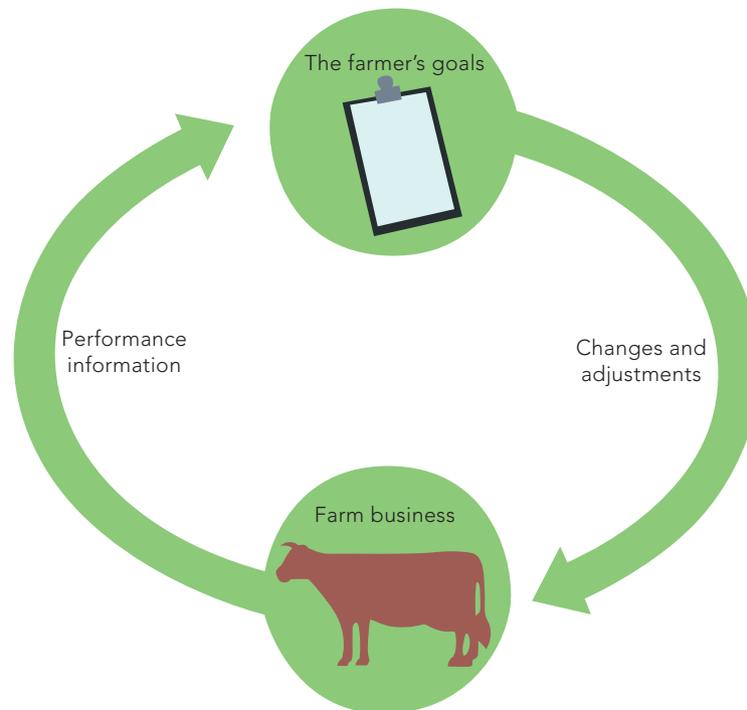


Figure 36.6 Monitoring and adjustment is a continuous process.

Chapter review

Things to do

- 1 Talk to a farmer to try to learn about these factors.
 - a The goals that are set for the farm business
 - b The enterprises on the farm
 - c Changes to the farm that have been made in the last 10 years
 - d Why the changes were made
 - e The markets the farmer is trying to reach
 - f The trends in the markets for the farm's products

Things to find out

- 1 Research the current prices being received by farmers for wheat, wool and beef. How do these prices compare with prices 2 years ago? (Refer to *The Land* market reports.)
- 2 Research the current prices of some inputs to a farm, such as diesel fuel and fertiliser. How do these prices compare with prices 2 years ago? (Refer to *The Land* market reports.)
- 3 Use the information you gathered in Questions 1 and 2 of this section to compare the change in the prices of products and the prices of inputs. Which has shown the greater change – the prices received by the farmer or the prices paid by the farmer?

+ Extension activity

- 1 Farm managers need to continually improve their skills and knowledge of farm management. Visit the [PROfarm](#) website for more information.
- 2 Follow three of the links on the [PROfarm](#) website and describe how a farmer's management skills could be improved by implementing the ideas outlined in the course.

connect

PROfarm

Test yourself

- 1 Describe what has happened to the price of farm products compared with the cost of farm inputs over recent times.
- 2 List four things to consider when setting the goals for a family farming business.
- 3 List two sources of finance for a farm business.
- 4 Explain why record keeping is useful in managing a farm business.
- 5 List the two sources of risk to a farm business.
- 6 Explain why it is recommended that more than one enterprise is selected for a farm.
- 7 Create a diagram to show how monitoring and adjusting is a continuous process in farm management as the years go by.

CHAPTER 37

DECISION-MAKING ON FARMS

Words to know

continuing education learning undertaken after a person has left school

decision choice of one course of action from two or more alternative courses of action

extension officers people who advise farmers on how to farm (e.g. a beef cattle officer gives advice on beef cattle production)

field days organised gatherings at which an aspect of farming is demonstrated for those interested to see and learn

financial budget the predicted expenditure and income from a farm business

input anything that goes into or is used up in a production enterprise (e.g. seed for a wheat enterprise or hay for a milk-production enterprise)

journal a magazine published regularly on a particular subject

noxious plants and animals that cause problems in some way, which landowners are legally required to control

physical budget the predicted use of inputs and level of production for a farm or enterprise of a farm

Introduction

Everyone has to make **decisions** and the farmer is no exception. The farmer has to make decisions every day that affect the level of performance of the farm and consequently the quality of life of those dependent on the farm. These decisions range in importance from small, everyday things (such as whether to mend the fence or drench the sheep today) to momentous decisions (such as whether or not to buy the farm next door). Examples of important decisions that the farmer must make include the following.

- Should I sell the lambs this week or next?
- Should I buy a new harvesting machine this year?
- Should we change from producing beef cattle to running Merino sheep for wool?
- Should soil conservation works be carried out on the farm?
- What variety of wheat should we sow this season?
- How much superphosphate fertiliser should be spread per hectare on the improved pasture?

All decisions involve risk – the likelihood or chance of the result of a decision having bad consequences. Risk for the farmer comes from two sources, as discussed in Chapter 36, page 406. The first is the risk that prices will change. The costs of **inputs** to the enterprises could rise and the price received for farm products may fall. Either of these may result in financial loss for the farmer. The second source of risk comes from the environment. The weather is important – both droughts and floods can cause farm enterprises to fail. The sudden or unexpected outbreak of pests and disease can also severely reduce production.

The quality of a decision depends on the accuracy of the information on which the decision is based. Therefore, good advice and information are essential for the farmer.

Making good decisions

Some decisions are easy for the farmer to make because it is obvious what must be done. For example, if a lot of rain has fallen and the ground is too wet for ploughing it is easy to decide not to plough. Other decisions – for example, deciding whether to buy a harvesting machine to harvest the wheat crop or to hire a contractor to do the harvesting – are not so easy to make. To make a good decision you must go through the following steps in the decision-making process.

- 1 Recognise that there is a problem or a need for a decision to be made. Sometimes it is clear when a decision has to be made and at other times it is not.
- 2 Collect as much information as possible about the problem. This is very important because how good the final decision is will depend on the information that is gathered. Very few decisions are made with all the relevant facts and information at hand. If you wait until all the information is available no decision will be made.
- 3 List all the alternative solutions to the problem. These alternatives will emerge as the information is collected. Write them down as they come to mind.
- 4 Choose one course of action from the list of alternative solutions. Choose the one that best suits your aims and purposes.



Figure 37.1
Everyday decisions



Figure 37.2
A momentous decision

- 1 Why do farmers need advice and information?



Figure 37.3 Recognise the problems.



Figure 37.4 Collect information.



Figure 37.5 Choose one course of action.



Shutterstock/Walanna

Figure 37.6 Put the plan into action.



Shutterstock/Kletr

Figure 37.7 Observe what happens.



Figure 37.8 Take responsibility for the decision.

- 5 Put the course of action into practice; that is, carry out the chosen plan.
- 6 Observe and evaluate what happens as a result of adopting that course of action. Did the plan work out the way you wanted it to or did something unforeseen come up to prevent the desired result?
- 7 Take responsibility for the results of your decision – whichever way it goes.

One thing should be clear: how good a decision is depends on the accuracy of the information used to make the decision. Information used by farmers to make decisions comes from records kept on the farm and from many other sources.

Budgets in decision-making

- 2 Outline briefly the steps in the decision-making process.

Many of the major decisions made on a farm are made with the goal of making a profit or a living. Budgeting is one tool used by farmers to help make decisions on a financial basis and to make a farmer more aware of the risks.

Budgets are predictions of what will happen in the future, usually next year. First, the farmer works out a **physical budget**. A physical budget estimates how much will be produced and how much of the various inputs will be needed (based on past production records or district averages) to achieve this production. For example, if the aim of the farmer was for the wheat enterprise to produce 300 tonnes of wheat, a physical budget would be drawn up as shown in Table 37.1.

Table 37.1 A physical budget for producing 300 tonnes of wheat

Wheat production target	300 t
Land required (at wheat yield of 1.5 t/ha)	200 ha
<i>Inputs</i>	
Fertiliser (at 100 kg/ha)	20 t
Seed (at 80 kg/ha)	16 t
Herbicide (at 21 L/ha)	400 L
Tractor running for cultivation and spraying (at 2 h/ha)	400 h
Harvesting (at 1.5 h/ha)	300 h

Next, a **financial budget** for the wheat enterprise is prepared. The price to be received and the costs of the inputs are estimated. A financial budget for the wheat enterprise already described is shown in Table 37.2.

Table 37.2 A financial budget aimed at producing 300 tonnes of wheat

Income	\$
300t of wheat (at \$280/t)	84 000
Costs	
Land rent (200 ha at \$23/ha)	4 600
Fertiliser (20t at \$720/t)	14 400
Seed (16t at \$300/t)	4 800
Herbicide (400 L at \$15/L)	6 000
Tractor running cultivation, sowing and spraying (400h at \$17.00/h)	6 800
Harvesting (300h at \$11.00/h)	3 300
Total costs	39 900
Expected profit (income – costs)	44 100

The farmer can make several different budgets to gain an idea of possibilities and outcomes by varying:

- the amounts of inputs (e.g. fertiliser or seed)
- expected levels of production (e.g. the worst possible yield and the best possible yield)
- the expected prices for the product
- the prices of the various inputs
- the combinations of inputs, expected yields, costs of inputs and expected prices.

There is a lot to calculate when drawing up a budget. This alone often reduces the number of alternatives a farmer considers.

Computers and software programs have taken the drudgery out of calculating, because the farmer can draw up multiple alternative budgets in a very short time. This gives the farmer a better chance of making a good decision.

Budgets can be drawn up for various levels of the farm operation. Whole-farm budgets are usually prepared for the next year, but if a farmer was thinking about going into an enterprise that would run for several years before any produce could be sold, whole-farm budgets would be made for several years. Budgets for single enterprises or even small parts of an enterprise are used when considering small changes, such as increasing the area of the farm sown to wheat or increasing the number of sheep being run.

Gross margins

A gross margin indicates the profitability of an activity on the farm. The gross margin includes only the variable costs (costs that change during production), not fixed or overhead costs. Gross margins are calculated on a per unit basis (e.g. per animal, per hectare, per person).

$$\text{Gross margin} = \text{total income} - \text{variable costs}$$

This calculation allows for general comparisons between possible enterprises on a farm, or on similar enterprises between farms in the same district.

View the [DPI Agriculture](#) website for an example of specific market-focused gross margins for beef cattle.

- 3** Draw up physical and financial budgets similar to those in Tables 37.1 and 37.2 to help answer the following questions.
- If the season was not as good as expected because there was a drought and the quantity of wheat produced was only 130 tonnes from 200 hectares of land, would the farmer make a profit from the wheat?
 - If the price of wheat fell to \$100 per tonne when it was sold, would the farmer make a profit?
 - If the yield was 1.7 tonnes per hectare, the price was \$160 per tonne, the cost of fertiliser was \$870 per tonne and the cost of harvesting was \$13 per hour, would the farmer make a profit?

connect

DPI Agriculture

Farm Business and Trade → Farm budgets and costs → Livestock gross margins → Examine beef cattle gross margins

Seeking advice and information

Many sources of both information and advice are available to the farmer.

Government sources

The Department of Agriculture in each state is very important to the farming community. Each department employs **extension officers** to distribute advice and information covering areas such as sheep, cattle, pastures, crops, bees, machinery and mechanisation, and horticulture. These officers also visit farms and conduct **field days** to share the latest ideas with farmers. The officers are situated throughout the farming districts so that they are easily accessible to the farming community.

Each Department of Agriculture (DPI in NSW) publishes information in regular **journals** and single subject sheets, known as *Prime facts* (in New South Wales) or *Ag Notes* (in South Australia). These useful sources of information sheets cover a wide range of subjects, and are accessible on the internet, so farmers can get the information they need promptly.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) also provides some important information and advisory services in specialised fields, as a result of research carried out into particular problems. For example, in northern New South Wales, the CSIRO gives feedback to cotton farmers about the level of pests in their cotton crops and the control measures that should be used at a particular time. In the Murrumbidgee Irrigation Area they provide assistance to rice farmers in the management of irrigation water.

The Livestock, Health and Pest Authority (LHPA) have officers who advise on livestock health, the control of **noxious** weeds and the control of noxious animals, such as the rabbit and feral pig.

Weather information is of special interest to farmers. Weather forecasts give farmers some idea of what the weather will be like in the near future and this helps them make production decisions. Weather records and climatic data give the farmer a picture of what the average weather is like in the district. Information on the average rainfall for the year, the average rainfall for each month and the temperature ranges likely throughout the year help the farmer to decide what kinds of production enterprises can be successfully carried out.

-
- 4 How does a farmer get information from the Department of Primary Industry (DPI)?
 - 5 Why are weather reports important to farmers?

Commercial and professional sources

Remember that most non-government providers of information have a profit motive. They are interested in selling their product or service. These providers include the following.

- *Chemical companies* give advice on the correct and safe way to use their products most efficiently. They market a wide range of products from pesticides, herbicides and stock drenches to growth promotants for livestock.
- *Veterinary health companies* supply medicines and drugs for treating animal diseases as well as vaccines for preventing disease. They also give advice on how to use their products correctly and safely.
- *Fertiliser companies* give advice on the use of fertilisers for crops and pastures. Some have soil-testing services that aid in detecting plant nutrient deficiencies. They can then recommend which fertiliser and how much should be used to rectify any deficiencies.
- *Seed companies* supply seed and give advice on how and when to sow different crops and pastures.

- *Feed companies* give advice on the correct way to use their feeds.
- *Banks* can give advice on loans and finance. They may also advise on property values and run services for customers, such as cheque accounts.
- *Stock and station agents* give up-to-date information on the market prices for livestock and property.
- *Insurance companies* advise on insurance of crops, livestock, property, buildings, vehicles, machinery and the lives of farmers and their families.
- *Solicitors* give legal advice. This is important when planning and setting up companies and partnerships, which farmers often form with their families. It is also advisable to use a solicitor when making a will and negotiating the passing of the ownership and management of a farm from one generation to the next (succession planning).
- *Accountants* are experts in taxation matters and setting up accounting procedures for a farm.

Other sources of information

- *Newspapers, books and magazines.* Weekly rural newspapers such as *The Land* in New South Wales, the *Weekly Times* in Victoria and the *National Farmer* provide up-to-date news on what is happening locally and internationally that could affect farms. They also contain market information and a wide range of classified advertisements, including those for the sale of properties, tractors and machinery, livestock and seed, and a host of other things that farmers want to sell or that other people think farmers are likely to buy. Rural magazines are published monthly and are a good source of new ideas and information about what other farmers have found successful.
- *Books.* Many books have also been published on various aspects of farming. They should not be ignored when looking for information for the farm.
- *Computers and the internet.* When computers are used for record keeping and for handling complex and tedious calculations, farmers can organise their information more efficiently and get better feedback on farm performance, leading to better management. Farmers using the internet on their computers can access various information services and data sources, from weather reports to market reports and technical information.
- *Education.* Opportunities for education in agriculture are becoming more readily available. Many Technical and Further Education (TAFE) courses in rural areas are useful to farmers, such as courses in wool classing and rural welding. Agricultural colleges and universities offer full-time, part-time, distance, online, short course and **continuing education** programs in many aspects of farming and farm management.
- *Field days.* A regular feature of rural life, field days are run by Department of Agriculture officers in cooperation with private firms. Field days give farmers the opportunity to see new technology of all kinds in use. Some field days are small, involving only a limited number of people with a specialised interest; for example, breeding queen bees. Others, such as field days where machinery can be compared while it works, are huge events attended by thousands of people.



Figure 37.9 Computers are common on farms

- 6 What role do books, magazines and newspapers play as a means of information gathering for farmers?
- 7 Explain how a computer is used on a farm.
- 8 What are field days for?

Chapter review

Things to do

- 1 Draw up a physical and financial budget for a vegetable crop you propose to grow on your school farm or in your garden at home. Grow the crop and keep accurate records of the amounts used and costs of seed, fertiliser and other inputs. Carefully record the amount of production and use prices for the vegetable at the local fruit shop to calculate how much you actually earned. Compare what happened with your budget.
- 2 Go to your local newsagent and make a list of all the newspapers and magazines about farming that are on sale.
- 3 Draw up a physical and a financial budget for the running of the poultry unit on your school farm for the next month.
- 4 Use the decision-making process described in this chapter to decide whether you should plant a crop of carrots or a crop of beans in a 1 m × 2 m plot on your school farm in the next month.

Things to find out

- 1 When you visit a farm, find out:
 - a why the farmer decided to run the enterprises that are currently on the farm.
 - b whether the farmer uses a computer to assist with budgeting.
- 2 Find out which educational courses on farming and agriculture would be available to you if you were leaving school:
 - a with a Higher School Certificate.
 - b without a Higher School Certificate.
- 3 Outline three examples of information that can be accessed from the internet and that would be useful to a farmer.

Extension activities

- 1 Use a spreadsheet to set up the physical and financial budgets shown in Tables 37.1 and 37.2. Key in the formulas so that you can change the level or the cost of any of the inputs or the price received for wheat and see instantly the effect that this has on the expected profit. For example, try decreasing the price of wheat to \$200/t; increasing the cost of fertiliser to \$300/t and herbicide to \$40/L. Find out some real prices and costs to use in your spreadsheet.
- 2 Find the website for the Department of Agriculture or its equivalent in your state and learn what information useful to farmers can be accessed on the site.
- 3 Go to the [Bureau of Meteorology](#) website to find out the weather forecast for your district for the next 3 days. Research the climatic records for your area. What are the annual average rainfall, average monthly rainfall, and the average maximum and minimum temperatures?

connect

Bureau of Meteorology

- 4 Contact a seed, feed or fertiliser company to find out about services they provide for farmers beyond supplying seed, feed or fertiliser.
- 5 Assess the role of computers as a tool for farmers to gain information to help manage their farms.

✓ Test yourself

- 1 Explain why budgets are so useful in a farmer's decision making.
- 2 List two reasons farmers would use a computer in the decision-making process.
- 3 List three opportunities for farmers to study courses that would improve their agricultural education.
- 4 A farmer must decide on a crop to grow this year. The decision-making process is being followed carefully and the farmer has reached the stage of deciding to grow canola. Outline the rest of the steps the farmer would follow to complete the decision-making process.
- 5 Construct a mind map that shows 10 commercial and professional sources of information for farmers. Start with a circle in the middle of a page with 'Farmer' written in it.

CHAPTER 38

FARM RECORDS AND INFORMATION STORAGE

Words to know

assets things a farmer owns (e.g. land, buildings, stock and machines)

credit money or goods given to people to be paid back or paid for in the future; there is usually a charge for credit (interest)

diary a daily or weekly record of events (e.g. a farm diary is a record of what happened on the farm)

enterprise one of the production subsystems (e.g. wheat production, wool production or pig production)

equity the difference in value between what the farmer owns (assets) and what the farmer owes to creditors (liabilities)

inventory a list of items a farmer has on the farm (e.g. livestock); it may include the number, quantity and value of those items

investor a person who puts money into a business with the hope of making money – the farmer invests in his own farm

liabilities debts (e.g. a loan from the bank or a fuel bill)

Introduction

Farm records tell the farmer what has happened on his or her farm. Records are useful for:

- showing how much was produced and how much was used to produce it (in wheat production, land, seed, fertiliser, fuel and chemical sprays are used)
- keeping track of progress on the farm
- making the farm business more efficient
- preparing taxation returns
- planning for the next year.

Physical records

Diaries are a day-to-day record of what happened on the farm. A **diary** is a means of collecting information but it does not organise the information. They are useful if they contain information that can be used for drawing up other records such as inventories and paddock records. Computer records are now kept although field diaries are still used.

The information that goes into the paddock record comes from the farm diary. The paddock book contains records of what happened to each paddock on the farm. There is a separate section for each paddock so that all the records about one particular paddock are in the one place. Records may include:

- name or number of each paddock
- area
- soil type
- grazing history
- pasture improvement activities (including fertiliser history)
- fodder production.

Table 38.1 shows the entries on a page of a paddock record book. It is easy to see the history of the paddock and how productive it has been.

Table 38.1 A page from a paddock record book

Paddock no. 1 Size: 24 ha						
Date	Operation	Fertiliser	Spray	Seed	Yield	Comments
17/1/14	Grazing sheep					95 put in
31/1/14	Sheep removed					95 out
2/2/14	Slashing					2 days
4/2/14	Irrigation					50mm
20/2/14	Weed control		Burkil 2L/ha			Bathurst Burr
2/3/14	Grazing					80 put in
13/3/14	Sheep removed					80 out
20/3/14	Sod seeding	Superphosphate 100 kg/ha sulfate of ammonia 85 kg/ha		Saia oats 80 kg/ha		
21/5/14	Irrigation					50 mm
15/6/14	Grazing sheep					130 put in
20/6/14	Sheep removed					130 out

Inventories are lists of things that the farmer has on the farm. Inventories kept would include:

- livestock
- hay stored on the farm
- fertiliser
- stock feed
- seed
- machinery.

1 How could the physical records kept in a diary be organised and made more useful?

The **inventory** is best kept so that it records gains and losses and it should be brought up to date every month. Table 38.2, an inventory for fertiliser, shows precisely how much fertiliser the farmer has at any one time.

Table 38.2 A fertiliser inventory (50kg bags)

Purchases (plus)					Use (minus)				
Date	Super	Molybdenum super	Nitrophoska	Sulfate of ammonia	Super	Molybdenum super	Nitrophoska	Sulfate of ammonia	Total
15/3/14	20	5	10	10					45
20/3/14					4		1	1	39
2/6/14							2	2	38
14/7/14							2	2	31
Subtotal	20	5	10	10	4		5	5	31
On hand	16	5	5	5					31
30/8/14					16				15
1/11/14	10								25
3/11/14					8		4	4	9
Subtotal	26	5	5	5	24		4	4	9
On hand	2	5	1	1					9

Financial records

Financial records tell the farmer what is happening to the farm business financially.

- Is it making a profit?
- How much money will have to be borrowed from the bank to keep the business afloat until the wheat crop is harvested and sold?
- How much is the money invested in the farm (capital) earning for the **investor** (usually the farmer)?

Farm financial records and the calculations made from financial records help to answer these questions.

Financial statements allow the farmer to know at any one time how much money is invested in the farm and how much money the farmer owes to other people (businesses and firms) who have lent money or supplied goods and services on **credit**. The farm and everything on it that the farmer owns are known as **assets**.

All the debts the farmer has are called **liabilities**. Table 38.3 is a financial statement for a lucerne farm on 30 June 2014. All the assets and their values are listed on one side. On the other side all the liabilities are listed with their values. The total assets and liabilities are calculated by adding up both sides of the financial statement. Total assets in this case are \$2 462 500 and the liabilities are \$993 300. The value of the

liabilities is then subtracted from the value of the assets. What remains, \$1 469 200, is the **equity** of the farmer or farm business.

$$\text{Equity} = \text{assets} - \text{liabilities}$$

Remember: a financial statement only tells us what the farmer's financial position is at one particular time.

Records of cash flow allow the farmer to answer the question: 'How much money am I earning?' The farmer subtract the farm costs from the farm income and the result is *profit*.

$$\text{Profit} = \text{income} - \text{cost}$$

Table 38.3 Financial statement for a lucerne hay farm

Assets	\$	Liabilities	\$
Land 400 ha at \$4000/ha	1 600 000	Loan for land purchase	800 000
House	350 000	Loan for machinery	175 000
Vehicles		Unpaid bills	
Tractor	175 000	Fertiliser	8 000
Truck	120 000	Fuel	6 000
Hay machines	140 000	Insurance	2 400
Car	25 000	Machine repairs	1 900
Ute	18 000		
Sheds (hay and machinery)	50 000		
Irrigation plant	80 000		
Hay 1000 bales at \$12/bale	12 000		
Fertiliser 10t at \$750/t	7 500		
Diesel fuel 2000L at \$1.50/L	3 000		
Money in bank	8 000		
Total assets	2 588 500	Total liabilities	993 300
		Equity	1 595 200

2 Of what use is the financial statement to the farmer?

Determining costs

The farmer must keep very accurate records of all bills, ensuring the following information is recorded for each bill paid:

- amount paid
- date paid
- recipient
- the purpose of the payment.

Paying bills with cheques is one way to record payments because the information is written on the cheque butt and stays in the cheque book. The cheque itself is sent to the payment recipient. To calculate the farm's monthly costs, the farmer adds up all the amounts on the cheque butts for that month.

It is easier to write all the details in a cash book than work from cheque butts. A cash book also allows the different costs to be put under headings for different **enterprises** on the farm, such as sheep, cattle or machinery repairs.

Farmers can also use computers to facilitate their payment (for example, electronic funds transfer, BPAY or PayPal) rather than cash or cheque. When using

- 3 List the records that are useful in keeping track of cash flow in a farm business.

an electronic form of payment, it is essential that the details of the transaction be recorded, either in a cash book or in suitable bookkeeping software.

Determining income

When farmers are paid for their produce they receive the money by cheque, cash or electronic funds transfer into their bank account. The following details of the payment must be recorded in the cash book:

- amount paid
- date paid
- payer
- purpose of the payment.

The income can be entered under enterprise headings in the same way costs were. At the end of each month the total income is calculated by adding up all the individual incomes for that month. Again it is more than likely that income records will be kept on computer using a bookkeeping program. These programs are very useful because they allow the farmer to keep a very close eye on what is happening to farm finances.

Once costs and income have been calculated, profit (or loss) can be determined for the month. If all the costs and income are added up for a 12-month period, the profit or otherwise for a year can be calculated (see Table 38.4). Working out the costs and income each month gives a farmer an overview of what is happening. It is easier to approach a bank for a loan if you know how much money you really need. A record of cash flow for the last 12 months helps your planning for the next 12 months because you can anticipate where cash is likely to be short and when borrowing may be necessary.

Having the costs and incomes for different enterprises in different columns in the cash book allows the farmer to compare the performance of each enterprise. The more profitable enterprises may be expanded and the less profitable ones may be abandoned.

Table 38.4 Summary of a farm’s cash flow over a 12-month period

Month	Income (\$)	Costs (\$)	Difference (\$)	Balance (\$)
July		2000	- 2000	- 2000
Aug.		1000	- 1000	- 3000
Sept.		1000	- 1000	- 4000
Oct.		1000	- 1000	- 5000
Nov.		6000	- 6000	- 11000
Dec.		8000	- 8000	- 19000
Jan.	30000	1000	+ 29000	+ 10000
Feb.		2000	- 2000	+ 8000
Mar.	4000	2000	+ 2000	+ 10000
Apr.		4000	- 4000	+ 6000
May	2000	1400	+ 600	+ 6600
June		1000	- 1000	+ 5600
Total	36000	30400	+ 5600	+ 5600

- 4 Explain how a farmer may use the record of cash flow for the business.

Chapter review

Things to do

Table 38.5 shows a farm diary over a 3-month period. Each date has two entries, under the headings Heads and Tails. The table contains information about costs of purchases and prices received for things sold. This information would normally be on cheque butts (costs) and incoming cheques (sales) or recorded in a bookkeeping program. To save space we have included them in the diary.

To choose which entry to use for a particular date when working on the inventory (question 1) or the cash book (question 2), just flip a coin.

Table 38.5 A farm diary

Date	Heads	Tails
SEPT	20 ha potatoes were planted 2 months ago	20 ha potatoes were planted 2 months ago
1/9	All sheep counted, rams 40, ewes 600, lambs 550, wethers 200	All sheep counted, rams 44, ewes 700, lambs 600, wethers 210
2/9	Side dressing of complete fertiliser for potatoes 100 kg/ha, cost \$160/ha	Side dressing of sulfate of ammonia fertiliser for potatoes 120 kg/ha, cost \$100/ha
10/9	50 old ewes culled: sold for \$22 each	60 old ewes culled: sold for \$22 each
12/9	Cold snap, 10 lambs and 1 wether die	Cold snap, 50 lambs and 10 wethers die
20/9	All sheep on farm drenched: cost \$1.00/head	All sheep on farm drenched: cost \$1.50/head
25/9	200 lambs sold for \$64 each	200 lambs sold for \$76 each
OCT		
2/10	150 lambs sold for \$60 each	100 lambs sold for \$62 each
4/10	Spray potatoes for potato moth: cost \$65/ha	Irrigate potatoes \$14/ha
6/10	1 ewe died – unknown cause	10 lambs died – pulpy kidney
16/10	Sold 150 lambs for \$64 each, 10 culled rams for \$40 each, 40 culled wethers for \$38 each	Sold 100 lambs for \$64 each, 5 culled rams for \$40 each, 38 culled wethers for \$38 each
20/10	Buy 50 young ewes \$100 each	Buy 60 young ewes \$105 each
28/10	Buy bags for potatoes \$1200	Buy bags for potatoes \$1100
29/10	Spray potato crop to kill plants before harvest \$70/ha	Slash potato crop to remove plants before harvest \$55/ha
NOV		
4/11	Sold 50 lambs for \$60 each	Sold 70 lambs for \$54 each
11/11	Harvest potato crop, cost \$300/ha	Harvest potato crop, cost \$380/ha
12/11	Casual labour at potato harvest 1 week \$760	Casual labour at potato harvest 1 week \$760
18/11	Buy 41 wethers for \$90 each	Buy 50 wethers for \$50 each
29/11	Buy 10 flock rams for \$320 each	Buy 5 flock rams for \$310 each
30/11	Sold 450 tonnes potatoes for \$700/t	Sold 380 tonnes potatoes for \$700/t

- 1 Use spreadsheet software to draw up a livestock inventory as shown in Table 38.6 and use the information in the farm diary (Table 38.5) to make a livestock inventory for the 3 months. Include formulas that calculate the subtotal and the stock on hand at the end of each month.

Table 38.6 Example entry: a livestock inventory for sheep if a 'tail' was thrown for 1 September

Plus					Minus				
Date	Rams	Ewes	Lambs	Wethers	Rams	Ewes	Lambs	Wethers	Total
1/9/14	44	700	600	210					1554

- 2 Use the information in the diary to draw up a cash book using spreadsheet software. Use the headings shown in Table 38.7. Make sure your cash book at the end of each month calculates:
 - a the total costs and income for potatoes and sheep.
 - b the progressive total income and expenditure. Check that the difference between these two figures is the same as the 'balance' at the end of the month.

Table 38.7 Example entry: cash book if a 'head' was thrown for 2 September

Date	Details	Income (plus) \$		Costs (minus) \$		Total (\$)
		Potato	Sheep	Potato	Sheep	
2/9/14	Fertilise potatoes with complete fertiliser			3200		-3200

Things to find out

- 1 A farmer calculates the return on the \$500 000 capital invested in the farm is 7.5 per cent. Find out what the farmer's capital could earn if invested in other ways, such as in banks, shares, real estate or bonds.
- 2 Find out what information is required so a farmer can calculate the return on the capital invested in a farm over a 12-month period. How is it calculated?
- 3
 - a Research and then describe how computers are used for keeping and storing farm records.
 - b Identify two software programs that are available for farm record keeping.

Extension activities

- 1 Use spreadsheet software to compile a financial statement using the information in Table 38.3.
- 2 Select an enterprise on the school farm and design a record-keeping system for it that enables you to track:
 - land, livestock and materials used
 - the costs of inputs such as feed and fertiliser
 - the income received from product sales
 - the profit or loss for a cycle of production, or one year.

Test yourself

- 1 List three reasons that records kept on farms are useful.
- 2 Describe how a farm diary is used as the basis for other more useful farm records.
- 3 Outline how a financial statement would be calculated for a farm.
- 4 Explain what a farmer can do before approaching financial institutions such as banks to obtain a loan to finance the farm business.

CHAPTER 39

SIMPLE EXPERIMENTAL DESIGNS

Words to know

bias a form of prejudice, or slant, experienced when collecting or analysing experimental results

control the standard to which a new technique, treatment or variety is compared, or a part of an experiment that does not receive the main treatment

data information gained through measurement (quantitative data) or the collection of observations (qualitative data)

experimental error a deviation from the true measurement expressed as a percentage

hypothesis a concept or idea to be assessed or tested

random selection choice without pattern or method so that all members of a population have an equal chance of being involved in an experiment

replication conducting the same experiment repeatedly to gain a more accurate estimate of the true value or result by reducing variability

scientific method a method of problem solving that involves the testing of an idea through the use of experiments and the analysis of data

standardise making all conditions for each aspect of an experiment (e.g. climate, soil or slope) as equal as possible

theory a generally accepted explanation of a principle or observation

Introduction

Farmers must make many decisions in the course of running their business. They have to decide on such things as:

- the type and amount of fertiliser to apply to a crop or pasture
- the amount of chemical spray to apply to a production subsystem
- the varieties of plants and animals to use on a farm.

Yet few farmers actually perform experiments to obtain results that will help them to make decisions. They may attempt simple trials or act on the basis of experience. Most often farmers apply the results of research carried out by experts from the Department of Agriculture, the Commonwealth Scientific Industrial and Research Organisation (CSIRO) or other firms involved in agriculture.

The scientific approach

People are naturally curious about what is happening around them. Scientists are simply people who have specialised in studying what is happening, or has already happened, in a vast array of areas. Some scientists study living systems, some study physical or chemical systems and others study social systems. Scientists attempt to use existing knowledge to solve problems or apply theories to practical situations. In studying events or attempting to solve problems scientists generate new ideas, facts and even more problems to be researched. Scientists use the **scientific method** to examine events. The scientific method can be broken down to a set number of steps that all scientists follow.

Outline the problem

Develop a clear statement of the problem or **theory** you want to investigate, so that everyone reading your experiment knows what you are trying to do. The statement will also help others who wish to repeat your experiment to determine if your results were correct.

Propose the problem

Once you have outlined the problem, you make an educated guess about what you think might happen – this guess is developing a **hypothesis**. A hypothesis needs to be able to be tested scientifically, and is written as a statement, often using an ‘I think it works this way’ or an ‘If ... then’ structure. A hypothesis helps you to decide the types of observations you need to make, the facts you need to establish, and the method you use to collect these.

It is important to remember that it is not possible to ‘prove’ a hypothesis; only to support or refute one.

Gather facts, or data

After formulating your hypothesis, you need to gather the **data** (the facts and observations). Usually, you will use an experiment to do this. Experiments test ideas, confirm observations and clarify deductions (if you are lucky). Experiments need to be repeated several times and the results compared. They must be carried out according to well-defined rules, which will be discussed in Chapter 40.

1 List and describe the main steps involved in the investigation of a problem based on the scientific method.

2 Define ‘hypothesis’.

Make observations and measurements

Critical to any experiment are accurate observations, or measurements of experimental results. It is important that what you record genuinely reflects, or is a measure of, what is occurring. Measurements must be objective and free from observer **bias**. Unfortunately, many factors may confuse the observer or confound the measurements being made. For instance, if you are measuring the effects of applying nitrogen to wheat by recording variations in plant height, how can you make sure that your measurements reflect the effects of the fertiliser rather than the effects of soil type, light intensity or temperature variation? If you are observing a minute organism under an electron microscope for the first time, how can you be sure that you are seeing an organism and not a foreign particle such as the embedding material? You must repeat experiments under identical conditions to test the validity of your observations. On the basis of your observations or measurements, the hypothesis or idea may be accepted, rejected or modified.

-
- 3 Why is it important to remove all sources of bias in an experiment?

Present the results

Once a series of measurements have been taken or observations recorded (that is, the 'method' part of the experiment has been completed), you must outline and present the results clearly. The reader must be able to interpret the results that you have obtained without any confusion.

You might present results using mediums such as diagrams, photos, scientific papers, graphs and tables, but you should match your chosen presentation format with the type of data collected and the intended audience. A scientific paper, detailing all of your ideas and measurements, may be necessary for a gathering of scientists, while a precise summary of your experimental findings may be all that is needed for publication in a newspaper. Diagrams should be clear, and not cluttered by too many labels. Measurements should be well presented and not overwhelming to the reader. Extract the important results that you wish to discuss and leave the remainder in an appendix to your experiment. Where possible, estimate the extent of **experimental error** when measurements are used.

-
- 4 What are some important points to consider when presenting results?

Draw a conclusion

Conclusions are reached on the basis of experimental evidence, and eventually lead to acceptance, modification or rejection of the original hypothesis. In reaching a valid conclusion – that is, one accepted by the majority because it seems to model or reflect accurately what has happened – you must account for all bias. Experimental design is an important factor that will allow you to eliminate factors that could lead to inaccurate conclusions. Many of your conclusions will lead to further experimentation and study. Through the application of the scientific method, over time, scientists have added to the growing body of knowledge and understanding of the real world.

Why conduct experiments?

Experiments are performed to test an idea or investigate an event. Examples of ideas to be tested include:

- the comparative yields of two varieties of plant
- the comparative growth rates of two breeds of animal
- the reliability of a new technique.

Consider the following scenario. An agronomist believes a new variety of wheat will produce more grain per hectare than a currently used variety. To test this idea a farmer decides to plant the entire farm with this new variety and to compare the yield with the previous year's crop. The new variety yields less and it is concluded that the new variety is inferior. However, during the year the farmer noted that rainfall was less than in the previous year. Concerned that other factors may have influenced yields, the farmer approaches the agronomist before discounting the new variety. The agronomist reports that another field experiment in the district indicated the new variety was, in fact, very superior in yield and decides to repeat the trial.

The area of land for the new trial is carefully chosen. The soil's acidity and alkalinity levels are measured. The land has no slope and is well drained; it is also free of trees, sheds and other structures that could interfere with plant growth. The area selected is divided into twelve plots of equal size and each plot is given a number drawn from a hat. Using **random selection**, the farmer plants six plots to the new variety and six to the old variety. Even-numbered plots are sown to the new variety and odd-numbered plots to the old variety (see Fig. 39.1).

5 What environmental factors could influence the outcome of a field experiment such as that conducted by the agronomist?

2 New	7 Old	3 Old	9 Old	10 New	5 Old
8 New	4 New	11 Old	1 Old	6 New	12 New

Figure 39.1 Trial design comparing old and new varieties of wheat

By testing the soil for nutrients and acidity and by selecting an area free from serious problems, the farmer and agronomist ensure that any differences in yield are because of the plants themselves, not other factors. An irrigation system supplies water at a uniform rate. Quantities of the same type of fertiliser are applied regularly to all plots. This process of **standardising** conditions between experimental sites is very important, allowing accurate conclusions based on reliable data from measurements.

The agronomist's experiment is reliable because three important factors are considered in its design.

- 1 Each variety of wheat is sown in a number of different plots. This allows the agronomist to gain a better estimate of its true yield. This process is generally called **replication**.
- 2 The design is random. To avoid accusations of bias (e.g. sowing the new variety in the 'better' plots) each plot has an equal chance of being sown with the new or the old variety.

6 Why are the plots randomly distributed?

7 Why is more than one plot of each variety used?

8 Define the following terms.

- a randomisation
- b standardising
- c control

- 3 The yield of the new variety is compared with that of the old with all other factors, such as soil fertility, rainfall and drainage, being equal. The old variety is a standard, or **control** with which the yield of the new variety can be compared.

Experimental design

Good experimental design is important to effectively test an idea. A good design allows for valid comparisons between treatments and assists in assessing trends in a population. Effective experiments are also efficient (in terms of time and money) to set up and analyse.

Apart from ensuring that an experimental design contains replication of treatments and random allocation of treatments to avoid confusing results, controls are needed as a comparison point. Controls may receive no treatments at all. For example, in a trial to determine the best level of fertiliser to apply to a hectare of oats, the control receives no fertiliser. Other plots receive varying amounts of fertiliser. To achieve replication, several plots receive the same amount of fertiliser (Fig. 39.2).

9 150kg/ha	7 50kg/ha	3 0kg/ha	12 150kg/ha
5 50kg/ha	10 150kg/ha	8 50kg/ha	4 0kg/ha
6 50kg/ha	2 0kg/ha	11 150kg/ha	1 0kg/ha

Figure 39.2 Fertiliser trial design

To prevent variations caused by factors that are not being tested, care is necessary. For example, care must be taken in the husbandry of the crop, to give it every chance to perform at its best. The selected site must be free of any factors that could affect the final result, such as trees shading the land or draughts in sheds. When applying materials such as fertiliser, insecticides or drenches, each group of test samples should receive the same rate of application and a range of application rates should be used.

When experiments involve livestock, animals must be carefully selected to avoid bias. Commonly, only animals of the same breed, age and sex are selected for a given experiment, and are maintained in identical environments and fed identical diets. In any experiment involving living creatures, their welfare must be considered. The experimental plot or herd should not be too large, because time and money may be limited, but it should be large enough to allow replication on an adequate scale. Other considerations in any experiment involving animals include what to feed the animals and how to keep environments identical, along with how to look after the welfare of the animals during the experiments.

Problem-solving in agriculture

During your agricultural course you will be in a position to question certain practices and present intelligent solutions to problems. To develop the skills necessary to question and test concepts, you must learn how to:

- design experiments
- collect and record data
- construct graphs
- interpret graphs and figures in an agricultural context
- produce a written report that interprets results, and draws and presents conclusions.

Farmers require answers to questions that directly relate to the management of the farm. Many of the trials and experiments performed collect measurements or data from large field sites in different locations. Experimenting in the field differs greatly from experimenting in a laboratory. In the laboratory many conditions can be accounted for or controlled, such as water levels, and light and temperature conditions. Even the soil can be made uniform by the selection of particular mixes for use in all pots. In the field the soil can vary in its physical and chemical make-up across a paddock in which a field trial is growing, while daily weather patterns can influence an experimental result significantly.

Keep in mind whether the design of the experiment and the steps followed by the experimenter allow you to make a valid conclusion on the basis of the data collected and analysed. Consider whether factors other than those considered in the experiment could have affected the final result. Also, decide whether or not the experimenter made the right measurements and analysed them correctly.

Practical reports

Practical reports should be written neatly into a separate practical book or keyed into word processing software. Diagrams, graphs and calculations should be recorded as part of any practical activity. Present reports under the following headings – although students, in consultation with their teachers, should learn to judge which headings suit particular experiments.

- 1 *Title*. This should be a brief, specific statement about the topic of the experiment.
- 2 *Date*. At the top of the report, record the date(s) on which the experiment was conducted.
- 3 *Students involved*. If the work involved the efforts of several students, this must be acknowledged.
- 4 *Aim and introduction*. State the specific aim, purpose or hypothesis. An introduction may be warranted where any relevant theoretical information is needed.
- 5 *Apparatus and material*. Mention all specific materials needed for the experiment. Standard pieces of scientific equipment, such as test tubes, need not be mentioned here.
- 6 *Method*. Briefly and clearly explain the steps taken in performing the experiment, using the third-person past tense; for example, 'The soil was sieved prior to use'. Outline methods used to cope with variance for all experiments involving numerical data collection and analysis. Nature is characterised by its variability.

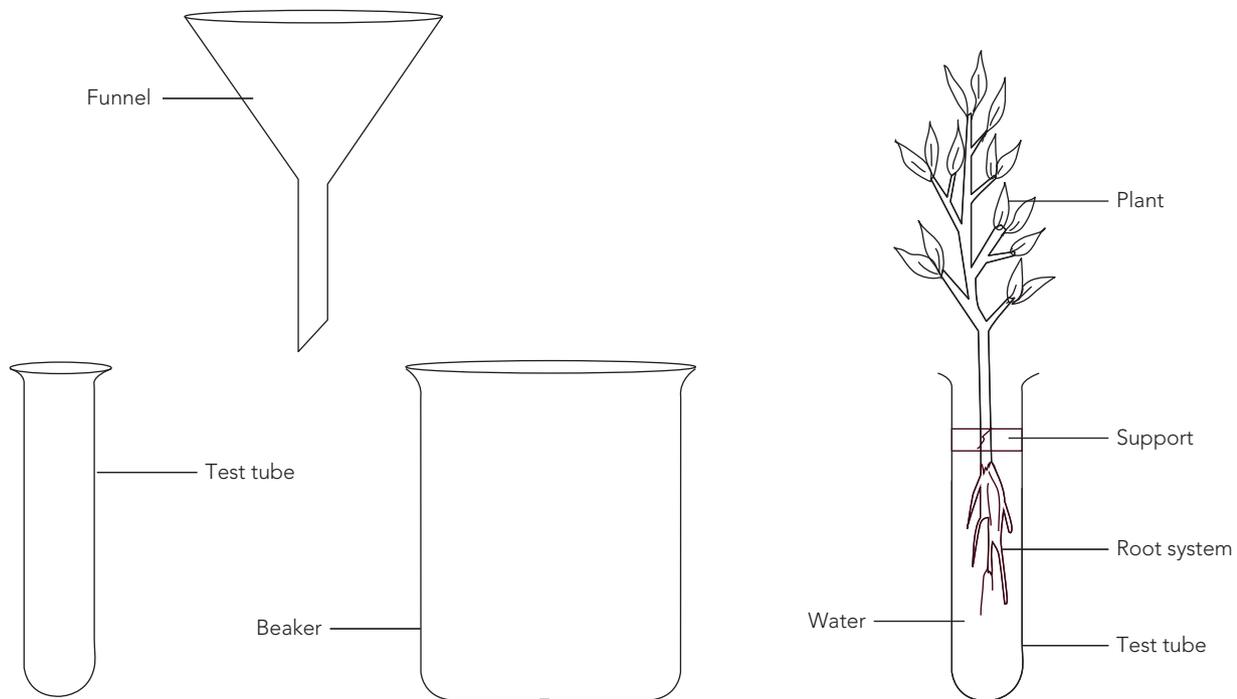


Figure 39.3 Examples of scientific diagrams

- 7 Diagrams.** These are useful when describing specific pieces of apparatus, observations, or experimental designs. Always use an HB pencil, or take a digital photo. This works well in the field, especially if wet conditions are encountered, and it allows mistakes to be corrected easily. Keep diagrams as clean lines; don't colour them in. Figure 39.3 shows some features of good diagrams.
- 8 Results.** Record observations and measurements in table form during the experiment. Show units of measurement, along with an estimate of error. Show calculations including relevant formulas and working out. Draw graphs on graph paper, in pencil (or use computer software), and ensure they are large enough to show all details. Label the axes and include suitable units of measurement. Title each graph and include a key to identify features if needed. See Chapter 40, page 438, for examples of how different types of graphs can be used to present results from experiments.
- 9 Conclusions.** State the actual findings, which should relate to the original aim stated in the introduction. Attempt to interpret data from tables, graphs or diagrams.
- 10 Discussion.** Outline relevant points arising from the practical, including problems encountered, comparisons with class averages to establish accuracy of observations, and suggestions of further issues for investigation. Discussing the role of experimental design factors and analysing the experiment design are important at this stage. In other words, critically analyse the steps taken that led you to draw your conclusions.
- 11 Questions.** Questions relating to practical work are often included at this point to link the practical aspect of the investigations to theoretical course aspects. These may be provided by the teacher; otherwise, attempt to synthesise the practical results with the theoretical concepts developed during the course in the conclusion.
- 9** List the headings that are required to write a good practical report.
- 10** Why do experiments in field situations require more care in their design and data analysis than those in a laboratory?
- 11** List three problems confronting people using animals for research purposes.
- 12** What questions should you ask yourself when examining a practical report?
- 13** Distinguish between diagrams used in scientific articles and those found elsewhere.
- 14** Distinguish between a discussion and a conclusion.
- 15** List and describe three methods of presenting results.

Chapter review

Things to do

- 1** A group of 20 day-old chickens were randomly divided into two groups of 10, Group A and Group B. The chickens in Group A were then reared under one system of management and the chickens in Group B under a different system of management. After 12 weeks each chicken was weighed. The results of the experiment are shown in Table 39.1.

It was concluded from these observations that Group B's system of management was superior to the Group A's system of management. Outline two reasons why this conclusion may not be justified.

Table 39.1 Body weights (g) after 12 weeks

Group A	Group B		
1415.0	960.0		
1391.0	1755.0		
1415.0	1700.0		
1387.0	1980.0		
1444.0	1075.0		
1415.0	1190.0		
1472.0	850.0		
1330.0	1700.0		
1415.0	1472.0		
1500.0	1980.0		
1418.4	1466.2		Mean or average weight per chicken (g)

- 2** Research shows that calves fail to grow well if cobalt is not present in sufficient quantity in their diet, and that the daily requirement of cobalt can be supplied by 8 mg of cobalt sulfate added to whole milk. A group of 50 calves aged 3–5 months are being fed good pasture and hay as well as whole milk, but are found to be doing poorly. You want to conduct an experiment to determine whether or not cobalt deficiency is the cause of the poor growth. Which of the following experimental procedures would you adopt? List two reasons explaining why you think this procedure is best.
- Feed cobalt supplement to all the calves.
 - Divide the calves into two groups, one group containing all the males and the other all the females. Feed the cobalt supplement to the male group only.
 - Select five calves at random, keep them on the existing diet but give the cobalt supplement to the rest.
 - Select 25 calves at random and feed them the cobalt supplement. Leave the remainder on the existing diet.
 - Select the 25 smallest calves, feed them the cobalt supplement but leave the other 25 on the existing diet.

3 A scientist begins to suspect that there is an association between the incidence of mastitis and the age of cowsheds. The scientist carries out a number of interviews and draws up a graph (Fig. 39.4) showing each point representing one farm. Use the graph to decide which of the following conclusions you think is correct.

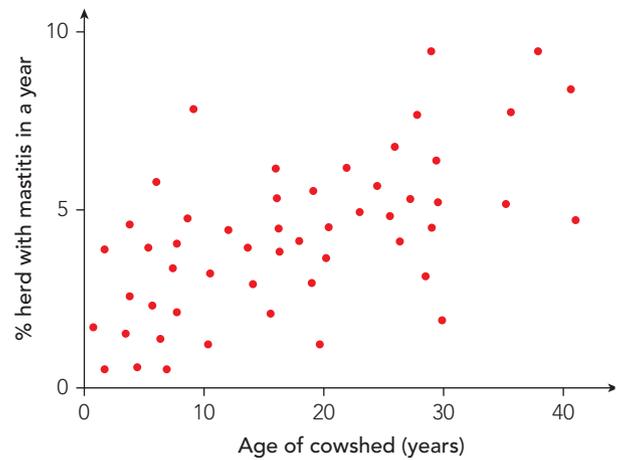


Figure 39.4 Incidence of mastitis

- a** There is no real association because some farms with new cowsheds have a high incidence of mastitis and some farms with old cowsheds have a low incidence.
- b** There is usually a higher incidence of mastitis in herds milked in old cowsheds so old cowsheds must cause mastitis.
- c** There seems to be an association of a high incidence of mastitis and old cowsheds but no further conclusions can be drawn from the information gathered.
- d** The higher incidence of mastitis on farms with old cowsheds is because the farms have been operating for a long time so the cows have become inbred and thus more susceptible to mastitis.
- e** The apparent lower incidence of mastitis on farms with new cowsheds is misleading because these farms have young inexperienced farmers who do not recognise the disease even though it is present.

4 An experiment was conducted to determine the optimum temperature for the germination of seeds of a new variety of wheat. The graph in Figure 39.5 shows the results obtained.

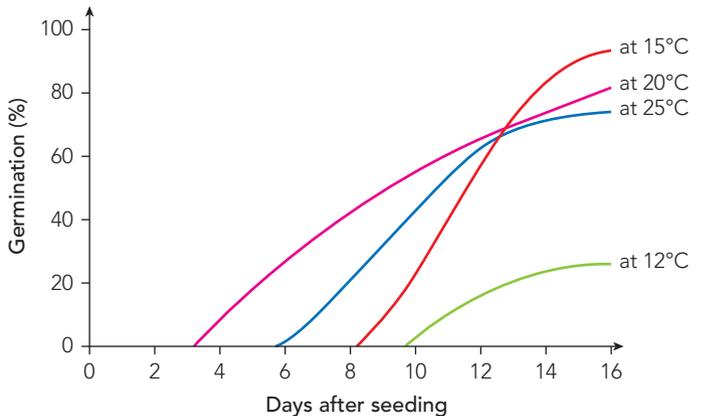


Figure 39.5 Temperature of germination of seeds

Decide which of the following conclusions is justified. Why did you decide this?

- a** The optimum temperature for germination is 15°C.
 - b** There is clearly no optimum temperature but all are satisfactory.
 - c** No conclusion can be drawn because the experiment was not conducted over a sufficiently long period.
 - d** No conclusion about optimum temperature can be drawn unless a time period is specified.
 - e** The optimum temperature was not tested.
- 5** Some farmers claim that burning off increases the production from native pastures more than the addition of superphosphate. Outline an experiment to test if this claim is true. Draw a diagram in your exercise book to show the layout of the experiment.

- 6 Examine Figure 39.6. Discuss what you may discover if you grow a legume, such as cowpeas, using the materials and design shown.

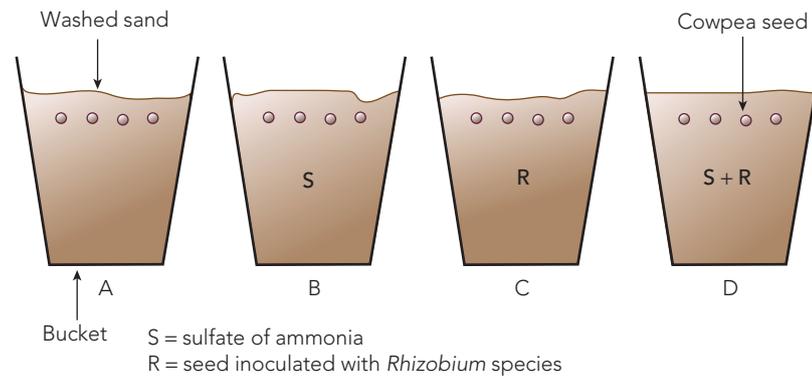


Figure 39.6 Materials and design for an experiment

- 7 A scientist wants to study the incidence and causes of mastitis in dairy herds and as a first step decides to conduct a survey to collect information. Of the 917 dairy farmers in this district, the scientist decides to interview 50, and collect answers to a prepared set of questions. A friend suggests it would save time to interview the 50 farmers closest to the scientist's home, which happens to be located in the centre of the dairying district.
- Why is this not a good suggestion?
 - What alternative suggestion would you make?
- 8 Develop a hypothesis that may explain the relationship suggested by Figure 39.4 and describe an experiment the scientist might conduct to test this hypothesis. Clarify how many cows should be used in the experiment and over what period the experiment should be conducted.

+ Extension activity

- How can farmers get informed about the results of experiments conducted in their local area, such as experiments by agronomists?
- Learn how to use the graphing facility on your spreadsheet program. Use data from any of the results of experiments in this chapter or use results from your own experiments to plot the different types of graphs and make sure you are able to correctly label the axes and give them a heading.
- Why have scientists adopted a particular method to solve problems?

✓ Test yourself

- 1** Design an experiment with the following aim:
'Does water-saving soil improver improve the production of bean plants?'
- The materials available are:
- 8 × 15cm plastic pots
 - enough potting mix to fill all the pots
 - water-saving soil improver
 - scales to weigh the beans.
- a** Describe how to plan and conduct the experiment (the method).
- b** Describe how to measure the results.
- c** Describe how to process the results. What calculations would you do?
- d** Describe how you would present the results.
- e** Assuming that the water-saving soil improver gave a 15 per cent increase in yield, write a conclusion for the experiment.

CHAPTER 40

COLLECTING, ANALYSING AND PRESENTING DATA

Words to know

analyse to examine and assess information relating to the problem posed by the experimenter

central tendency statistical measures of the most common value

mean the average value

median the middle value of a group of values

mode the most commonly occurring value

population the total number of plants or animals living in an area

range a statistical measure of the spread of values

sampling measuring or assessing representatives of a population for particular features

variable a feature being measured such as height, weight or growth rate

Introduction

In a natural **population** no two individuals are exactly the same – genetic makeup and changes in the environment ensure that differences exist.

Natural populations of plants or animals are often large and can cover huge areas of land. Animals may also migrate in and out of any experimental area. Lack of time or funds may make it necessary to measure a population feature, such as weight, height, or number of males or females, by **sampling** the population. These population samples (such as samples of measurements of the weight of chickens in a pen or height of wheat plants in a field), if properly collected and measured, are a reliable guide or estimate of the entire population. A good sample is one that allows each member of the population an equal opportunity of appearing in the sample. This is achieved by repeated, random (non-selective or without bias) sampling of the population.

Once an experiment is conducted, it produces data, which has to be **analysed** to produce results and presented in a way that makes the results clear. Measurements based on population samples build up a picture or trend about a feature of a population. To make predictions or conclusions about a population, the researcher needs to know:

- how reliable were the samples of the population in which the feature or **variable** was measured
- how the measurements made on the samples stand in relation to the rest of the population.

-
- 1 Define 'population sample'.
 - 2 Why is it important to take select samples in a random manner?
 - 3 Why should several samples be taken?
 - 4 When measuring a population feature, what two points must a researcher consider?

Testing an idea

The experimenter must have an idea or **hypothesis** to test (see Chapter 39, page 424). A scientific experiment is designed to test this idea. Once the experiment is set up, observations or measurements are made and results collected. Results are presented and analysed, and conclusions drawn. The experimenter uses the conclusions to accept, reject, modify or reserve judgement on the original idea.

Over time, other people, by repeating the experiment, will obtain results leading to a general acceptance or rejection of ideas. Moving from a hypothesis or question to experiment, and then conclusions based on results from the experiment, is termed the scientific method. This method of problem solving can be used in a glasshouse or a laboratory, where the surroundings can be totally controlled, or in the field. Because of the many interacting factors in a natural system, it may be necessary to conduct experiments in the field to gain answers to problems experienced by farmers.

Different types of experiments

To assess the response of a total population to a change in variables, such as fertiliser levels, or water, soil or animal management techniques, a sample population is studied. Conclusions about the entire population are based on the conclusions drawn from measurements taken from the samples.

-
- 5 When making estimates of plant populations why is it important to consider specific areas, such as 1 m²?

Sampling plant populations

Samples of plant populations are selected randomly, usually by standing in a field and throwing a ruler over your shoulder. A sample area is marked out, with specific observations made and measurements taken. The area is often as small as 1 m². Small sample squares such as this are known as quadrats. A 1 m² quadrat represents $\frac{1}{10000}$ of a hectare (ha), but findings based on examination of several quadrats can be applied confidently to a much larger area. Alternatively, data may be collected from a transect marked out by a string line; for example, the length of the line taken up by various kinds of plants or bare earth may be recorded.

Sampling animal populations

6 What factors should be considered when selecting animals to be used in an experiment?

Experiments involving animals must be carefully planned. When selecting animals to be included in an experiment you must make sure that the animals are:

- the same breed, where a variable such as a type of feed is being examined
- the same sex
- the same age
- kept in identical conditions
- receiving exactly the same management, except for the variable being measured
- sufficiently numerous to justify the conclusions drawn from the experimental results.

7 Identify one method for estimating the number of individuals in a population.

If any doubt exists over how the experiment was conducted, the results are invalid. Collecting data on large animal populations often involves capturing, tagging and releasing animals. This process allows scientists to estimate population numbers and map out distributions (i.e. where the animals are found). For example, studies of the behaviour of bees often require them to be counted, marked and released.

By altering environmental conditions, the reaction of animals to changed conditions can be studied. For example, experiments may be set up to test whether a field planted with a variety of crops provides its own pest control by presenting many different colours and smells to troublesome insects. Experiments such as this require the establishment of both control and test plots and the estimation of insect populations for each situation.

Sampling micro-organism populations

It is often impossible to count all the organisms present in an environment because of the large number and small size of the organisms concerned. The following method is frequently adopted to obtain an accurate idea of the number and type of micro-organisms present in a sample of material.

The sample is placed in a Petri dish (Fig. 40.1), which is divided into a number of squares of equal size (Fig. 40.2). Squares are selected at random and the organisms in them are identified and counted. After counting several samples of a known surface area, accurate estimates of the total population are possible.

Analysing data

To demonstrate this we will again look at the agronomist's experiment with old and new varieties of wheat (see Chapter 39, page 426). The yield obtained from each plot is shown in Table 40.1. These results do not answer the original question posed by the agronomist:



Shutterstock/Alexander Rathis

Figure 40.1 Mould and bacterial colonies can be grown in a Petri dish.

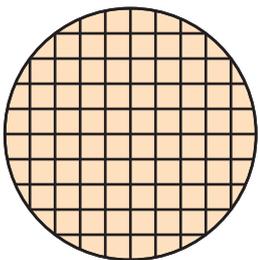


Figure 40.2 Estimating microbial numbers

'Does the new variety give a greater yield than the old variety?'
To answer this question the agronomist must analyse the data.

Table 40.1 The yield of wheat (kilograms per plot)

Plot no.	Old variety (kg)	Plot no.	New variety (kg)
1	80	2	100
3	84	4	95
5	71	6	80
7	71	8	80
9	60	10	75
11	64	12	70

The first step for the agronomist is to calculate the average or **mean** yield for each variety by adding up the yields for each plot and dividing by the number of plots. The mean for the old variety is calculated as follows:

$$\begin{aligned} \text{Mean of old variety} &= \frac{\text{Total yield from old variety plots}}{\text{Number of old variety plots}} \\ &= \frac{80 + 84 + 71 + 71 + 60 + 64}{6} \\ &= \frac{430}{6} \\ &= 71.7 \text{ kg/plot (rounded up from 71.66)} \end{aligned}$$

The mean for the new variety is calculated in the same way.

$$\begin{aligned} \text{Mean of new variety} &= \frac{\text{Total yield from new variety plots}}{\text{Number of new variety plots}} \\ &= \frac{100 + 95 + 80 + 80 + 75 + 70}{6} \\ &= \frac{500}{6} \\ &= 83.3 \text{ kg/plot} \end{aligned}$$

There are two other methods of estimating what the central value of the yield is for each variety: the **median** and the **mode**. The median is the value nearest the middle – half of the values are on either side of it. The median for the old variety is 71 kg/plot; for the new variety, 80 kg/plot. The mode is the most frequently occurring value. For the old variety, the mode is 71 kg/plot; for the new variety, 80 kg/plot.

Once these values are calculated the agronomist must compare these values of **central tendency** – the mean, median and mode – for both varieties. In all cases the new variety has larger values. The agronomist can now conclude that the new variety produces a better yield than the old variety.

The agronomist now needs to know the spread of results for the plots in each variety. Widely spread values indicate variation. The **range** – the number of possible values between the smallest and largest value observed – is one simple measure of how spread out or variable a set of results is. Range is obtained by subtracting the smallest value from the largest.

For the old variety the range is $80 - 60 = 20$ kg/plot. For the new variety, the range is $100 - 70 = 30$ kg/plot. This shows that the old variety is less variable (or more uniform) than the new variety.

-
- 8** Calculate the mean for the new variety using the information in Table 40.1. Do you agree with the figure given in the text?

-
- 9** A farmer recorded the weights of the fleeces of 200 Merino ewes as they were shorn. The heaviest fleece was 12 kg and the lightest was 3 kg. The weight of the fleece nearest the middle was 7.5 kg. The most frequently occurring fleece weight was 7 kg.
- What was the median and the mode for fleece weight?
 - What was the range of fleece weights?
 - Can a mean be calculated from this information?

The agronomist may summarise the results in a table, such as Table 40.2, to show that the new variety gives a higher yield than the old variety but is also more variable.

Table 40.2 A summary of results

	Old variety (kg/plot)	New variety (kg/plot)
Mean	71.7	83.3
Mode	71.0	80.0
Median	71.0	80.0
Range	20.0	30.0

Presenting data and results

10 What sort of graph would you choose to best represent each of the following?

- a Average rainfall in each month of the year
- b Change in temperature in a glasshouse over a 24-hour period
- c The constituents of milk from a Friesian cow

So far we have seen that results of experiments can be presented in the form of tables. It is often easier to understand and interpret results if they are shown in a visual form. Sometimes photographs are used; most often graphs are used. Different kinds of graphs have particular uses.

Pie graphs are used to represent the proportion of the individual parts making up the whole. For example, Figure 40.3 is a pie graph of the constituents of a loam soil. Each constituent is shown as a percentage of the volume of the soil.

Histograms are used to show how different things compare with each other. The agronomist's results comparing the old and new wheat varieties can be presented in a histogram, as in Figure 40.4. The rain that falls in each month of the year can also be represented in a histogram.

Continuous line graphs are used to show how something varies or changes as some other factor changes. For example, as an animal gets older it grows and its live weight increases. Figure 40.5 shows how the average weight of chickens changed over 10 days in a student's experiment.

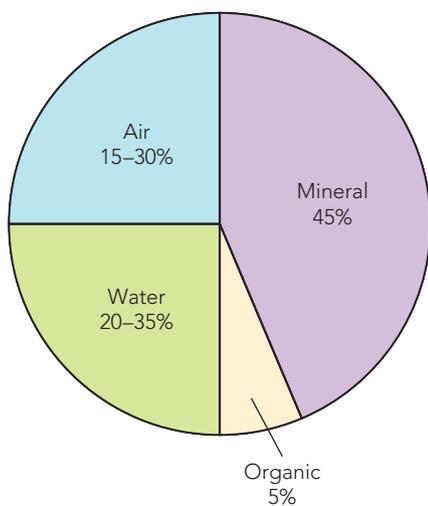


Figure 40.3
A pie graph of the constituents of soil

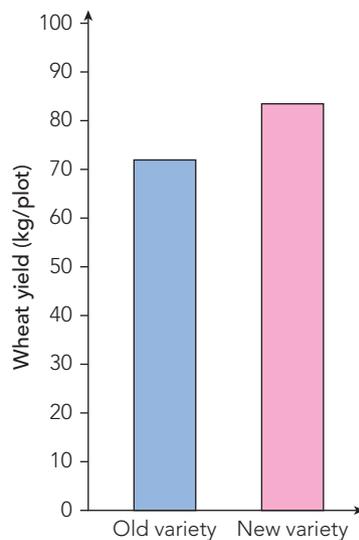


Figure 40.4 A histogram showing the agronomist's results for the two varieties of wheat

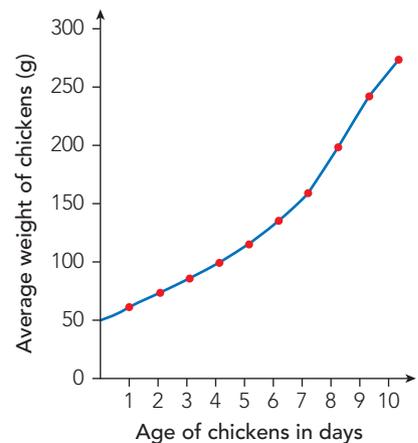


Figure 40.5 A line graph showing how the average weight of chickens changes over 10 days

Chapter review

Things to do

- 1 a Randomly select an area of pasture and mark off a $1\text{ m} \times 1\text{ m}$ square.
Draw a map of the square indicating:
 - i the type of grasses in the square
 - ii the type of legumes in the square
 - iii the type of weeds in the square
 - iv the amount of bare space in the square.
 Select a particular plant and count the number of plants in the sample square or quadrant.
 - b Repeat the procedure for three other randomly selected areas of the pasture.
 - c Examine your maps and construct a master diagram to indicate the distribution of plants in the pasture. Draw conclusions about the grasses that would be most dominant in the pasture, the legumes that would be present in the greatest numbers and the most common weed.
 - d Examine the population estimates for the plant you counted. Average the numbers and then estimate the total number of these plants present in the pasture, assuming a uniform pasture and environment.
 - e Compare your conclusions with those of your classmates. Are your observations accepted or rejected by the majority of other students?
- 2 a Select an area that contains a number of small animals such as ants, slaters or termites. Suspend above the area a $1\text{ m} \times 1\text{ m}$ sheet of clear plastic divided into a 10 cm grid marked with a water-insoluble marking pen as shown in Figure 40.6. Randomly select members of the colony and follow their movements as you look down through the sheet. Use the water-soluble marking pen to trace the movements on the sheet. Make a diagram to illustrate the general movements of a sample of the organisms observed.
 - b Without disturbing the colony too much, place around it food sources resting on various coloured pieces of cardboard. Map the pattern of movements for a sample of organisms. Record your results.
 - c Examine your results and draw conclusions. Discuss these conclusions with other members of your class and compare results. Do you need to repeat your observations?

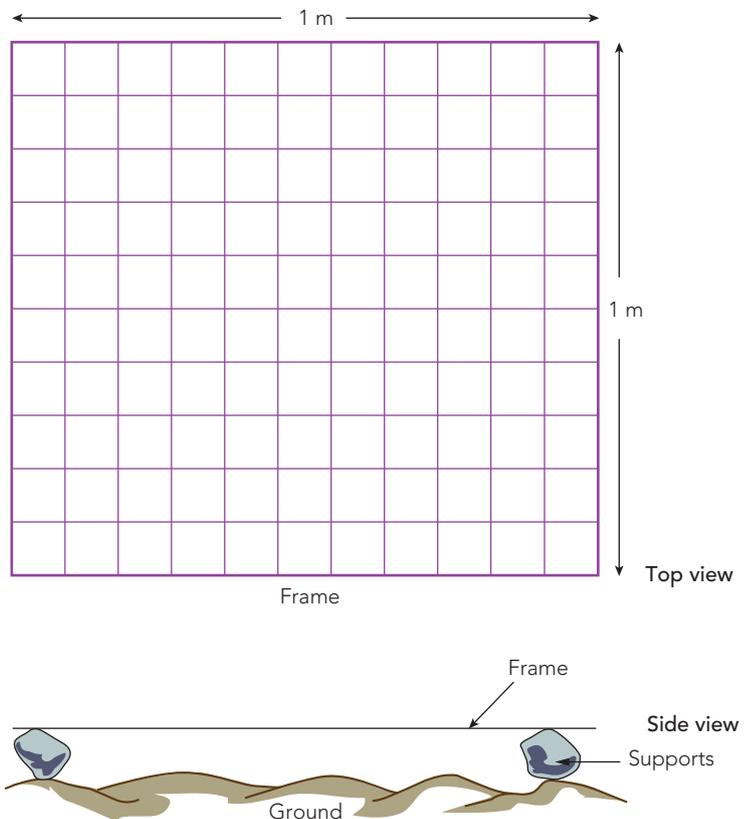


Figure 40.6 Tracking small animals

- 3 Obtain an agar plate from your teacher and place some sour milk on the agar. Replace the lid of the agar plate and seal it with tape. Incubate the culture. When you get the Petri dish back do not open it (so you are not exposed to the micro-organisms growing on it). Hold it carefully and examine the many different types of micro-organisms present.
Divide the plate into a 5 × 5 grid. Randomly select three areas in the grid system and complete these steps.
 - a Sort the colonies into categories based on shape and colour.
 - b Accurately count the numbers of each type of colony in the sample areas.
 - c Obtain an estimate of the number of organisms in the entire plate by multiplying your estimates by the total number of grids on the plate.
 - d Decide how accurate your estimates of the number and types of organism on the plate were.

Table 40.3 Live weight of Simmental × Hereford steers after 6 months

Lot fed (kg)	Pasture fed (kg)
385	400
390	355
380	385
400	360
395	400
405	405
400	380
395	400
400	350
410	405

Table 40.4 Thickness of fat on the loin of Simmental × Hereford steers after 6 months

Lot fed (mm)	Pasture fed (mm)
13	6
8	8
10	5
9	9
11	8
9	7
10	7
2	6
7	7
12	10

- 4 Twenty Simmental × Hereford steers of the same age were randomly divided into two groups. One group was fed in a feedlot; the other was allowed to graze on an improved grass/legume pasture for 6 months. At the end of this time all the steers were weighed on electronic scales. Their live weights are recorded in Table 40.3.
 - a What was the person doing this experiment trying to find out? (What was the aim?)
 - b What should the experimenter do to ensure other factors do not influence the results?
 - c For each group find the mean, median, mode and the range. Present the findings in a table similar to Table 40.2. You may like to use a spreadsheet to do this.
 - d Which treatment produced the heaviest steers?
 - e Which treatment produced the most variable results?
 - f Are there any doubts about accepting results that vary over a wide range, such as those for the pasture fed group?
 - g Draw a histogram to show the average weight of each group of steers.
 - h Write a suitable conclusion.
- 5 At the same time as the steers were weighed the thickness of fat on the loin was measured using a sonic scanner. The results obtained are recorded in Table 40.4. Analyse these results in a similar way to that used in question 1. Using a spreadsheet would be a good way to do this. Write down your conclusions.

- 6** A student conducted an experiment to see what effect the level of protein had on the growth of young chickens. The trial was carried out for 10 days using two groups of 25 chickens. One group was given feed containing 21 per cent protein and the other group was given feed with 18 per cent protein. The average weights of the chickens in each group for each day of the trial are shown in Table 40.5.

Draw a line graph to represent these results. Put the live weight on the vertical axis (y) and the time in days on the horizontal (x) axis. Use a different coloured line for each of the protein levels in the feed. This can be done using a spreadsheet program.

Table 40.5 Average live weight of chickens (g)

Day	Given 18% protein	Given 21% protein
0	63	62
1	70	64
2	81	90
3	89	100
4	98	112
5	107	128
6	116	142
7	122	163
8	123	181
9	141	200
10	157	241

🔍 Things to find out

- How do farmers find out about the results of scientific research?
- Visit a research station and look at the types and design of experiments being carried out.
- Look through magazines and newspapers written for farmers and list the number of times experiments are discussed.
- Contact a nearby research establishment involved in agricultural research and find out what its main research projects are. The CSIRO, Department of Agriculture and Soil Conservation Service are possibilities.
- Go to the library or visit the [CSIRO](#) website and find a journal that reports scientific or agricultural research. What methods are used to present the results?
- Select a variety of plant or animal that has been recently introduced into your area and find out why it was introduced. What studies were done before the introduction of the plant or animal?
- Try to develop your skills in drawing graphs from data in a spreadsheet. Use the data presented in Table 40.5 for this purpose.

connect

CSIRO

+ Extension activities

- Experimental results can often indicate an answer to a problem, but other factors may exist to prevent people doing what is suggested by the experimental evidence. What could some of these factors be? Make up a class list of them.
- A farmer grew a crop of barley in a paddock which had previously been sown with lupins. The barley appeared to grow much faster than usual and it was a very green colour. The farmer thought that the lupins may have caused this to occur. The idea was tested by sowing barley into an area that had been sown under lupins previously and also into another area that had previously been sown to successive crops of wheat. He found that barley grew faster and greener in paddocks where lupins had been previously sown.

The farmer finally stated that barley grows better in soil where lupins had previously been sown.

- a What observations has the farmer made?
- b What is the hypothesis for the experiment?
- c Describe the experiment.
- d Outline the results.
- e Assess the farmer's conclusion.

✓ Test yourself

- 1 In a natural population, why are no two individuals exactly the same?
- 2 In your notebook, write each of these words with the correct definition from the list below.
data, sampling, variable, population
 - gathering features from representatives of a much larger group
 - information gained from measurement or the collection of observations
 - a particular feature being measured
 - the total number of organisms living in an area
- 3 List six factors that must be considered when choosing animals for use in an experiment.
- 4 Why is it important to analyse data?
- 5 List three ways that data can be analysed and describe the importance of one of these methods.
- 6 Describe three types of graphs that can be used to present data.

GLOSSARY

abomasum	the fourth and true stomach of a ruminant animal where digestive juices are produced
active immunity	resistance acquired in animals after exposure to a disease
adventitious	roots formed from areas of the plant other than the underground root system
agistment	a location where livestock are moved to and rent is paid by the farmer for obtaining better feed for livestock
agribusiness	those activities involved in the production, processing, distribution and marketing of food and fibre products
agronomist	a person who studies and experiments with various crop plants and pastures, assessing their growth, sustainability and economic potential in agriculture
algae	photosynthetic plants without stems, roots or leaves and ranging in size from single-celled to multi-celled organisms, such as giant seaweeds
allelopathy	the effect on one plant's growth of another plant caused by the release of chemicals into the surrounding area
alluvial soil	deep, fertile transported soil deposited by a stream, usually in a flood plain
aluminium toxicity	a toxic effect on crop plants caused by the aluminium available in the soil
anaerobic	oxygen-free
analyse	to examine and assess information relating to the problem posed by the experimenter
anatomy	the study of the structure of organisms
anemometer	an instrument used to measure wind speed
angiosperm	flowering plant with seeds enclosed in an ovary
angling quality	the ease or difficulty of catching a fish
animal husbandry	the practices involved in raising and managing the welfare of farm animals
annual plant	a plant that completes its lifecycle within 12 months
antibiotic	a chemical produced by a living micro-organism to control, and usually kill, the growth of neighbouring organisms (generally micro-organisms)
antibody	a protein made by animals in response to bodily invasion by pathogens; it combines with the pathogen (or poison), rendering it harmless
apiarist	a person who keeps bees
apiary	a place where beehives are located
apiculture	keeping bees on a commercial basis
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 but four pairs of legs (e.g. spiders and mites)
arthropod	the largest grouping of organisms in the animal kingdom; includes insects and arachnids; they have jointed legs and a hard exoskeleton
artificial insemination	the process in which semen is deposited in the female reproductive tract by a person using artificial insemination equipment
asexual reproduction	reproduction without male and female gametes (reproductive cells); also known as vegetative reproduction
assets	things a farmer owns (e.g. land, buildings, stock and machines)
auction	a public sale in which goods are sold to the highest bidder
autotroph	an organism that produces its own food
axil	where the leaf joins the stem
backfatter	a fat pig too heavy for the bacon trade; more than 90 kg dressed weight
baconer	a pig ready for market, usually 60–75 kg dressed weight
bacteria	single-celled microscopic organisms; some cause organic material to decay or cause disease; others are important in the formation of cultured dairy products and fixing nitrogen both in the soil and in the roots of legumes
barren	not capable of breeding
bias	a form of prejudice, or slant, experienced when collecting or analysing experimental results
biennial plant	a plant that grows from seed in the first year and flowers in the second year
biodiversity	the range and variety of organisms
biotic	relating to living organisms

bloat	a non-infectious disease caused by grazing animals overeating legume plants; rapid production of gases trapped in foam causes the rumen to swell, resulting in breathing difficulties and possibly death
boar	a male pig older than 6 months of age
boundary	something that divides a system from its environment; it can be physical (e.g. a shed wall or fence), economic or psychological
bran	a carbohydrate food obtained from the outer covering of the wheat seed
breed society	an organisation that maintains a register of animals that breed true to type and outlines standards relating to appearance that must be met for that particular breed
broadcasting	a method of applying fertiliser by spreading it over the surface of the soil
broadleaf weeds	weeds that belong to the dicotyledonous group of plants
broiler	a young chicken of either sex, raised for meat; usually up to 8 weeks old
brood (bees)	the eggs, larvae and pupae that will become fully grown bees; housed in cells in honeycomb
brooder	a device designed to give young chickens the best environment for growth
buck	a male goat
budding	a form of grafting, where a dormant bud is transferred from the scion into the bark of the rootstock of another related plant type; the bud forms a shoot if the tissues of the scion and the rootstock grow together
bullock	a castrated male bovine 3 years of age or older
business	the organising and running of a farm so that money can be made
buyer	a person who purchases agricultural products or produce
calf	a young animal of either sex, from birth up to 10 months of age
canopy	the leaves and stems of a plant
carbon credit	a certificate or permit to allow the production of 1 metric tonne of carbon dioxide or another greenhouse gas
carbon sequestration	natural or artificial process that removes and traps carbon dioxide from the atmosphere
carbon trading	an emissions trading approach that relies on the buying and selling of carbon credits
carbonising	removal of vegetable matter, such as seeds and cotton, from wool using acids and other chemicals
carcase	remains of the animal body after the head, feet, hide, tail and internal abdominal organs (except kidneys) are removed
carnivorous	meat-eating
carrying capacity (aquaculture)	the maximum weight of fish a dam can support
cashmere (goat)	any type of goat with the ability to grow a downy undercoat (technically there is no cashmere goat breed)
cashmere (fibre)	very fine, soft and warm fibre from the downy undercoat of a goat; used in light to heavy fabrics
castration	removing testicles from a male not required for breeding
cell	the basic structural unit of all living things; living things are made up of either a single cell (unicellular) or many cells (multicellular)
central tendency	statistical measures of the most common value
cereals	large-seeded grasses used for food
chevon	goat meat
chicken	a young bird, from hatching to approximately 4 months; also used as a general term referring to poultry
chlorophyll	a green, light-sensitive pigment in plants that absorbs light energy and enables the process of photosynthesis
chloroplast	the structure in the cells of the plant that contains chlorophyll
climate	the average conditions of the Earth's atmosphere based on records taken over at least 30 years
cockerel	a male bird younger than 12 months
cold-blooded	animals, such as fish, whose bodies do not stay at a constant temperature; instead, their body temperature matches that of the environment
colostrum	the first milk that a mammal (e.g. a cow) makes to help its newborn fight disease
commodity	goods of trade
condition score	an assessment of an animal's condition based on its fat and muscle score
consumers	people who buy and use a product to satisfy their needs or wants (e.g. people buying fruit and vegetables to eat)
contagious disease	a disease that spreads from sick to healthy organisms
continuing education	learning undertaken after a person has left school

control	the standard to which a new technique, treatment or variety is compared, or a part of an experiment that does not receive the main treatment
coolant	a liquid that circulates through the engine and radiator of the tractor and keeps it cool; the coolant is usually water but may have some special chemicals added to it
cotton gin	a factory that separates cottonseed from the lint and packs the lint into 227 kg bales
cotyledon	the food source of a seed embryo
credit	money or goods given to people to be paid back or to be paid for in the future; there is usually a charge for credit (interest)
creep grazing	allowing smaller or younger animals in a herd or flock access to new pasture through specially constructed fences or gates while excluding older or larger animals
cria	(pronounced kree-ah) a newborn alpaca up to 6 months of age
crisps	thin slices of potato that have been fried in oil until they are crisp (salt and other flavourings are usually added to enhance taste)
crop rotation	the process of growing different crops, including pasture, from one year to the next on the same piece of land
crossbreeding	using different breeds of similar genetic makeup to produce a hybrid
crosspollination	pollination between flowers of different plants of the same species; in fruit trees from one variety to another
crusher	the business that purchases the crop and extracts the oil from the grain
crutching	shearing wool from the breech area
culling	removing an animal from a herd because of age, disease, low production or physical deformity or abnormality
dairy farmer	a person who keeps cattle for milk and milk products
dam (alpaca)	<i>see</i> hembra
data	information gained through measurement (quantitative data) or the collection of observations (qualitative data)
decision	choice of one course of action from two or more alternative courses of action
deficient (soil)	used to describe a soil lacking a particular nutrient or element
defoliant	a chemical applied to cotton plants as they mature, which causes the leaves to drop off
development	changes in the composition and proportions of a plant as it ages
dew point	the temperature at which water droplets form in the air
diary	a daily or weekly record of events (e.g. a farm diary is a record of what happened on the farm)
dicotyledon	one of two classes of flowering plants, a plant with two cotyledons (e.g. clover, canola)
dipping	applying chemicals to sheep to control external parasites
direct drilling	direct placement of seed into the soil with little or no soil preparation
disbud	to remove excess buds, thus allowing only a few buds per stem to develop fully
disease	any condition that produces a change in the normal functioning of an organism
disinfectant	a chemical used to destroy disease-causing micro-organisms (generally bacteria)
diversified farming	mixed farming, where more than one subsystem or enterprise exists on a farm
doe	a female goat
domestic market	for sale within Australia
domestication	the process of selection and breeding of wild plants and animals into cultivated and tamed species
dormancy	delayed germination of a seed
dormant	when pasture seed that is still alive, but because of various factors, does not germinate in reasonable conditions
drafting	separating sheep into different groups based on such aspects as age, body condition and sex
draw bar	a tractor fitting for a trailing machine to be attached so that it can be pulled along
drench	a chemical given orally to animals, generally to control internal parasites
drenching	administering medicine to treat internal parasites
dressed weight	weight of the carcass
drill	a machine used to sow seeds of a crop in evenly spaced rows at the correct depth
dry cow	a cow that is not lactating or producing milk; usually she has completed her lactation and is pregnant
dual purpose	an animal that serves more than one purpose (e.g. meat and milk production)
early maturing	varieties that have a short growing period and reach maturity in fewer days than other varieties
early tuber bulking	period in tuber development when growth in size is rapid

economic threshold	level of pest numbers that will cause sufficient damage to the crop to make it worthwhile spraying with pesticides
ecosystem	the relationship between an interacting community of organisms and their physical environment
embryo (plant)	a young plant in the seed
emergence	when the germinating seedling breaks through the surface of the soil
endocrine glands	ductless glands producing hormones or body regulators
endosperm	the food store surrounding an embryo in a seed (if it is not absorbed by the embryo)
enterprise	an individual activity on a farm that can produce an income; for example, raising beef cattle, growing wheat
environment	the immediate surroundings
equity	the difference in value between what the farmer owns (assets) and what the farmer owes to creditors (liabilities)
erosion	the wearing away of material and the movement of weathered material by various agents such as wind, water or gravity
establishment	when a seedling has emerged and starts to photosynthesise, thus becoming self-sufficient
ewe	a sexually mature female sheep
exchangeable aluminium	aluminium ions in the soil that are available and can be taken up by the plant roots in exchange for hydrogen ions
exoskeleton	external body covering of an arthropod
exotic pasture	a pasture of plants that have been introduced from overseas (introduced pasture species)
experimental error	a deviation from the true measurement expressed as a percentage
extension officers	people who advise farmers on how to farm (e.g. a beef cattle officer gives advice on beef cattle production)
extensive farming	growing animals or plants over large areas of land, and aquaculture with low stocking rates
extraction	removal of honey from frames kept in the supers of a commercial beehive; honey extraction occurs immediately after the removal of the beeswax cappings from all the cells on the frame
eye (potato)	a bud on the tuber
fallowing	resting of a paddock, usually in a ploughed state
William Farrer	(1845–1906), developed a rust-resistant variety of wheat that could be planted in many areas of New South Wales
farm manager	a person who makes decisions related to the financial and practical operations of the farm
farrowing	the production of a litter of one or more piglets
fatty acids	organic acids made of chains of carbon atoms with an acid group attached
feral goat	a wild goat
fertilisation (animals)	one sperm from the male unites with one ovum from the female
fertilisation (plants)	occurs when the male sex cell from the pollen grain unites with the female sex cell in the ovule. The fertilised ovum develops into a seed.
fertiliser	any manure or chemical substance used to make soil more fertile by replacing plant nutrients removed by crops or leached from the soil
fertility	the ability of an animal to reproduce
field capacity	the amount of water left in a soil that was saturated then left to drain for 24–48 hours
field days	organised gatherings at which an aspect of farming is demonstrated for those interested to see and learn
financial budget	the predicted expenditure and income from a farm business
fingerling	a fish older than 'fry' stage but not yet an adult
finisher	a pig in its last 4–6 weeks before slaughter
firm	a company conducting a business
flushing (sheep)	increasing the level of nutrition to ewes prior to joining
fodder	plant material grown to feed livestock; includes stored material such as hay, silage or grain
French fries	potato chips; long thin pieces of potato that are deep fried or pressure cooked in oil and served hot (a very common fast food)
friable	soil that has a good structure and easily crumbles; it is well aerated and drained
fruit	the swollen ovary wall that surrounds some seeds
fry	a young fish just after hatching
fungi	plant-like organisms including rots, mildews and moulds that lack chlorophyll and possess threads (hyphae); can be parasitic and cause disease in plants and animals or feed on organic matter

fungicide	a chemical substance used to control or prevent fungal growth
furrow	a continuous hollow or trench made by the tine of a tillage machine as it passes through and disturbs the soil
geneticist	a person who studies how characteristics (genes) of plants and animals are inherited
genotype	the genetic makeup of an individual organism (animal)
germination	a process occurring in the seed under favourable conditions when it absorbs water, swells and begins to grow, sending out roots and a shoot
gestation period	the time from conception to birth
gilt	an unmated sow
grading	dividing goods into similar quality lines or classes based on weight, colour, shape or other criteria
grafting	the union of tissue of two different plants of the same species
Gramineae	botanical name for the grass family of plants
grazier/pastoralist	a farmer who raises livestock that graze on pasture (e.g. sheep or cattle), for an income or hobby
greenhouse effect	the overall increase in temperature caused when solar radiation is unable to escape from the Earth's atmosphere because of the build-up of atmospheric gases, particularly carbon dioxide
grower (pig production)	a pig between weaning and finishing
growers (occupation)	people who raise plants to sell from seed, tubes or pots
growth	an irreversible increase in the size of an organism
harvester	a machine that gathers in the mature crop for sale or storage (e.g. combine harvester, forage harvester)
hatchery	a place that produces fingerlings for sale to the public and for stocking public waters
head (plant)	the part of the plant where the grain or seed forms – usually near the top
heifer	a female cow older than a calf, from 6 months of age until she has had a calf herself
hembra	a breeding female alpaca
hen	a female bird older than 12 months and after the first adult moult
herbicide	a chemical substance used to control or prevent the growth of plants (generally weeds)
herbicide tolerant	varieties of the crop that are not affected to any extent by the herbicide
heterosis	increased rates of growth and fertility levels resulting from the production of a hybrid
heterotroph	an organism that needs a supply of food from its surroundings
hogget	a shorn or unshorn sheep 12–15 months of age
honey	the sweet, sticky fluid made by bees using nectar from flowers
hormone (animal)	a chemical substance secreted by ductless or endocrine glands directly into the bloodstream to control body actions or processes
hormone (plant)	an organic material, produced in particular areas of the plant, that has specific effects on the plant
horticulturalist	a person who oversees operations involving the cultivation of plants for research or commercial use
host	an organism that supports another one living in or on its body
humus	a stable product in soil formed through the breakdown of organic matter
hybrid (animal)	the result of crossmating animals of different breeds or species
hybrid (plant)	a plant produced by crossing individuals that are genetically different
hybrid vigour	the increased vigour (e.g. growth, litter size, milk production) of crossbred animals
hydraulic system	system used to transfer power by pumping oil through pipes to operate pistons that in turn move parts of the machine
hydroponics	growing plants without the use of soil in carefully balanced nutrient solutions
hyphae	thread-like structures that are part of the structure of fungi
hypothesis	a concept or idea to be assessed or tested
immunity	resistance to a disease
implement	a machine attached to or drawn by a tractor to carry out a particular operation (e.g. ploughing)
improved (pastures)	the use of introduced species of pasture grasses, legumes or a combination to enhance pasture production
inbreeding	a method of breeding closely-related animals
incubator	a heated structure used for hatching eggs
infertile	a soil lacking, or deficient in, one or more nutrients or elements that cannot sustain significant plant life as a result
inflorescence	the arrangement of flowers on a plant
inoculum (pastures)	a mixture of nitrogen-fixing bacteria, peat and a sticky medium

input	anything that goes into or is used up in a production enterprise (e.g. seed for a wheat enterprise or hay for a milk-production enterprise)
insect	a particular type of arthropod, with a body composed of three body parts, three pairs of legs and one pair of antennae
insecticide	a chemical substance used to kill insects
intensive farming (aquaculture)	systems with high stocking rates, where farmers provide the feed for the fish and the fish environment is carefully controlled
inter-row cultivation	cultivation with machines between the rows of a crop to kill weeds
intravenous injection	the injection of fluid into a vein
inventory	a list of items a farmer has on the farm (e.g. livestock); it may include the number, quantity and value of those items
invertebrate	an organism without a backbone
investor	a person who puts money into a business with the hope of making money – the farmer invests in their own farm
irrigate up (crop establishment)	process of germinating and establishing a crop using irrigation, not relying on rainfall
irrigation	the application of water to a crop to provide moisture not directly provided by rain
joining	putting together male and female livestock for the purposes of breeding (e.g. joining the ram with the ewes)
journal	a magazine that is published regularly on a particular subject
kid	a young goat aged up to approximately 1 year
lactation period (cows)	the time from calving until the cow stops producing milk
lamb	a young sheep from birth until weaning
late maturing	varieties that have the longest growing period; taking longer to reach maturity than other varieties
legume	a type of plant (bearing a pod) which also ‘fixes’ or converts nitrogen into a form usable by the plant through the action of specific bacteria living in its roots; examples include clovers, peas, lucerne and broad beans
liabilities	debts (e.g. a loan from the bank or a fuel bill)
lint	the fibres of cotton that grow in the cotton boll and are attached to the seeds
livestock agent	a person who buys and sells animals on behalf of other people
lodge	crop plants that fall or are blown over by wind
longevity	the time period over which a seed can germinate
William Lowrie, Professor	(1857–1933), Director of Agriculture in South Australia and principal of Roseworthy Agricultural College in 1887; his research indicated the need for superphosphate to be added to Australia’s soils
lubrication	the application of a ‘lubricant’ such as grease or oil to a part of a machine to reduce friction where two metal surfaces rub together (e.g. an axle in a bearing)
macho	an entire male alpaca used for breeding
manufacturing industries	those that produce manufactured goods (e.g. cars, machinery, clothes)
marbling	fine flecks of fat within the meat (intramuscular)
John and Elizabeth Macarthur	(1767–1834) and (1766–1850), founders of Australia’s wool industry
market garden	a small farm used for producing vegetable or flower crops
market gardener	a person who grows fruit, vegetables and/or flowers for sale
markets	places where farm produce is sold
marking	the time when several important management operations, such as branding, castration and dehorning, are conducted on livestock
mastitis	inflammation of the udder, usually from a bacterial infection
Samuel McCaughey	(1835–1919), introduced the ‘wrinkly-skinned concept’ into Australian Merino sheep breeding
HV McKay	(1865–1926), improved on the design of the stripper developed by John Ridley so that it completed the threshing, winnowing, sieving and bagging as the machine went along. By 1934 the McKay family firm had developed the Sunshine Harvester
meal	the protein-rich remains after the oil from the seed has been removed by crushing
mean	the average value
median	the middle value of a group of values
metamorphosis	change in body form; some insects have a complete change from larva to adult (e.g. flies)
milk yield	the volume of milk produced during lactation

mining industries	those involved in extracting valuable ores and minerals from the ground and then selling them (e.g. gold, coal, bauxite, iron)
mode	the most commonly occurring value
mohair	a long and lustrous fibre produced by Angora goats
mollusc	soft-bodied invertebrates with a shell, either external or internal, and a muscular foot (e.g. snails)
monitoring	measuring what happens in a production process (e.g. how much feed is eaten by growing pigs and how much weight they put on as a result of eating this feed)
monocotyledon	one of two classes of flowering plants, a plant with one cotyledon (e.g. grasses, palms and bananas)
monogastric	an animal with one stomach
mulch	a layer of material placed on the surface of any soil
mulesing	surgically removing skin from the breech area of the sheep
mustering	gathering sheep together into a mob so they can be moved to different places around the farm
mycelium	a mass of fungal hyphae
mycorrhiza	an association between a fungus and the roots of a plant
native pasture	contains plants originating in that particular country; for example, Australian native plants planted in Australia
natural immunity	resistance due to natural barriers (e.g. skin)
natural pasture	contains plants of both native and naturalised origins (exotic plants that have responded well to local conditions)
nematodes	round worms that are parasitic on plants, or free living in water and soil
neps	small lumps in the lint resulting from tangled cotton fibres
nitrogen-fixing bacteria	a bacteria that allow the legume to produce protein from nitrogen gases in the atmosphere; some are found in nodules on legume plant roots and some are free-living in the soil
nodes	points on the stem where leaves arise
nodules	lumps or swellings on the root systems of legumes, caused by bacteria invading or infecting the plant root system
noxious weeds and animals	plants and animals that cause problems in some way, which landowners are legally required to control
nucleic acid	a chemical that occurs in all cells and determines the type of organism and its genetic make-up
nucleus colony	a colony comprising a queen bee and workers
nursery bed	a special seedbed where seedlings are raised for transplanting; often a more protected environment than the field where the crop is grown
nutrients (fodder)	chemical constituents of fodder that are digested and used by an animal (e.g. starch, vitamins and inorganic salts)
oestrus (heat)	the period when a female domestic animal or livestock is willing to mate with the male
omasum	the third stomach of a ruminant animal, sometimes called the bible because of leaf-like partitions that line its walls, which removes 60–70 per cent of the water from the rumen fluid
omnivorous	eating both meat and plants
orchardist	a person who establishes, cultivates and manages fruit trees
organ	a collection or group of tissues (similar or different) that combine to perform a specific function
organic farming	farming based on the use of organic (natural) materials
organic matter	material that originally came from living things – dead and decaying plants, animals and manures; important in holding water and plant nutrients in the soil as well as improving the structure of the soil
osmosis	movement of water from an area of high water concentration to an area with little water, through a selectively permeable membrane
output	items or material produced in a system and removed from it
ovulation	the release of an egg from a mature follicle
ovule	the structure in flowers that develops into a seed after fertilisation
palatable (pasture)	feed that is easily eaten and digestible; feed that grazing animals like to eat
parasite	an organism that lives on or in, and obtains its food from, another living organism (host)
parent material	the rock that lies beneath the subsoil and that weathers to form soil
passive immunity	resistance acquired by injection with antibodies produced by another individual or source
pastoralist	<i>see grazier</i>
pasture	a balanced community of plants (generally grasses and legumes) that provides grazing animals with their food requirements
pathogen	a disease-causing organism

ped	the unit of soil structure
pedigree	a recorded outline of the parentage of an animal
George and Frederick Peppin	Englishmen who settled in the Riverina area in the 1850s and developed a large-framed Merino suitable for the Western Plains of New South Wales
perennial plant	a plant that grows from season to season
permanent pasture	a plant community that lasts longer than 5 years
pesticide	any chemical substance (usually dust or spray) used for the destruction of any pest; usually an insecticide
phenotype	the appearance and production of an organism
pheromone	a chemical substance released by an animal that influences the development or behaviour of other animals of the same species
phloem	living vessels that move food in the form of sugars throughout the plant
photosynthesis	manufacture by plants of food, by converting light energy into chemical energy in the form of sugars
physical budget	the predicted use of inputs and level of production for a farm or enterprise of a farm
physiology	the study of functions of a living organism or any of its parts
plough	a machine for turning soil; there are various types such as mouldboard, chisel and blade
plumule	the stem section of an embryo
pollard	a carbohydrate food also obtained from the outer covering of the wheat seed
polled	an animal without horns
pollen	the microscopic hard capsule that contains the male reproductive cell of a plant
pollination	movement of pollen from the anther to the stigma of a flower
population	the total number of organisms living in an area
pore	the space between soil particles, usually containing air or water
porker	a pig ready for market, usually 45–60 kg dressed weight
post-emergent	herbicide that is applied to the crop after it has emerged from the soil
potato tubers	(seed potato) planting material, ideally the size of a matchbox with a minimum of two ‘eyes’; used for planting the next crop
poultry farmer	a person who raises fowl for meat or eggs
predator	an organism that kills and eats another
pre-emergent	herbicide that is applied before or at sowing, before the sown crop emerges from the soil
primary tillage implement	used to break up the soil in the first stages (e.g. ploughs)
process	an action that changes inputs into outputs
processing	the various stages of treatment, from harvesting to packaging or canning (e.g. tomatoes are washed and peeled before canning)
produce	anything produced on the farm that is sold (e.g. wool, wheat, pigs, vegetables, milk or beef cattle)
producer	a person who produces goods or services
protozoa	single-celled organisms having many animal-like features
puberty	the age at which an animal can first reproduce
pullet	a female bird younger than 12 months
pustules	clusters of fungal spores bursting through the surface of the plant
quota	a quantity (e.g. of milk) which the farmer is required to produce; this term has been replaced with the term ‘contract’
radicle	the root section of an embryo
ram	an entire male sheep (not castrated)
random selection	choice without pattern or method so that all members of a population have an equal chance of being involved in an experiment
range	a statistical measure of the spread of values
rate	a measure of production in a specified time interval
replication	conducting the same experiment repeatedly to gain a more accurate estimate of the true value or result by reducing variability
reproductive phase (plant)	the part of a plant’s lifecycle after flowers begin to form
residual	a term used to describe a chemical that remains active and does not break down in the natural system for a period of time
resistance	the ability of a group of organisms to survive a particular pest treatment
resources	things that are used in production (e.g. land, labour, fertiliser, money)
retailers (horticulture)	people who sell plants to consumers through shops and nurseries

reticulum	The second stomach of a ruminant animal, closely joined to the rumen or first stomach. The reticulum is also called honeycomb due to its physical appearance. This stomach breaks down coarse fibre until it is fine enough to enter the rumen for fermentation
John Ridley	(1806–1887), designed and built the stripper for harvesting wheat; it removed the grain in one operation, by means of sharpened prongs, then threshed and winnowed the grain
road train	a prime mover (truck) with up to three trailer units used for transporting sheep or cattle to market or agistment
rooster	a male bird older than 12 months
rootstock	that part of a graft that contains the lower stem and root system of a plant
root zone	the soil from the surface to the depth of penetration of the deepest roots of a crop
rotational grazing	moving livestock in a pattern from one paddock to the next to allow grazed areas to recover
rumen	the first stomach of a ruminant animal where food is fermented by bacteria and fungi and cellulose is digested
ruminant	an animal with four stomachs, including a rumen inhabited by millions of microbes (e.g. sheep, cattle and goats); alpacas are called ruminants but have only one stomach with three compartments
James Ruse	(1760–1837), Australia's first farmer to produce enough food for his family and have some left to sell
sampling	measuring or assessing representatives of a population for particular features
saturated	soil pore space is filled with water
scarifier	a secondary tillage machine used for cultivating the soil, mainly to break a surface crust and remove some weeds
scientific method	a method of problem solving that involves the testing of an idea through the use of experiments and the analysis of data
scion	the part of a graft that contains the upper stem and leaf section of a plant
scutellum	the cotyledon of a grass embryo
secondary tillage implement	used to further reduce the size of soil aggregates, after primary tillage
seedling	a young plant that has just established itself after germination
seed potato	tubers or pieces of tubers with eyes that are planted to grow the new crop
self-pollination	movement of pollen from the anther to the stigma of the same flower
semen	the fluid that contains sperm produced by the male sex organs
seminal fluid	secretions produced by glands in the male reproductive system
service industries	those that provide services to people (e.g. banks lend money, stock and station agents assist with buying and selling animals)
set (potato)	a seed potato
set (fruit production)	when, as the result of pollination, the fruit in the flower starts to develop and does not fall off the tree when flowering is over (fruit that is not pollinated usually falls and is lost)
sexual reproduction (plants)	fusion of male and female gametes (pollen and ovule) to form a seed containing an embryo
shot grain	grain that has started to germinate and the first root has started to emerge
silage	plant material that is stored with little drying, in anaerobic conditions, where it slightly ferments and is preserved; used for stock feed
silo	a structure used for storing silage or grain
siphon	a curved length of plastic pipe used to take irrigation water from the channel to the furrow between the rows of plants
sire (alpaca)	<i>see</i> macho
Maria 'Granny' Smith	(1799–1870), an orchardist who first recognised and cultivated an edible green apple, which was named after her
RB and CH Smith	invented the stump-jump plough in 1876
sodic clay	a clay soil that contains a lot of sodium ions and disperses easily when it becomes wet
soil acidification	the processes by which soils become more acidic
soil aggregate	a desirable natural lump or small clod composed of many soil particles held together; ideally aggregates form after soil breaks, following cultivation
soil degradation	the breakdown of soil structure and loss of fertility
soil profile	a vertical section through a soil from the surface to the underlying parent material
soil salinisation	the processes by which salt accumulates in the surface layers of the soil
soil scientist	a person who studies the origin, management and use of soils

soil structure	the arrangement of soil particles in a soil
soil texture	the proportions of sand, silt and clay in a soil
sow	a female pig used for breeding
spawn (fungi)	spores that have germinated and formed mycelia
spawning	the process of egg-laying by a fish
sperm	sex cells of male animals
spinner	factory that spins the clean cotton lint into thread that can then be woven or knitted into fabric
spores	reproductive structure of fungi and some bacteria
springer	a cow showing signs of approaching calving
sprung grain	grain that has started to germinate and has a noticeable bump where the embryo is
standardise	making all conditions for each aspect of an experiment (e.g. climate, soil or slope) as equal as possible
staple food crop	a crop that people eat almost every day and that makes up a major part of their diet
station	a large property used for grazing (sheep or cattle)
steer	a male calf castrated when young
Stevenson screen	external structure used to house instruments needed to measure temperature and humidity
stolon	an underground stem
stoma	an opening found mainly on the underside of leaves, allowing air and water to exchange with the atmosphere
store	an animal of any age or sex not in fat-enough condition for slaughter for a good quality carcass
straw, stalk	remains of a cereal crop (e.g. wheat)
strip grazing	grazing sections of a paddock divided by an electric fence
stubble	the stems that remain after the crop has been harvested
stubble retention	the residue left after a crop is harvested is not removed by burning or any other means but is retained so that it decomposes and is incorporated in the soil
subsoil moisture	moisture stored deep in the soil that can be accessed by crop plant roots (e.g. 80 cm of subsoil moisture means the soil has moisture available to the plant to a depth of 80 cm)
subsystem	a system that itself forms part of a larger system. This may be a farm enterprise, such as growing wheat, or a discrete unit of the farm, such as the soil.
succulent (pasture)	feed that is juicy and therefore high in water content
sugarcane sets	short pieces of sugarcane cut so that each piece has at least two buds or growing points on it
supplementary feed	additional feed given to an animal in times of need so as to maintain sufficient nutrient levels
sustainability	the ability of a farm to maintain and improve its environmental resources, such as soil and biodiversity, and to continue to be profitable
sustainable agriculture	a system of agriculture that maintains production levels over a long time
swarm	movement of a queen and bees from a hive
system	a group of objects that interact to achieve some purpose
tail docking	removing the tail from a young lamb
tail water	irrigation water that has passed through the crop and not soaked into the soil, which is collected and used again
tariff	a tax imposed on imported or exported goods to affect trade
Headlie Taylor	(1883–1957), held the patent for the Header Harvester concept and joined the McKay family firm to develop the machine that evolved into the Sunshine Harvester
technology	the practical application of knowledge such as the use of machinery, computers and/or techniques for undertaking agricultural practices (e.g. the machinery and the method used to grow a wheat crop)
temporary pasture	a mix of plants that lasts from 3 to 5 years
testa	the outer covering of the seed
theory	a generally accepted explanation of a principle or observation
tillering	refers to the branching pattern of growth of the wheat stem
tine	a long steel point on a fork or tillage implement, which ‘disturbs’ the soil; there is usually more than one tine on a tillage machine
tissue	a specialised group of cells that together carry out a specific function (e.g. muscle cells form muscle tissue)
trachea	an air-conveying tube of the breathing system
transaction	a commercial business carried out or performed where a conclusion or settlement is reached

translocation	movement of sugars through the plant from areas of manufacture to areas of storage or active growth
transpiration	water loss from the plant through the stomata
transplant	move rooted seedlings from one location to another, generally from a punnet or seed tray to a garden bed
trash (cotton)	the remains of the cotton plant: the leaves, stems and bolls
tuber	swollen underground stem where a plant (e.g. potato) stores starch
tuber set	period of growth when the potato plant starts to initiate and develop tubers
urea	nitrogenous waste collected and excreted by the kidneys
vaccination	the injection of a substance to produce immunity or resistance to a disease
value adding	further processing of a product so that it can be sold for a higher price
variable	a feature being measured such as height, weight or growth rate
variety	a plant within the same species that differs genetically and therefore has different characteristics such as disease resistance. Examples include fruit tree varieties such as Pink Lady, Granny Smith, Delicious and Jonathan apples
vealer	a calf reared on its mother for purposes of slaughter at 8–12 months
vegetative phase	the part of a plant's life cycle in which active growth of stems, leaves and roots occurs
vermin	animals that are destructive, annoying, or harmful to human health, including rats and mice
vernalisation	exposure of some types of plants to a period of cold to induce them to flower
vertebrate	an organism with a backbone
veterinarian (vet)	a person who studies and treats the diseases and injuries of domestic animals
viability	the ability of a seed to germinate
viruses	parasitic, non-cellular organisms
weaner	a young animal that has been weaned from its mother
weaning	the permanent separation of a female mammal from her young
weather	daily changes in the atmosphere in precipitation, temperature, wind, pressure, cloud cover and other factors
weathering (cotton)	damage to the cotton lint in the open bolls caused by rain while waiting for harvest
weathering (soil)	the breakdown of rock to form soil
wether	a male animal castrated while still immature
wholesalers	people who specialise in supplying certain types of plant to nurseries, landscapers or retail outlets
wilt	when a plant collapses due to loss of excessive amounts of water
wilting point	the point at which a plant can no longer obtain water through its root system from the soil pores
windrow	a raked row of cut plant material ready for drying
windrowing (canola)	cutting the top parts of the canola plants that have the seedpods on them and placing them into rows on top of the cut stubble
withholding period	the time period after the application of a chemical during which the plants or animals treated cannot be used for human consumption or processing
xylem	dead, hollow vessels conducting water and minerals from the plant roots to the rest of the plant
zooplankton	microscopic animals living in the surface waters of dams, rivers and other water habitats

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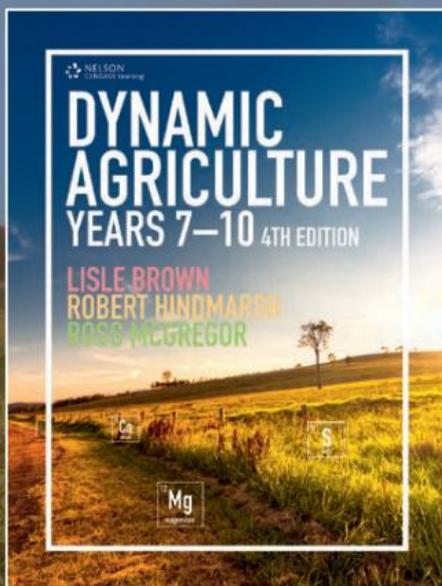
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The fourth edition of *Dynamic Agriculture Years 7–10* has been meticulously updated to include the latest information in agricultural practices. The full colour design engages students, and along with videos and worksheets provides a complete course of study for Stage 4 and 5 of the BOSTES Agricultural Technology syllabus.

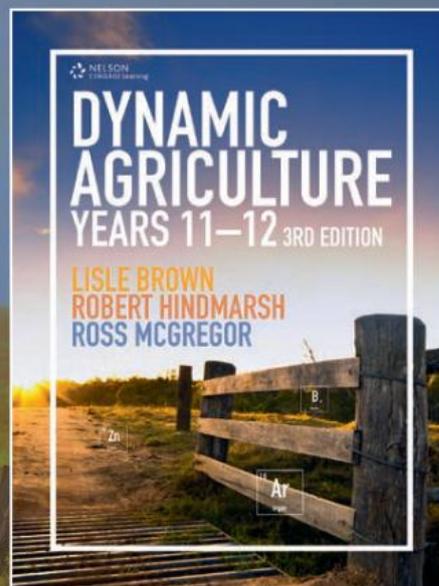
The Words to know list at the beginning of each chapter enables students to review and understand new terms, and the Connect boxes link students out to industry websites so they can become familiar with the wider agricultural community.

The textbook includes questions ranging from remembering and understanding-style questions, which appear in the margins, to applying, analysing, creating and extension questions at the end of each chapter. End-of-chapter questions are identified by thinking level and offer students an opportunity to undertake a variety of activities.

This lively and accessible book enables students to attain the deep knowledge, understanding and skills necessary to actively participate in the dynamic world of modern agriculture.



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