- outline differences in P, S and L energy waves produced by an earthquake
- identify energy transfers and transformations involved in L waves as they travel along the earth's crust
- explain how the difference in time of arrival of P and S waves can be used to locate an earthquake epicentre
- describe the difficulties of monitoring and predicting earthquakes

**Earthquakes**

We do not normally think of Australia as a place where disastrous earthquakes occur. That idea was shown to be a myth at 10.27 am on 28 December 1989. Newcastle, north of Sydney, was devastated by a moderate earthquake measuring 5.6 on the Richter Scale. This earthquake claimed 13 lives—the first such fatalities in Australia. Earthquakes of magnitude 5.6 are fairly small and don’t normally cause such extensive destruction to buildings and other structures. However, a thin layer of loose sediment under the city area appeared to magnify the ground motion (shaking).

The Newcastle earthquake struck without warning in an area people thought was safe from earthquakes. However, there had been six prior, relatively large earthquakes reported in the lower Hunter Valley since 1829. Some other Australian Earthquakes are listed in the table.

### Australian earthquakes

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Magnitude (Richter)</th>
<th>Estimated damage ($)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1892</td>
<td>Launceston, TAS</td>
<td>6.9</td>
<td></td>
<td>Epicentre located in the ocean</td>
</tr>
<tr>
<td>1897</td>
<td>Beachport, SA</td>
<td>6.5</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1902</td>
<td>Warooka, SA</td>
<td>6.0</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1903</td>
<td>Warnambool, VIC</td>
<td>5.3</td>
<td>0.39 million</td>
<td></td>
</tr>
<tr>
<td>1918</td>
<td>Bundaberg and Rockhampton, QLD</td>
<td>6.3</td>
<td></td>
<td>Epicentre located in the ocean</td>
</tr>
<tr>
<td>1935</td>
<td>Gayndah, QLD</td>
<td>5.7</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1941</td>
<td>Meecherrie, WA</td>
<td>7.2</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1946</td>
<td>Launceston, TAS</td>
<td>6.0</td>
<td></td>
<td>Epicentre located in the ocean</td>
</tr>
<tr>
<td>1948</td>
<td>Robe, SA</td>
<td>5.6</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1949</td>
<td>Dalton and Gunning, New South Wales</td>
<td>5.5</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1954</td>
<td>Adelaide, SA</td>
<td>5.4</td>
<td>78 million</td>
<td></td>
</tr>
<tr>
<td>1959</td>
<td>Berridale, New South Wales</td>
<td>5.3</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1961</td>
<td>Robertson-Bowral, New South Wales</td>
<td>5.6</td>
<td>3.7 million</td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>Meckering, WA</td>
<td>6.9</td>
<td>10 million</td>
<td>Surface faults formed; 16 people injured</td>
</tr>
<tr>
<td>1972</td>
<td>Wilpena, SA</td>
<td>5.3</td>
<td></td>
<td>Damage unknown</td>
</tr>
<tr>
<td>1973</td>
<td>Picton, New South Wales</td>
<td>5.5</td>
<td>2.5 million</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>Cadoux, WA</td>
<td>6.2</td>
<td>9.5 million</td>
<td>Surface faulting formed</td>
</tr>
<tr>
<td>1985</td>
<td>Lithgow, New South Wales</td>
<td>4.3</td>
<td>0.1 million</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>Tennant Creek, NT</td>
<td>6.8</td>
<td>2.3 million</td>
<td>Surface faulting formed</td>
</tr>
<tr>
<td>1989</td>
<td>Newcastle, New South Wales</td>
<td>5.6</td>
<td>100 million</td>
<td>13 deaths; 150 people injured</td>
</tr>
</tbody>
</table>
Earthquakes and How They Are Measured

Earthquakes take place along large cracks in the Earth called faults. Forces push the two sides of a fault in different directions. Sometimes there is a slow movement that is not felt, but which shows up when fence-lines or roads develop a bend. On other occasions, the two sides of the fault are locked together. Friction between the rocks on both sides allows little movement to occur and enormous amounts of elastic potential energy are stored. Eventually the forces become too great and the rocks on one side of the fault moves. The movement may be a series of small jerks, or one large devastating jerk.

The location beneath the surface of the Earth where movement occurs is called the focus of the earthquake (Figure 6.3). The stored energy is released as seismic waves that travel outwards from the focus. Elastic potential energy is converted to kinetic energy as the ground moves. The point on the surface above the focus is called the epicentre.

The seismic waves produced by earthquakes are detected by seismographs. A large mass is suspended in such a way that it remains stationary as a seismic wave passes. However, as the drum is attached to the Earth the seismic waves do move the drum. The pattern recorded is called a seismogram. The first part of a seismogram records the primary (P) waves - compression waves that cause minor tremors. The particles move back and forth in the direction of the wave in the same manner as sound waves. The next waves to arrive also cause only minor tremors and are called secondary (S) waves. These are transverse waves where the particles move at right angles to the direction of the wave. Water waves and electromagnetic waves such as light are also transverse waves. Both primary and secondary waves travel through the Earth and are used to determine its internal structure.

The next waves to arrive are the waves that travel over the Earth’s surface and these can cause a lot of damage. L waves (long waves) vibrate more slowly than waves that travel through the Earth, but last longer and can circle the Earth more than once before dying out. Some L waves shake the rock from side to side like S waves and are very destructive, partly because of their greater amplitude and partly because they take longer to travel through an area. The other L waves act like ocean waves rolling across the surface of the Earth. They are not as destructive as the horizontally-moving L waves because buildings can stand being raised and lowered, but not shaken from side to side.
The difference in the time of arrival of P and S waves can be used to plot the distance of seismic stations from earthquake epicentres. This is because the speeds of P and S waves through the Earth are slightly different, and one lags behind the other. The further the seismograph is from the epicentre, the greater the difference in their time of arrival. While each seismograph tells geologists how far away the earthquake was located, it does not tell them the direction. To overcome this problem, circles can be drawn on a map to scale with a radius equal to the distance from the earthquake. If this is repeated for three seismographs, the location of the earthquake can be found where the three circles cross.

Earthquake waves (a) P waves are compression waves. (b) S waves are transverse. (c) Some transverse L waves move the ground from side to side. (d) Other transverse L waves move the ground up and down.

There are two major ways to measure the intensity of earthquakes. The well-known Richter scale measures the amount of energy released at the site of an earthquake. The energy that reaches a location depends on the size, or amplitude, of the waves traced out by a seismograph. It also depends on the distance between the seismograph and the focus of the earthquake. We have just seen how this distance is measured. To find the amount of energy released at the focus, we combine these two readings to...
produce the Richter scale. On the Richter scale, a rise of one unit in magnitude represents a tenfold increase in the energy released during the earthquake.

The magnitude on the Richter scale tells us little about the effects of an earthquake on people. An earthquake with a high value on the Richter scale may cause little loss of life because it occurs in a sparsely-populated area. An earthquake may be of low magnitude, but if the focus is close to the surface near a city, it can be very destructive. The second scale used to measure the intensity of an earthquake does so by recording the amount of damage it causes. It is called the Mercalli scale.

<table>
<thead>
<tr>
<th>Magnitude (Richter)</th>
<th>Intensity (Mercalli)</th>
<th>Effect on people and objects (on the Mercalli scale)</th>
<th>Number per year</th>
<th>Energy released (TNT equivalents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1.9</td>
<td>I</td>
<td>Negligible</td>
<td>700,000</td>
<td>2 kg TNT</td>
</tr>
<tr>
<td>2-2.9</td>
<td>II</td>
<td>Feeble</td>
<td>300,000</td>
<td></td>
</tr>
<tr>
<td>3-3.9</td>
<td></td>
<td></td>
<td>40,000</td>
<td></td>
</tr>
<tr>
<td>4-4.9</td>
<td>III</td>
<td>Feeble</td>
<td>6,000</td>
<td>Small atom bomb (20,000 tonnes TNT)</td>
</tr>
<tr>
<td>5-5.9</td>
<td>IV</td>
<td>Moderate</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-6.9</td>
<td>VII</td>
<td>Very strong</td>
<td>120</td>
<td>Hydrogen bomb (million tonnes TNT)</td>
</tr>
<tr>
<td></td>
<td>VIII</td>
<td>Great</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IX</td>
<td>Very great</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>7-7.9</td>
<td>X</td>
<td>Disastrous</td>
<td>1 every few years</td>
<td>60,000 hydrogen bombs</td>
</tr>
<tr>
<td>8-8.6</td>
<td>XII</td>
<td>Catastrophic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Plate Tectonics and Earthquakes

Around 95 per cent of earthquakes occur at the edges of crustal plates. Because of Australia's geological position, we are more likely to suffer what are called intraplate earthquakes. These are different from and poorly understood in comparison with the more familiar type that occurs along the edges of crustal plates. About 5 per cent of earthquake activity is within the centre of stable rigid plates such as Australia. The Newcastle earthquake was one of these intraplate earthquakes. These are very difficult to predict because they do not occur in any regular pattern. The best we can say is that they are caused by the stresses and strains of the crustal plates as they move across the mantle. Because the focus is generally shallow, they are potentially very damaging to life and property when close to populated areas.
Earthquakes and crustal plates

Most earthquakes are located along the edges of the crustal plates. Since Australia is in the middle of its plate, earthquakes are relatively less destructive.

Predicting Earthquakes

Humans have no ability to control earthquakes. Even earthquake prediction is proving a very difficult problem to solve. We can be fairly sure where big earthquakes will take place - along the margins of the crustal plates. It is also possible to make long-term predictions about the likelihood of earthquakes in an area. The hazard map shows the probability of an earthquake occurring anywhere in Australia, based on the historic earthquake record.

Far more difficult is the job of making short-term predictions - days or even hours ahead. Since we know so little about intraplate earthquakes, this is effectively impossible in Australia. A major research effort is needed to understand how such earthquakes occur before we can make short-term predictions.

Regions on the edge of crustal plates are making some progress, particularly in China and the United States. Some of the things that geologists use to try to predict earthquakes are:

- The rising or falling of the surface of the ground. This has been seen in the past when people saw the sudden withdrawal of the ocean along coasts. Today, electronic monitoring is used in appropriate areas.
• If there has been no earthquake along a known fault, then one is more likely. This requires geological dating of evidence for previous Earth movements.
• The recorded history of earthquakes in an area. Some large faults have not had an earthquake for several hundred years.
• Strange behaviour of local animals. This was successfully used by the Chinese in Haicheng in 1975.
• Changes in the level of water in local wells. This was successfully used by the Chinese in Haicheng in 1975.
• An increase or fluctuation in the amount of radon gas released in deep wells has been known to change before an earthquake.
• The electrical conductivity of rocks in the area around earthquakes has been known to change before an earthquake.

Some nations have been able to install modern instrumentation to help make predictions. This is especially true for the San Andreas Fault in the United States. Some of these instruments are:
• Earthquake-prone areas may have a network of seismographs to monitor the small earthquakes that can occur before a major earthquake. Tiny shocks often increase in number and magnitude leading up to a large shock.
• Seismographs can also measure P wave velocity changes of about 10-15 per cent before earthquakes. Sometimes the velocity decreases for a while, then increases back to normal just before the main shock.
• Lasers are used to measure the change in length of lines across a known fault line.
• Some boreholes are fitted with strainmeters to monitor the build-up of forces in earthquake prone regions.
• Wire creepmeters are also able to measure stretch in their length due to gradual movements along a fault.

None of these is totally successful. Although the Chinese were very successful at predicting the Haicheng earthquake of 1975, no significant indicators gave a warning before the Tangshen earthquake of 1976.

Questions:
1 Why are there relatively few earthquakes in Australia?
(A) Australia is located along the edge of a crustal plate.
(B) Australia is located near the middle of a crustal plate.
(C) The edge of a crustal plate runs down the middle of Australia.
(D) Australian has no one trained to measure earthquakes.

2 Identify the instrument used to detect and measure earthquakes.
(A) Seismograph.  (B) Seismogram.
(C) Seismic wave.  (D) Seismobob.

3 In which order do seismic waves arrive from an earthquake?
(A) P wave; S wave; L wave.
(B) S wave; P wave; L wave.
(C) L wave; S wave; P wave.
(D) Primary wave; secondary wave; L wave.

4 How do we measure the distance to an earthquake?
(A) The time it takes P waves to arrive.
(B) The time it takes S waves to arrive.
(C) The difference in the time of arrival of P and S waves.
(D) The total of the time of arrival of P and S waves.

5 Which of the following measurements is the most damaging?
(A) II on the Mercalli scale.  (B) 3 on the Richter scale.
(C) IX on the Mercalli scale.  (D) 7 on the Richter scale.

6 Outline the differences in P, S and L energy waves produced by an earthquake.
7 L waves travel along the surface of the Earth’s crust.

(a) Identify the energy transfers involved.

(b) Identify the energy transformations involved.

8 Explain how the difference in time of arrival of P and S waves can be used to locate an earthquake epicentre.

9 Describe the difficulties in predicting earthquakes.

10 The locations of three seismographs in Australia are shown in Figure 6.10. Use the data in Table 6.3 to determine the location of the epicentre of each earthquake.

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Distance from Adelaide (kilometres)</th>
<th>Distance from Brisbane (kilometres)</th>
<th>Distance from Charters Towers (kilometres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>1610</td>
<td>2100</td>
<td>1190</td>
</tr>
<tr>
<td>X</td>
<td>1960</td>
<td>3350</td>
<td>2970</td>
</tr>
<tr>
<td>Y</td>
<td>690</td>
<td>1240</td>
<td>1740</td>
</tr>
<tr>
<td>Z</td>
<td>1200</td>
<td>530</td>
<td>1450</td>
</tr>
</tbody>
</table>

11 Describe how seismographs can be used to record and monitor earthquakes.

12 Compare the Richter scale and Mercalli scales used to record and monitor earthquakes.
identify some of the conditions that can combine to trigger a bushfire, including dry weather, high temperatures and flammable vegetation

describe the effect of the slope of the land and intensity of the wind on the speed of the bushfire

identify and describe some of the energy transfers and transformations associated with bushfires

discuss the reduction of fuel by controlled burns and backburns in reducing the risk of bushfires

Bushfires

In conditions of 10 per cent humidity, temperatures of 35°C and 50 kilometres per hour winds, even small bushfires can be disastrous. One such fire in Sydney jumped a river and raced up the steep 20° slope of a hillside reserve. Some houses soon burst into flame as the fire reached the top of the slope. After one hour the hillside reserve had burnt out. However, houses were still catching fire for more than two hours after the fire had started. Much of the destruction in this fire came from house-to-house ignition well after the fire had been extinguished. One person was killed. More than 100 homes and other structures were destroyed. Some of our worst bushfires are listed in the table below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Date</th>
<th>Location</th>
<th>Area burnt (ha)</th>
<th>Fatalities</th>
<th>Homes destroyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td>14 January</td>
<td>Dandenong Ranges, Victoria</td>
<td>2 000</td>
<td>8</td>
<td>454</td>
</tr>
<tr>
<td>1967</td>
<td>7 February</td>
<td>Hobart, Tasmania</td>
<td>6 600</td>
<td>20</td>
<td>310</td>
</tr>
<tr>
<td>1983</td>
<td>16 February</td>
<td>Upper Beaconsfield, Victoria</td>
<td>9 200</td>
<td>20</td>
<td>238</td>
</tr>
<tr>
<td>1983</td>
<td>16 February</td>
<td>Macedon, Victoria</td>
<td>29 500</td>
<td>7</td>
<td>628</td>
</tr>
<tr>
<td>1983</td>
<td>16 February</td>
<td>Mt Osmond, South Australia</td>
<td>3 885</td>
<td>9</td>
<td>9 100+</td>
</tr>
<tr>
<td>1994</td>
<td>27 December 1993 to 16 January 1994</td>
<td>New South Wales</td>
<td>800 000+</td>
<td>4</td>
<td>206</td>
</tr>
<tr>
<td>2001</td>
<td>24 December 2001 to 16 January 2002</td>
<td>New South Wales</td>
<td>733 342</td>
<td>0</td>
<td>109</td>
</tr>
<tr>
<td>2002</td>
<td>6 September to 16 December 2002</td>
<td>New South Wales</td>
<td>100 000+</td>
<td>1</td>
<td>42</td>
</tr>
</tbody>
</table>

In a bushfire, the fuel is everything that burns. You will remember that plants and their products such as wood in houses are carbon compounds. During combustion these compounds combine with oxygen to produce carbon dioxide and water. The chemical energy stored in the carbon compounds is released as heat and light energy.

Fuel + oxygen → carbon dioxide + water + heat

To start the combustion reaction, we must raise its temperature until the ignition temperature is reached. This is why we light fires with a match. The less moisture present, the lower the ignition temperature. Once the fire has started, the heat produced is sufficient to take the fuel above the ignition temperature and keep the fire burning.
Bushfire Conditions

The weather is the major factor in determining if a season will be bad for bushfires. Bushfire danger is low after recent rainfall and when there are low temperatures and light winds. Along the east coast we often get westerly winds during late winter and early spring. These winds dry out the bush. If by late spring we also get hot weather accompanied by low relative humidity and high winds, then the bush and grass can be extremely flammable.

Fire weather is most dangerous when hot and dry winds blow from the inland, particularly if coming from a westerly or a north-westerly direction. The worst conditions occur when deep low-pressure systems near Tasmania bring strong, dry, westerly winds to the coast. This occurred in both 1994 and 2001. Other factors affecting the danger and behaviour of bushfires include:

- quantity, type, condition and distribution of fuel
- air temperature and sunlight
- relative humidity
- wind direction and velocity
- rainfall
- topography.

Spread of Bushfires

The spread of a bushfire depends on the fuel, the weather and the terrain. The most important fuel is the plant matter on and near the ground. However, in an intense fire driven along by strong winds the shrubs and even the crowns of the forest trees can begin to burn. The most basic type of fuel is grass. Grass burns rapidly so that the fire does not last for long in any one area. Grass fires spread quickly, often up to 20 kilometres per hour, and can quickly change direction if the wind direction changes. The fuel that is most important in determining the spread of a forest fire is the litter on the floor of the forest. This includes small fast-burning leaves, twigs and bark less than 6 mm in thickness. Larger fuels, such as branches and logs, burn out after the front of the bushfire has passed. A forest fire will spread relatively slowly, often less than 12 kilometres per hour, and respond slowly to changes in the wind direction.

The intensity of a fire depends on the amount of fuel. The less the amount of fuel, the less there is to burn and the less intense the fire. If there are 5 to 7 tonnes per hectare of fuel or less in an area, firefighters would have a good chance of extinguishing a fire even under extreme weather conditions. If there is more than 15 tonnes per hectare, then the area may be considered hazardous and present difficulties for firefighters. The amount of fuel in dry sclerophyll forest around Sydney can often reach 20-25 tonnes per hectare.

<table>
<thead>
<tr>
<th>Fuel moisture content (%)</th>
<th>Fine dead fuel combustion characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%+</td>
<td>Live green leaves must be dried to burn.</td>
</tr>
<tr>
<td>80%</td>
<td>Approximate wilting point – green leaves die rapidly.</td>
</tr>
<tr>
<td>30-35%</td>
<td>Fibre saturation level.</td>
</tr>
<tr>
<td>28-30%</td>
<td>Eucalypt litter fuel will not burn.</td>
</tr>
<tr>
<td>22-28%</td>
<td>Eucalypt litter fuel very difficult to ignite, burning difficult to sustain.</td>
</tr>
<tr>
<td>20-24%</td>
<td>Grass fuel will not burn.</td>
</tr>
<tr>
<td>16-22%</td>
<td>Eucalypt fuels difficult to ignite. Good for controlled burns. Pine fuels burn readily.</td>
</tr>
<tr>
<td>13-16%</td>
<td>Eucalypt litter fuel moderately easy to ignite, burning sustained. Pine fuels easy to ignite.</td>
</tr>
<tr>
<td>10-13%</td>
<td>Burning readily sustained, fire behaviour predictable. Lower limit for low intensity controlled burning.</td>
</tr>
<tr>
<td>5-10%</td>
<td>Severe fire behaviour, crowning likely, progressively smaller fire embers start spot fires.</td>
</tr>
<tr>
<td>3-5%</td>
<td>Extreme, erratic fire behaviour, crowning and spotting are common.</td>
</tr>
</tbody>
</table>

Fuel moisture content (CSIRO)
The intensity of a fire also depends on the moisture content. The level of moisture in dead plant material determines how readily the fuel will ignite and how completely it will burn. The greater the level of moisture the higher the temperature needed to ignite the fuel and the less readily it burns. The amount of moisture in dead plant matter changes during the day depending on the temperature and the relative humidity of the air. Fuel will usually absorb moisture from the air if the humidity is above 50 per cent. Below 50 per cent fuels will lose moisture to the air and below 20 per cent fuel moisture content reaches a dangerously low level. The level of moisture present in living plants is high and the plant has to be dried out by the flames before it will burn.

You can perform an experiment to compare the flammability of fresh and dry leaves. You will need a convex lens and a sunny day. Support the lens with a clamp and stand, and then focus light from the Sun onto a dry leaf so that you get the spot a small as possible. Keep this distance constant as you time how long it takes to get dry and fresh leaves to burn. The dry leaf will burn, but it may not be possible to get the fresh leaves to burn at all.

Weather’s influence on the behaviour of bushfires includes rainfall, the temperature and relative humidity of the air, and the wind speed. Rainfall determines the general type of vegetation and thus the type and amount of fuel available for burning. Rainforests with high rainfall burn less readily than dry sclerophyll forests with low rainfall. Recent rainfall then determines how much moisture is held by the fuel and how long it takes to dry out. In summer, the moisture from rainfall may evaporate very quickly and in grasslands the moisture may last for only a few hours after the rain stops.

The temperature and relative humidity of the air determines the moisture content of the dead plant matter once the effects of rainfall have evaporated. The higher the relative humidity and the cooler the air, the higher will be the moisture content. As the humidity falls and the temperature rises, the moisture content decreases. If the fuel is very moist, the more heat energy that is needed to boil off the water in the fuel before it can then heat up the fuel to its ignition temperature. The lower the moisture content of the fuel, the easier it is to ignite and the more heat energy is given off to heat more fuel.

In many ways, wind is the weather factor that determines how dangerous a fire may become. If there is little wind, a fire will spread slowly allowing better control of a fire. The faster the wind blows, the faster a fire will spread. Wind will blow burning embers ahead of the fire front starting new fires and increasing the difficulty of controlling the fire. The process is called spotting and the fires produced this way are called spot fires.

The slope of the terrain, and particularly its angle compared to the direction from which the wind is coming, is a major factor that influences fire behaviour in hilly country. Slopes facing south tend to be moister than those facing north as they are heated less by the Sun. The angle of slope also affects the rate of spread of the bushfire. Fires move uphill faster than downhill. This is because the heat generated from the fire causes the hot air to rise. Not only does this carry forward embers, but it also dries out the vegetation ahead of the fire making it easier to ignite.

The fire intensity helps determine how much fuel will burn. As the fire increases in intensity, it dries out more and more leaves higher in the trees. If the fire is intense enough, or driven by strong winds, the
crowns of the forest trees catch alight and contribute to the behaviour of the fire. This process is called crowning.

Fighting Bushfires

For a fire to spread it requires fuel to burn, air for combustion and heat for the fire to continue burning. The goal in controlling a fire is to remove one or more of these factors.

If fuel is removed, the fire goes out. In bushfires this can be achieved in advance of the fire season by controlled burning or the physical removal of the fuel. Controlled burning involves deliberately burning potential fuel for a fire when there is no wind. Moisture levels must be low enough to allow burning, but not so low as to create a damaging fire. The frequency of controlled burning will depend on the type of vegetation and the vulnerability of flora and fauna to fire. Fuel is physically removed when home-owners clear vegetation and leaf litter near their houses. During a bushfire emergency, the removal of fuel can be carried out physically with the use of bulldozers to clear a fire line. The removal of fuel can also be carried out through the lighting of small controlled fires to remove the fuel ahead of the fire. These fires, called back-burning, are lit from control lines and must only be done by experienced firefighters.

If air is removed, the fire will also go out. The removal of air from a bushfire is quite difficult as fires are normally quite big and cover a large area. However, domestic and industrial fires can be extinguished by water-based foam sprayed onto the fire. The foam prevents the air reaching the fire. On a smaller scale, a layer of dirt shovelled onto the fire will act as a blanket to put out a fire.

Heat is removed from a fire by cooling the fire. When water is sprayed over a fire, the heat turns the water into steam, thereby depriving the fire of the heat needed to keep the fire going. Without energy in the form of heat, the fire cannot heat unburnt fuels to ignition temperature to burn them and the fire will go out. In addition, the water can help prevent oxygen reaching the fire.

Protecting Yourself and Your Home

Many people live close to or even in the bush and their homes are quite vulnerable to bushfires. What steps can be taken to help protect homes and other property? Firstly, the site of the house needs to be chosen carefully. Fires travel faster uphill and in front of the wind, which is likely to blow from the north-west, west or south-west on a serious fire day. Many of the houses destroyed in the fire described at the start of this chapter were built on a cliff that faced west. Care is needed when planting gardens. Smooth-barked trees are preferred as they do not provide fuel that allows fire to reach to the crown. Trees with stringy and papery barks and those that form bark in strips and sheets each season provide plant matter that burns easily. Many gum trees, stringy-barks and paperbarks are like this. Trees and shrubs, such as melaleucas and leptospermums, that produce many twigs and dead branches, increase fire intensity when they ignite, and should not be planted too near buildings. Other trees, such as conifers, eucalypts, turpentines, melaleucas and leptospermums that contain high levels of resins and volatile oils, should not be planted near buildings or on slopes below buildings in fire-prone areas.

All plants will burn, but fire-retardant plants do not ignite as readily as most others. Features of plants that provide protection from fire include:

- high salt content of leaves
• high moisture content of leaves
• low volatile oil content of leaves
• thick bark protecting conductive tissues and dormant buds
• seeds enclosed in woody capsules
• dense crown
• lowest branches out of reach of ground fires.

Many rainforest plants, fruit trees, fruit shrubs, fruit vines, vegetables, fleshy-leafed plants and salt-marsh plants are examples of fire-retardant plants. Unfortunately, many fire-retardant species are not fire-resistant and are severely set back or die after exposure to fire.

To reduce the risk of fire, keep the amount of fuel (leaves, twigs, logs, dead grass) near to the house to a minimum. Fires will not burn if there is no fuel.

• Maintain a clear area, such as regularly-mown lawn, near the house.
• Remove dead branches and twigs and any strips of bark from trees to reduce the chances of ignition.
• Plant trees at a distance (at least five metres) from the house so that limbs and branches will not hang over the roof, dropping leaves in the gutters.
• Keep trees and shrubs two metres apart so that there isn’t a continuous canopy which could carry fire to the house.
• Arrange the trees to provide a non-flammable windbreak on the side of the house from which fires are most likely to come. This will reduce the wind near the house and reduce the fire’s intensity and the rate at which it spreads. It will also intercept burning embers carried by the wind. You can sometimes be personally in danger during a bushfire. This is particularly true if you live in or close to the bush.
### Fire safety

(http://www.nswfb.nsw.gov.au/)

**Protecting the home from bushfire**

- Clean leaves from gutters regularly and fit quality metal leafguards.
- Screen vents leading into the roof with fine metal wire mesh.
- Fit metal and not plastic flyscreens on windows and doors.
- When installing LPG cylinders around your home, make sure that pressure relief valves face outwards so that flame is not directed towards the house.
- Keep woodpiles and other flammable materials well away from the house and covered.
- Keep your lawn short and the backyard tidy, free from any build-up of flammable material.
- Do not deposit tree loppings, grass clippings etc. behind your property into council reserves or bushland.
- Ensure your garden hoses are long enough to reach the edge of your property.
- Plant trees and shrubs that are less likely to ignite due to their lower oil content.
- If you have a swimming pool, have a Static Water Supply sign placed on your front fence. Contact your local fire station for information.
- Consider purchasing a portable pump to use from your swimming pool or water tank.
- On Total Fire Ban days obey regulations regarding BBQs and open fires.
- Ensure all members of the family know where the community evacuation area is.
- If there is a Community Fire Unit nearby, become a member.
- Make sure that the fire hydrant outside your home is easily located and not obstructed.

**If a bushfire threatens your home**

- Close all windows and doors.
- Ensure someone has notified the fire brigade.
- All family members should move to a substantial room furthest from the fire front.
- Take garden hoses and connections inside, fill bath and buckets with water.
- If time allows, block downpipes with rags and fill gutters with water.
- Block spaces beneath doors with towels or blankets to keep smoke out.
- Remove coir mats and garden furniture away from the house.
- Reassure children that they will be safe.
- After the fire passes, go out and extinguish any spot fires in gutters etc.

**If a bushfire threatens your home (continued)**

- Beware of any electric power lines that may have dropped onto the ground.
- If you can’t extinguish the fire, move all family members to a burn-out area.
- Ensure all family members and pets consume enough water to prevent dehydration.
- If ordered to evacuate by police, you should report to designated evacuation location.
- Some hardware stores stock special valves and plugs to block downpipes and gutters. Also be careful not to overfill gutters as excess water may damage internal walls.
- Wear eye protection, enclosed shoes and wool or cotton full-length clothing when extinguishing spot fires.

**If trapped in your car**

- Pull to the side of the road in a location free from vegetation underneath.
- Turn your ignition off to isolate the electric petrol pump.
- Turn your headlights on.
- Close all windows and air vents.
- Cover the occupants with a blanket etc. to protect them from radiant heat.
- Stay low down in the vehicle until the fire passes.
- If you have a mobile phone or CB radio, call 000 for assistance.
- Remain in the vehicle until the fire passes and smoke clears.

**If trapped in the bush**

- Never enter the bush if smoke or fire is in the area.
- Seek shelter in your vehicle or a large body of water.
- Never run uphill to escape a fire.
- Try to find an open space such as a previously burn-out area, rocky ground or clear litter away from you and shelter behind your haversack or fallen log.
- Stay low to the ground for fresh air and cover up exposed skin for protection from radiant heat.
- Never attempt to run through a bushfire unless it is small with flames less than one metre in height. (This should only be done as a last resort.)
- If your mobile phone or CB is within transmission range, use them to notify NPWS or 000 of your situation and location.
- Remember when camping notify NPWS rangers of your location and obey fire restrictions.
Bushfire Questions:
1 Which of the following sets of conditions is most likely to result in a bushfire.
(A) Wind 50 kilometres per hour from west; temperature 39°C; humidity 11 per cent.
(B) Wind 15 kilometres per hour from south; temperature 19°C; humidity 91 per cent.
(C) Wind 50 kilometres per hour from east; temperature 9°C; humidity 51 per cent.
(D) Wind 15 kilometres per hour from north; temperature 29°C; humidity 91 per cent.

2 In which season of the year is Sydney most likely to experience bushfire?
(A) Late winter. (B) Late spring-early summer. (C) Mid summer. (D) Late summer-early autumn.

3 Which of the following sets of conditions are best for reducing fuel with a controlled burn in the Sydney region?
(A) Wind 15 kilometres per hour; fuel moisture content 10 per cent; late spring.
(B) Wind 10 kilometres per hour; fuel moisture content 40 per cent; mid summer.
(C) Wind 5 kilometres per hour; fuel moisture content 5 per cent; early summer.
(D) Wind 1 kilometres per hour; fuel moisture content 20 per cent; autumn.

4 Why do firefighters use shovels to place soil over the smouldering remains of a bushfire?
(A) Makes the area cooler to walk over. (B) Adds moisture to extinguish the fire.
(C) Cuts off the supply of oxygen to the fire. (D) Removes evidence that a bushfire has been in the area.

5 Which of the following plants is the most dangerous to have growing near a house?
(A) Ribbon gums with long strands of bark hanging from the trunk and leaves containing eucalyptus oil.
(B) Blue gums with smooth bark and leaves containing eucalyptus oil.
(C) Ironbarks with thick rough bark and leaves containing eucalyptus oil.
(D) Stranger figs with smooth bark and fleshy leaves containing a lot of moisture.

6 Identify three of the conditions that can combine to help trigger a bushfire.
7 Describe the effect of the slope of the land on the speed of the bushfire.
8 During a bushfire, energy is transferred and transformed in various ways.
   (a) Identify the energy transformations during a bushfire in dry vegetation.
   (b) Identify the energy transformations during a bushfire in moist vegetation.
   (c) Describe how a bushfire can transfer energy.
9 Discuss how the reduction of fuel can reduce the risk of bushfires by:
   (a) controlled burns
   (b) back-burns.
10 Identify two types of native vegetation that promote the spread of bushfires.
11 Describe the use of water to retard the progress of fire.
12 Describe the use of natural plants to retard the progress of fire.
13 Identify five precautions that can be taken before the bushfire season to minimise the likelihood of damage to a house by fire.

14 (a) Describe an experiment you have carried out to compare the flammability of dry and fresh leaves.

(b) Outline the controls you used to make a valid comparison.

(c) Describe how you increased the accuracy of your measurements.

(d) What conclusion did you make?

15 Explain what steps should be taken if caught by a bushfire when out bushwalking.

2002 HSC
(d) In your study of this option, you have undertaken research into the factors that promote the spread of bushfires.

(i) Identify ONE factor found in your investigation that promoted the occurrence or spread of a bushfire.

(ii) Outline the steps you would take to assist survival if you were caught in a bushfire.

(iii) Outline an investigation you have performed to compare the flammability of dry and fresh leaves. Include the aim, the method used and the findings of your investigation.
2006 HSC

(a) John wished to build a house on his new bushland property, at a site with the least risk from bushfire. This is a sketch John made to consider two possible house sites.

(i) Identify ONE factor that can affect the speed of a bushfire approaching John’s house if he built it at site A.

(ii) John decided to build his house at site B. Explain precautions John could undertake to reduce the risk to his house.