UNIT 2

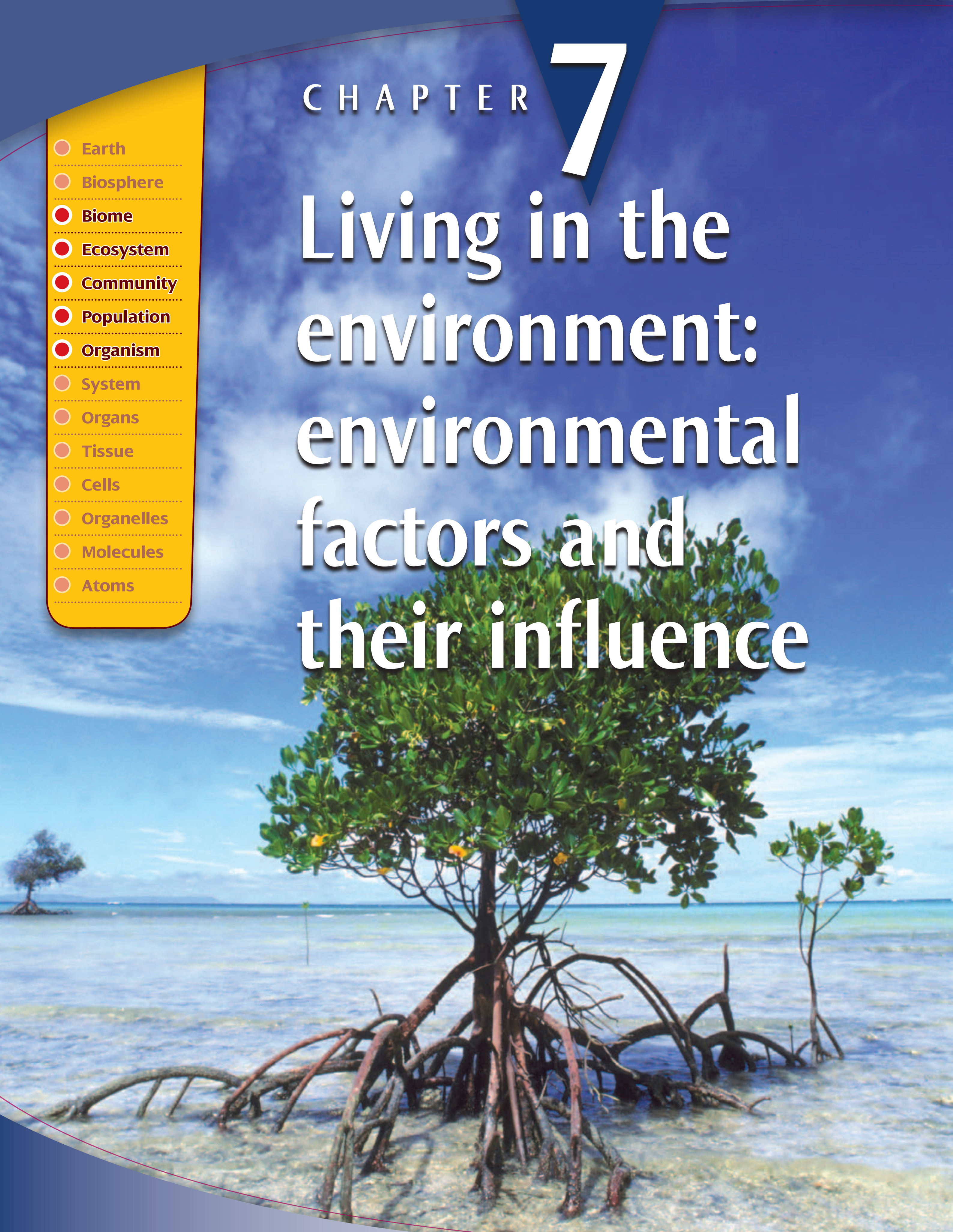
Organisms and their environment

The biosphere has a great many ecosystems, all of which provide homes to a large number and variety of living organisms. How do factors, both biotic and abiotic, that operate within the ecosystems influence the kinds of living things that are able to survive there? What effect does change to the ecosystem, both natural and human-induced, have on the organisms continued success in that ecosystem? How can we monitor and best understand these complex ecosystems so that we can minimise our impact on these natural systems and their inhabitants?

- Earth
- Biosphere
- **Biome**
- **Ecosystem**
- **Community**
- **Population**
- **Organism**
- System
- Organs
- Tissue
- Cells
- Organelles
- Molecules
- Atoms

CHAPTER 7

Living in the environment: environmental factors and their influence



Key knowledge

- Environmental factors: biotic and abiotic factors; availability of resources
- Structural adaptations: relating major features of organisms to survival value
- Physiological adaptations: tolerance range of organisms; maintaining equilibrium by detecting and responding to changes in environmental conditions
- Plant tropisms: growth responses; rhythmic activities
- Techniques used to monitor environmental change and species distribution

A polar bear does not live in a desert, nor a fish in a tree! It is obvious, but why? Every living organism, whether a bacterium, frog or eucalypt tree, depends for survival on being able to make use of the resources in its environment. It will live only where it has the capacity to obtain what it needs.

Survival in a particular place or **habitat** involves not only the kind of resources available but the **adaptations** an organism has – the structural, physiological (body functioning) and behavioural characteristics – that enable it to compete successfully to obtain its requirements, often in changing conditions.

There are few places on Earth, if any, where environmental conditions are stable throughout the year and from one year to the next. Change is a feature of existence and life forms, **biota**, have evolved to live in an extraordinary range of places that make up the Earth's **biosphere**.

Terrestrial **biomes** differ from aquatic biomes. Freshwater fish and water plants living in a billabong experience different environmental conditions from marine fish and seaweeds in the ocean. Polar bears of the Arctic have different conditions to deal with compared to the crocodiles and marsupials of the Northern Territory. Mammals, birds and vegetation of equatorial regions experience more consistent temperatures throughout the year, but precipitation can vary according to altitude and distance from the coast. Desert hopping mice, spinifex grass and cocoon frogs have to survive in hot deserts characterised by sparse rainfall and high temperatures that plummet during the night. In contrast, in Antarctica, despite seemingly inhospitable conditions, well-adapted plants and animals flourish.

In this and the next two chapters we investigate the way organisms live in their environment: the kinds of environmental factors that influence them and some of the major structural, physiological and behavioural adaptations that plants and animals have that enable them to meet their needs.

bioTERMS

habitat
the place in which an organism lives

biota
life forms

biosphere
'layer' of the Earth, including waters, lower atmosphere and soil, which supports life; the sum total of all the Earth's ecosystems

biomes
areas of the Earth linked by a common feature

Environmental factors

In everyday language, 'environment' tends to mean the physical space or surroundings in which an organism lives. Biologically, 'environment' means the sum total of all the factors that affect an organism. These can be categorised according to whether the factors are **abiotic** or **biotic**:

- Abiotic factors are physical and chemical factors such as temperature, light intensity, texture and pH of the soil, concentration of significant gases in water or air, and the availability of water.

- Biotic factors are to do with the presence or absence of other living things that affect an organism, such as more of their own kind, competitors, collaborators, predators, disease-causing organisms or parasites, and availability of mates.

Table 7.1 Environmental factors that affect the distribution of species.

Regional factors	Local factors
Abiotic factors Atmospheric gases Average amount of precipitation (rainfall, snow) Average temperatures Climate (sum of rainfall, wind patterns, temperature) Geographic barriers (mountains, oceans) Hydrology (water systems) Length of growing season Seasonal distribution of rainfall Seasonal temperature range Soil Topography (altitude, slope)	*Abiotic factors* Atmospheric gases Daylight length Degree of exposure (to light, heat, wind, wave) Drainage Fire Light levels Pollutants Relative humidity Salinity Snow coverage Soil type (parent rock) and quality (texture, water-holding capacity) Solar radiation Temperature Topography (altitude, slope, aspect) Weather (sum of local 'climate' factors)
Biotic factors Regional distribution of producers affects distribution of consumers	*Biotic factors* Competitors (within populations of same species, or different species) Collaborators (members of the same species or of different species) Herbivores (insects, browsers, grazers) Humans Parasites (rusts and so on) Predators

Tolerance limits

For many abiotic factors such as temperature and oxygen concentration, a particular species has a level or *tolerance range* within which it functions best (Figure 7.1). This is its **optimum range** for that factor and it may be broad or narrow depending on the species. Outside that range an organism begins to suffer **physiological stress** and its functioning is affected. For example, you may know of the consequences of experiencing prolonged periods of extremes of temperature that can result in heatstroke or hyperthermia.

bioTERMS

optimum range
narrow range within the tolerance range an organism has for an abiotic factor, and at which the organism functions best

physiological stress
stress caused when an organism experiences conditions outside its tolerance range

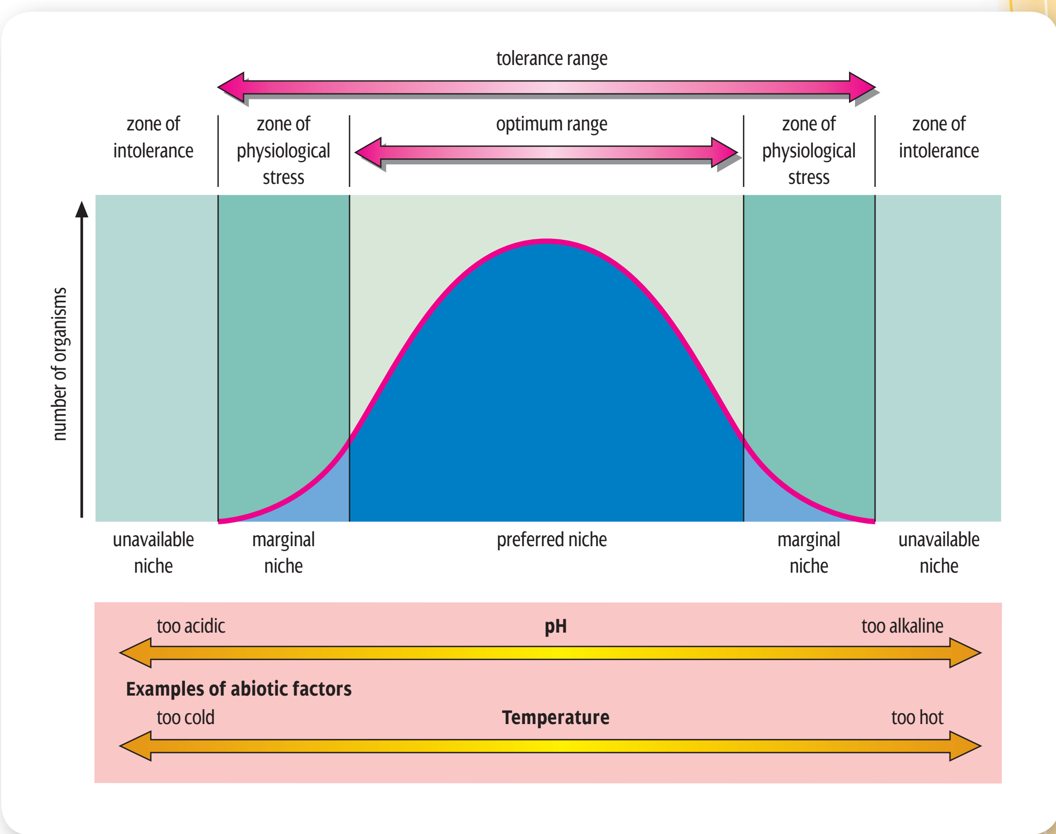


Figure 7.1 The tolerance range is a range for an abiotic factor within which an organism functions best.

Figure 7.2 Directions for growing seedlings.

Some plants, such as moss and many ferns, are 'shade-loving', while others require a high light intensity if they are to thrive. A shade-loving plant placed in bright light will not survive, and vice versa (see Figure 7.2).

Inside and outside – internal and external environments

The relationship between the internal and external environments of a living thing is important. In the case of unicellular organisms such as *Paramecium*, *Amoeba* or microscopic algae, everything to the inside of its cell membrane constitutes the internal environment. In a multicellular organism, internal environment refers to the conditions within its cells and in the extracellular fluid between its cells.

BIOBOX 7.1
INSIDE AND OUTSIDE

Why is the state of the internal environment so important? A number of conditions affect the way cells function. For example, the concentration in cells and tissue fluids of solutes such as glucose and hydrogen ions (pH) and gases such as oxygen and carbon dioxide affects cell metabolism.

Movement of materials across membranes is affected by the concentration of water molecules, nutrient particles and ions, such as those of sodium, potassium and chloride, on either side of the cell membrane. Metabolic activity within cells is controlled by enzymes and the activity of enzymes is affected by temperature; so change in environmental temperature can be significant in the way an organism functions.

Conditions in the external environment place different pressures on organisms but they possess, to varying levels of complexity, structures, behaviours and physiological features that enable them to live their lives in their particular habitat.

Adjusting to change

Some organisms can adjust to changing conditions if the changes are gradual. Some fish species can withstand slight changes in temperature as they move from place to place within a body of water. A skink in the desert will emerge in the morning and absorb the heat of the Sun. As the day progresses, its body temperature rises to the skink's optimum. When it reaches the upper limit of tolerance the skink will move into the shade.

A sessile plant, such as a mulga tree, spinifex or seaweed, has no capacity to move. It relies on its structure and physiology to survive in its environment. Even so, at a particular stage in its life cycle, a plant's seeds, spores or fruits can be dispersed to different – and perhaps more favourable – areas.

In some habitats, environmental conditions vary on a regular basis. If a swamp tends to dry up in summer, frogs and many invertebrates will burrow in the mud, seeds and eggs will lie dormant and birds will migrate to other areas where resources are more plentiful. These kinds of responses or behaviours shown by animals will be considered in more detail in later chapters.

REVIEW

1 Draw a concept map to show the relationship between the following: biosphere, habitat, ecosystem, community, biome, environmental factors.

2 For each of the following organisms, make a list or draw a relational diagram of what you consider are the four most important abiotic factors and the four biotic factors that influence them:
   - a a sea anemone in a rock pool
   - b a tree in a paddock
   - c an insect larva in the soil.

   Explain in what way each factor affects each organism. Put your answers in a table or annotate your relational diagram.

3 Distinguish between 'zone of physiological stress' and 'zone of tolerance'.

4 Fish living in estuaries have a wide tolerance range for salinity. Why is this so?

5 Why is it an advantage for a migratory eel to have a wide tolerance range for temperature?

Geographic distribution

The geographic range and distribution of a species depend on the resources available in the environment and whether it can obtain what it needs. This in turn depends on its own characteristics or adaptations to the prevailing abiotic factors, including its tolerance range. The wider the species' tolerance range, the more widely will be the geographic range (Figure 7.3).

Of course, biotic factors influence the distribution of a species within the range. The brightly coloured Leichhardt's grasshopper, called Alyurr by the peoples of Western Arnhem Land, occurs in small populations that are totally dependent on one food source, *Pityrodia*, a resinous bush. The availability of the bush is a limiting factor in that it determines the maximum population of the species. However, even though the bush has a wide distribution it is not matched by the distribution of the grasshopper. This is probably because of invertebrate predators – spiders, wasps and other insects – that gather on the plant in the dry season. These are not warned off by the bright red of the grasshoppers as are the vertebrate predators, such as birds.

Another factor that might affect the distribution of the small populations is fire. Much of the controlled burning that takes place is in May and June – a time when the juvenile grasshoppers have not yet developed wings. The grasshoppers are burnt but their host plant, *Pityrodia*, is fire-tolerant; it just grows back lush and green. If the young grasshoppers do fall into cracks and escape being burnt, they starve before their food source recovers.

The distribution and abundance (how many there are in a given area) of different kinds of species depend on how well they obtain the resources they need for their survival.

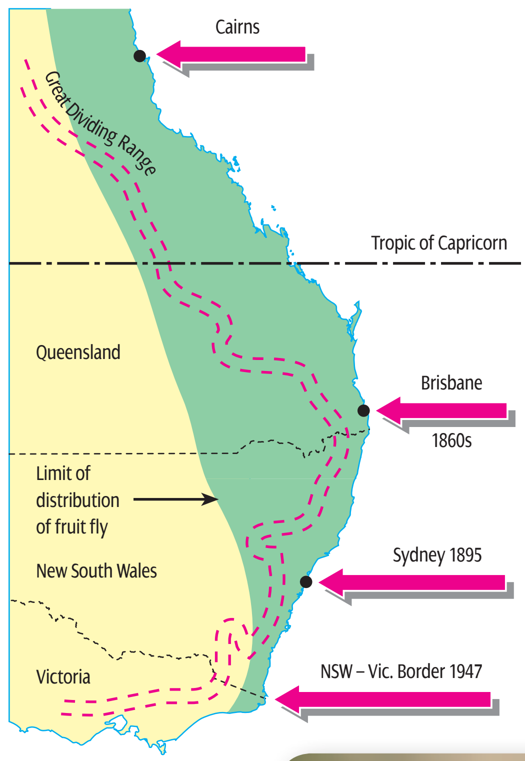


Figure 7.3 (left) The Queensland fruit fly has extended its geographic range south by evolving a tolerance to extreme temperatures. The Cairns population, where temperatures are relatively stable, is less tolerant of low and high temperatures than are southern populations. Other fruit flies have developed physiological differences in tolerance to alcohol, a product of the fermenting juices in certain fruits.

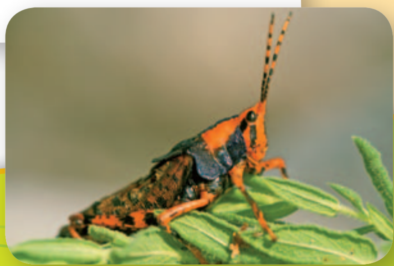


Figure 7.4 (right) Alyurr, the Leichhardt grasshopper.

REVIEW

6 Describe the relationship between tolerance limits of organisms and their distribution.

7 Give one example for each of a structural, behavioural and physiological adaptation possessed by an organism. In what way does each adaptation help the named organism to survive?

8 The physical environment determines the distribution and abundance of plants. Explain.

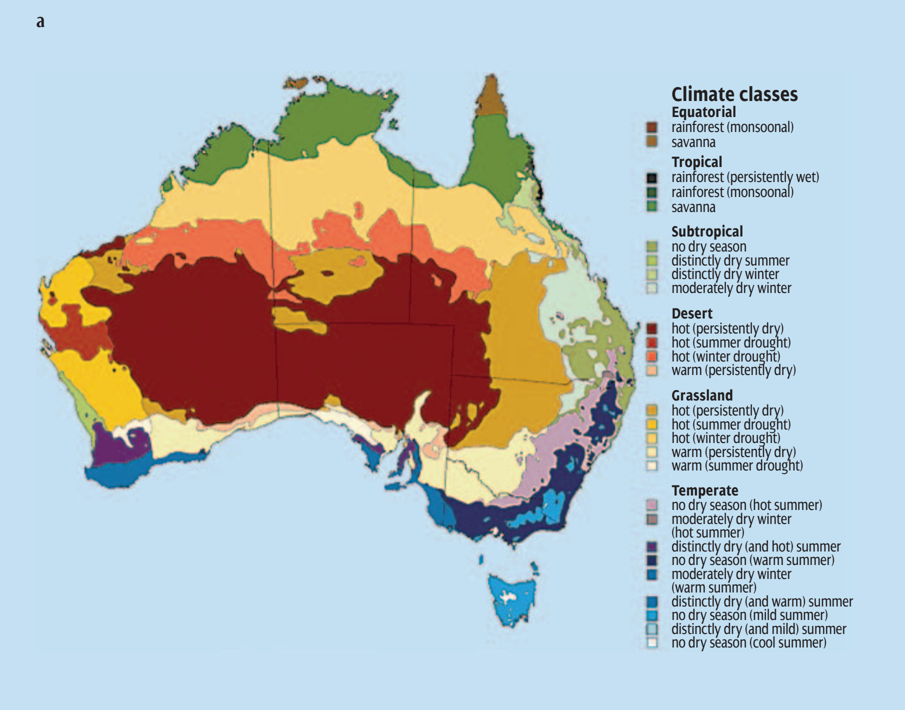
9 Explain what is meant by a limiting factor.

Ecosystems

Particular sets of environmental factors characterise ecosystems – systems in which there is exchange or cycling between living things and non-living components. For example, plants take up water from the soil and release water vapour to the atmosphere and organic wastes produced by organisms are returned to the soil. The concept of an ecosystem can be summarised as:

ecosystem = habitat + community of living things

Within a particular habitat there are microhabitats, small scale but distinctive differences in physical and chemical factors that affect what lives there. In school grounds and local parks, under a log, on an exposed rocky surface, in cracks and crevices, in a rock pool, microhabitats may support their own micro-community in a micro-ecosystem within the whole.



Source: Australian Bureau of Meteorology website

STUDENT CD

Vegetation types

Figure 7.5 (a) Key climate groups and their subdivisions. **(b)** Vegetation patterns in Australia Regional patterns of climate and vegetation are linked. Regional distribution of vegetation influences the kind of communities present.

Vegetation types

The interactions between components of ecosystems are described in Chapter 11. Here we consider ecosystems in terms of the kind of vegetation supporting the rest of the community that becomes established. The types of plants that grow and their distribution are largely determined by abiotic factors such as soil and climate.

Ecosystems can be distinguished from each other by their overall appearance and the kind of communities they support; mangrove swamps are distinct from alpine regions and marine ecosystems from inland deserts, but the naming of ecosystems has not been consistent. Terms developed and used in the Northern Hemisphere are not necessarily applicable to the Southern Hemisphere. For example, is savanna woodland equivalent to open woodland or to semi-arid woodland?

A more consistent system of classifying Australian vegetation was developed by Ray Specht, Professor of Botany at the University of Queensland from 1966 to 1989. In his system, classification of ecosystems by type of vegetation is according to two factors: the height and percentage of canopy cover of the tallest layer (stratum) of vegetation. Plants tend to grow to different levels depending on the prevailing abiotic factors. An ecosystem may be distinguished by several layers (strata). In a dry sclerophyll forest, for example, the strata include the top canopy of trees, the middle layer of shrubs and the bottom layer of grasses. A tree is defined as a woody plant over 5 m tall having a single stem; a shrub a woody plant with many stems.

If a shrubland is dominated by mulga (*Acacia aneura*) it is described as mulga shrubland; sclerophyll forest systems are dominated by eucalypts. 'Sclerophyll' means the leaves of the eucalypt trees have a thick cuticle.

Table 7.2 Classification of Australian vegetation (according to Specht).

	% canopy (foliage cover) of tallest stratum			
Form and height of the tallest stratum	<10% Very sparse	10–30% Sparse	30–70% Mid-dense	70–100% Dense
Trees 30 m+	Tall open woodland	Tall woodland	Tall open forests	Tall closed forests
Trees 10–30 m	Open woodland	Woodland	Open forest	Closed forest
Trees 6–10 m	Low open woodland	Low woodland	Low open forest	Low closed forest
Shrubs 2–8 m	Tall open shrubland	Tall shrubland	Open scrub	Closed scrub
Shrubs 1–2 m	Low open shrubland	Low shrubland	Open heath	Closed heath
Hummock grasses	Open hummock grassland	Hummock grassland	–	–
Herbaceous plants	Sparse herbland	Open herbland	Herbland	Closed herbland

REVIEW

10 What are the components of an ecosystem?

11 How are ecosystems distinguished from each other?

12 Describe the characteristics of a sheoak woodland.

13 Why are ecosystems often described in terms of their vegetation? Which factors influence the distribution of vegetation?

Measuring environmental factors

Human impact on natural ecosystems has made it increasingly important that we know more about them. When studying ecosystems to analyse and explain the distribution of populations of species and changes to them, careful **quantitative** measurements of factors (Table 7.3) are necessary. These are in addition to any **qualitative** descriptions, such as the area being 'hot and dry' or 'exposed and windy', descriptions that tend to be subjective unless clearly defined.

To carry out a systematic study of a particular ecosystem it is necessary to work out not only which environmental factors need to be measured but which aspect of the factor. For example, for temperature, is it the maximum, minimum or time of day the temperature is taken that is significant? Is it the temperature at ground level or is it the air temperature at different heights? As the temperature in bodies of water tends to decrease with depth, is it important to know precisely at what depth the temperature has to be taken?

Differences in physical conditions vertically and across a habitat give rise to **stratification** and **zonation** (Figure 7.7) of the biota that live there.

bioTERMS

qualitative
descriptions that do not involve measurements

quantitative
measurements that can be quantified – expressed in units

stratification
vertical differences in abiotic conditions, giving rise to 'layers' or strata

zonation
horizontal differences in abiotic conditions that give rise to distinctive zones

Table 7.3 Some physical and chemical (abiotic) factors operating in ecosystems and the instruments used to measure them.

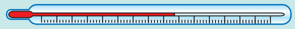
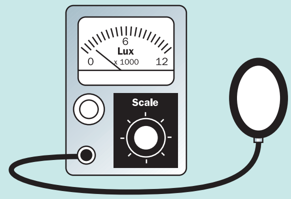
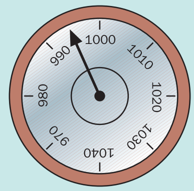
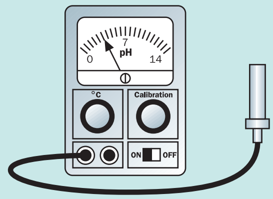
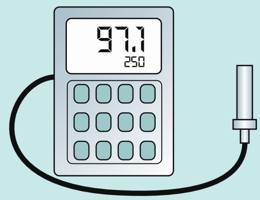
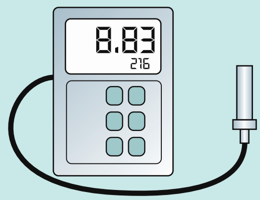
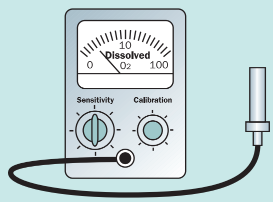
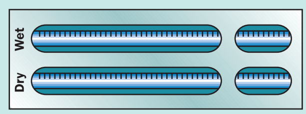
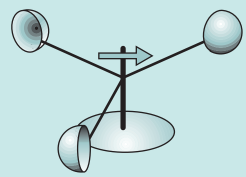
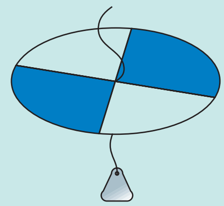
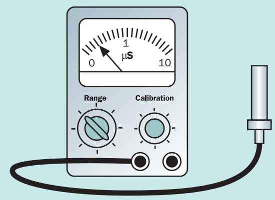
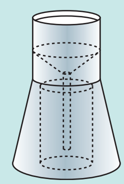
Factor	Significance	Instrument	Illustration
Temperature	Affects growth rate, cellular processes, solubility of gases in aquatic media, behaviour.	Thermometer, electronic thermometer	
Light	Light intensity and colour affect photosynthesis, visibility affects detection of prey.	Light meter	
Pressure	Pressure increases with depth in oceans, affecting solubility of gases; pressure decreases with altitude.	Barometer	
pH (hydrogen ion)	Acidity or alkalinity of soils affects plant growth by affecting the availability of inorganic nutrients.	pH meter, indicator papers	
Conductivity	Refers to the ability of a liquid to conduct electricity because of the ions present. It therefore provides a measure of inorganic materials available to terrestrial or aquatic plants.	Conductivity meter	
Salinity	The total amount of salts dissolved in water, very high in sea water, very low in fresh water. Significant in determining tolerance of organisms.	Salinity meter	
Oxygen	Important to organisms that respire aerobically; fairly constant concentration in the atmosphere (20%), varies in aquatic environments. The amount of organic pollution can be determined by biological oxygen demand (BOD); waterlogged soils have lower oxygen levels.	Dissolved-oxygen meters	
Humidity	Affects water loss from plants (transpiration rate) and evaporation from animals; relative humidity (%) expressed as the amount of water vapour in the air compared to what the air would hold if completely saturated at that temperature.	Hygrometer	

Table 7.3 continued

Factor	Significance	Instrument	Illustration
Wind speed	Wind can cause physical damage to plants and affect rate of transpiration; can contribute to dehydration in animals and can affect behaviour; stillness of air can be significant.	Anemometer (wind speed), wind vane (direction)	
Turbidity (amount of suspended material in water)	Affects intensity and quality of light reaching aquatic plants for photosynthesis.	Secchi disc	
Soil or water nutrients, salinity	Organisms have tissues in balance with their aquatic surroundings; terrestrial plants have particular nutrient requirements.	Chemical testing kits, conductivity kits	
Rainfall	Contributes to water availability.	Rain gauges	

Biobox 7.2
Viewed from above

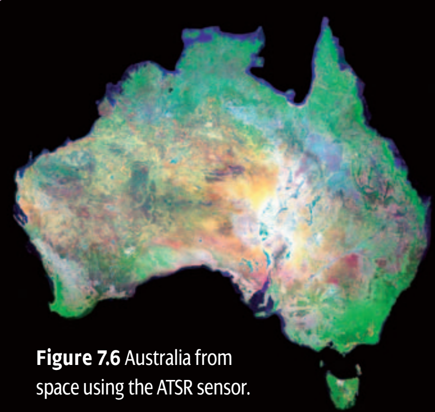


Figure 7.6 Australia from space using the ATSR sensor.

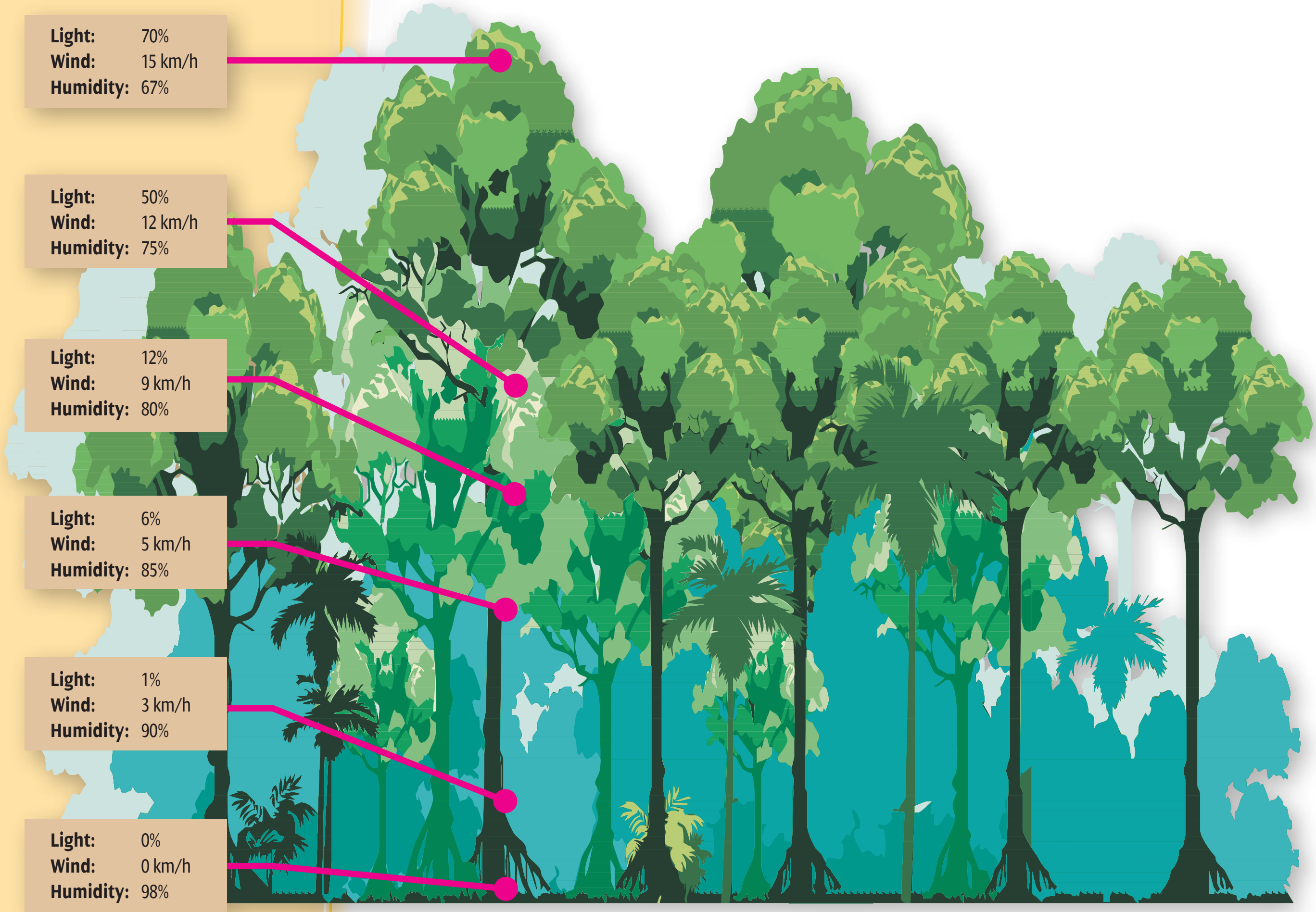
Remote sensing by satellite is used to measure the reflectance of different wavelengths of radiation by the Earth's land surfaces, ocean surfaces and the atmosphere. Remote sensing, together with ground-sensing technology, provides measurements that help scientists to monitor the environment and understand important processes that sustain our planet.

A variety of satellite sensors can take measurements of:

- surface temperature of oceans, to within one-quarter of a degree
- ocean colour from which the chlorophyll concentration can be estimated and therefore phytoplankton distribution
- variations in sea level
- thermal infra-red radiance from the Earth's surface, which can be used to monitor vegetation cover and types
- lidar (light radar) for studies of clouds and plumes.

One of the sensors, the Along-Track Scanning Radiometer (ATSR), probes each location on the Earth's surface twice as the satellite passes overhead.

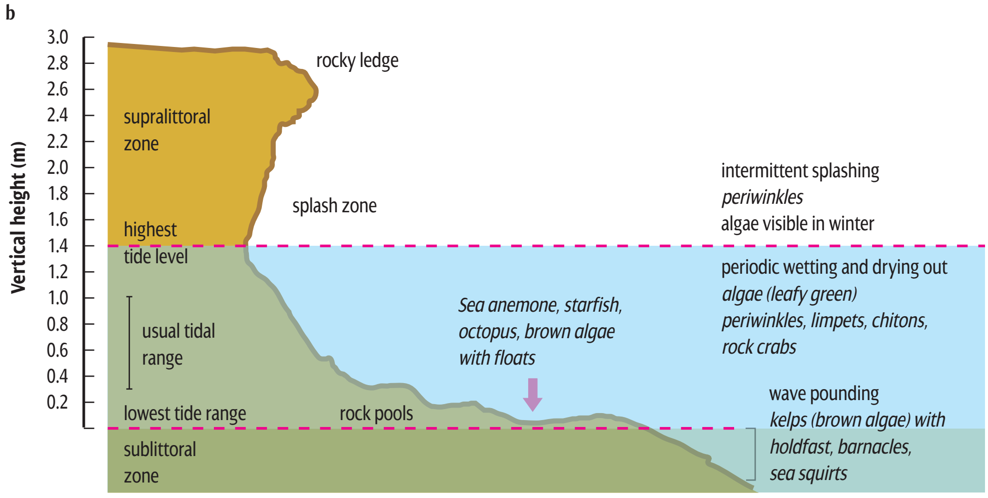
The image of Australia in Figure 7.6 is a composite of 100 satellite images, each approximately 500 km square. (Copyright: Commonwealth of Australia, ACRES, Geoscience Australia) a



Source: Biozone Learning Media, *Year 11 Biology Student Resource and Activity Manual*

Figure 7.7 Differences in abiotic conditions result in **(a)** vertical stratification in a tropical rainforest **(b)** intertidal zonation.

b



bioTERMS

transect
a cross-section across an area

The distribution of plants in an area can be determined by marking a straight line across the area and recording the type and number of plants along the line. This cross-section is referred to as a **transect**. Sometimes additional information about factors that may influence distribution, for example soil type, is recorded.

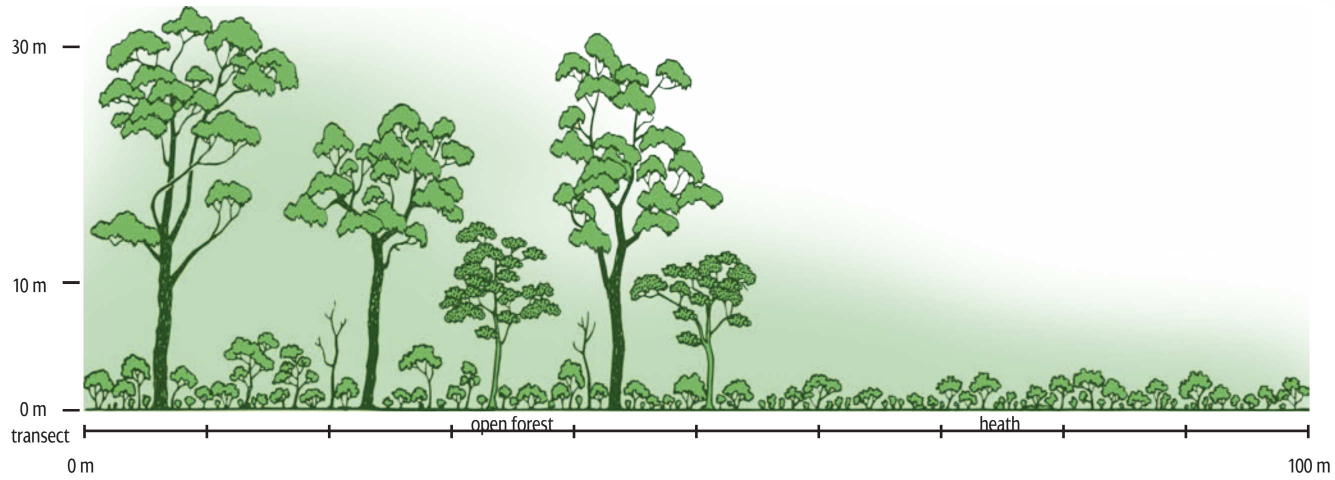


Figure 7.8 Transect across an area.

Other factors, such as soil texture, gradient and direction of slope, may need to be taken into consideration, too. All the data (information) collected have to be recorded and collated (put together) appropriately before they can be analysed effectively. Advances in computer technology, including **bioinformatics**, and other technologies have made recording, collation and analysis much easier than formerly.

bioTERMS

bioinformatics
developments in computer technology that use techniques from applied mathematics and statistics to solve biological problems; enables collection and analysis of large volumes of data

Why go to the trouble?

At a time when we are facing major issues in relation to the survival not only of ourselves but also of the biosphere as a whole, the knowledge that we gather about our ecosystems is of little value unless it is put to good use. The information obtained by measuring environmental factors is used to monitor the health of ecosystems and to help make decisions about how best to ensure their sustainability.

It is not enough to monitor and measure abiotic environmental factors in isolation from each other or in isolation from their effect on communities of living things. People have always been studying their environment. Aboriginal Australians depended on their powers of observation of the natural phenomena around them: daily and seasonal patterns in the weather, positions of stars in the sky, the ebb and flow of tides, the migration of animals important to them as food supplies, and the changes to plant and animal life from season to season. These were the indicators of change that they had to be able to predict and respond to if they were to live sustainably. This **holistic** view is as important for survival today as it was then.

Review

14 Which instruments would you use to measure oxygen levels, turbidity and concentration of particular chemicals in a freshwater creek? Explain why this information about the creek might be needed.

Living on land and living in water

Conditions in the environment pose challenges to all organisms, but particularly to those that live in harsh environments or those subject to extremes of change. Those living in low rainfall zones, for example, or in exposed coastal locations have different challenges to face from those in marine or freshwater environments.

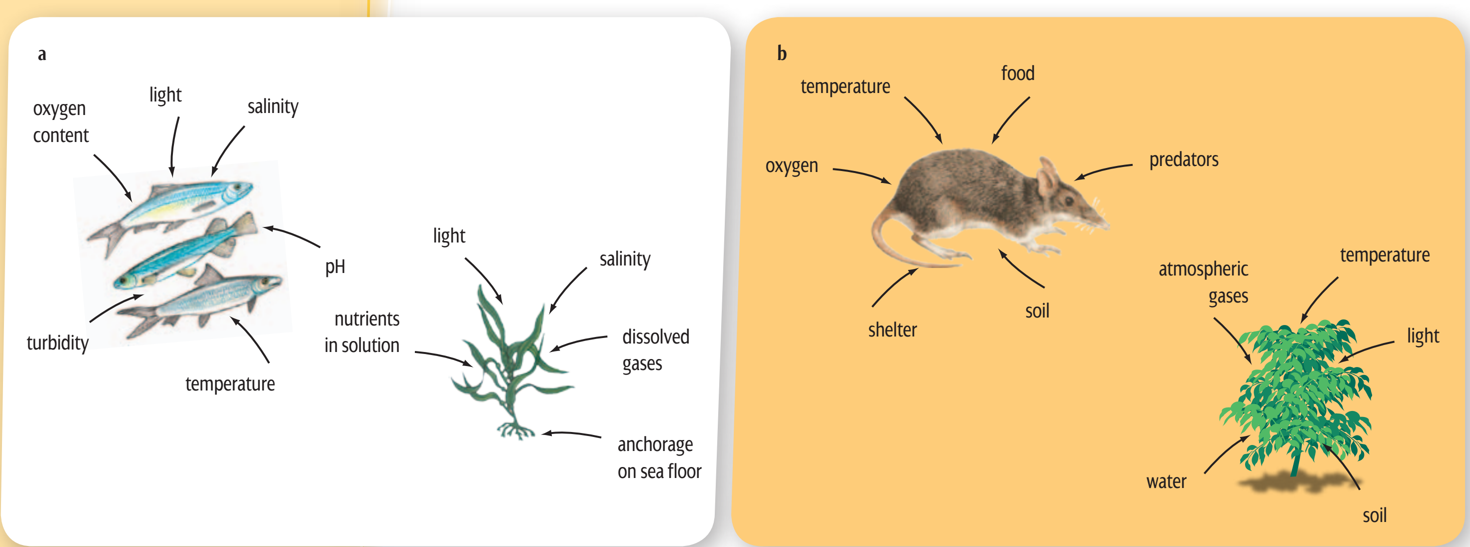


Figure 7.9 Significant environmental factors in **(a)** an aquatic and **(b)** a terrestrial habitat.

All organisms have basic requirements. In this chapter the focus is on the general adaptations of complex plants that enable them to use the resources of their environment.

Plants are photosynthetic organisms that need light, water, carbon dioxide for photosynthesis, oxygen for cellular respiration and different kinds of ions for nutrients.

Temperature is an important factor too, as it affects the rate of cell metabolism and division and therefore of growth and development.

Temperature

Temperature variations in air can be considerable from place to place and from time to time. Within a single day variations of up to 20°C can be experienced and even more in deserts. In water such variation does not exist. The temperature of oceans remains relatively stable; along the edges of coasts there may be slight variations. In smaller freshwater bodies of water, temperatures may vary by several degrees within a depth of about 5 m. This temperature difference affects the values of dissolved oxygen – it decreases with depth.

Gaseous exchange

The diverse body forms and structures of plants are adaptations to living in different environments, but there are some features that they have in common. Leaves, or their equivalent, have tissues that contain large numbers of chloroplasts. They have evolved to maximise the absorption of light energy for photosynthesis; their stomata, generally on the under-surface, regulate gaseous exchange and control water loss. Aquatic plants have greater difficulty than terrestrial plants in exchanging carbon dioxide and oxygen – they have to rely on gaseous diffusion over the whole of their surface.

Biobox 7.3
Leaves can tell a story

Table 7.4 Leaf characteristics and what they do.

Leaf characteristics	Function	Examples
Plants (sclerophylls) with hard, thick cuticle	Reduces evaporation Reduces wilting	
Reduced number of stomata	Reduced water loss	
Epidermal hairs trap moist air	Increases humidity, reduces diffusion gradient	
Inward rolling of leaf enclosing surface with stomata	Increases humidity, reduces diffusion gradient	
Water storage in succulent stems or leaves	Increases water conservation	
Reduction in area of leaf surfaces: phyllodes and cladodes	Reduces water loss Reduces heat gain	
Shiny leaves reflect heat and light	Reduce heat gain	
Leaves dangle	Reduce area exposed to Sun	

Mangroves solve the problem of lack of oxygen in waterlogged soils of swamps and estuaries by having aerial roots called **pneumatophores** or peg roots. These aerial roots, which link with underground roots, have numerous pores over their surface that allow for gaseous exchange.

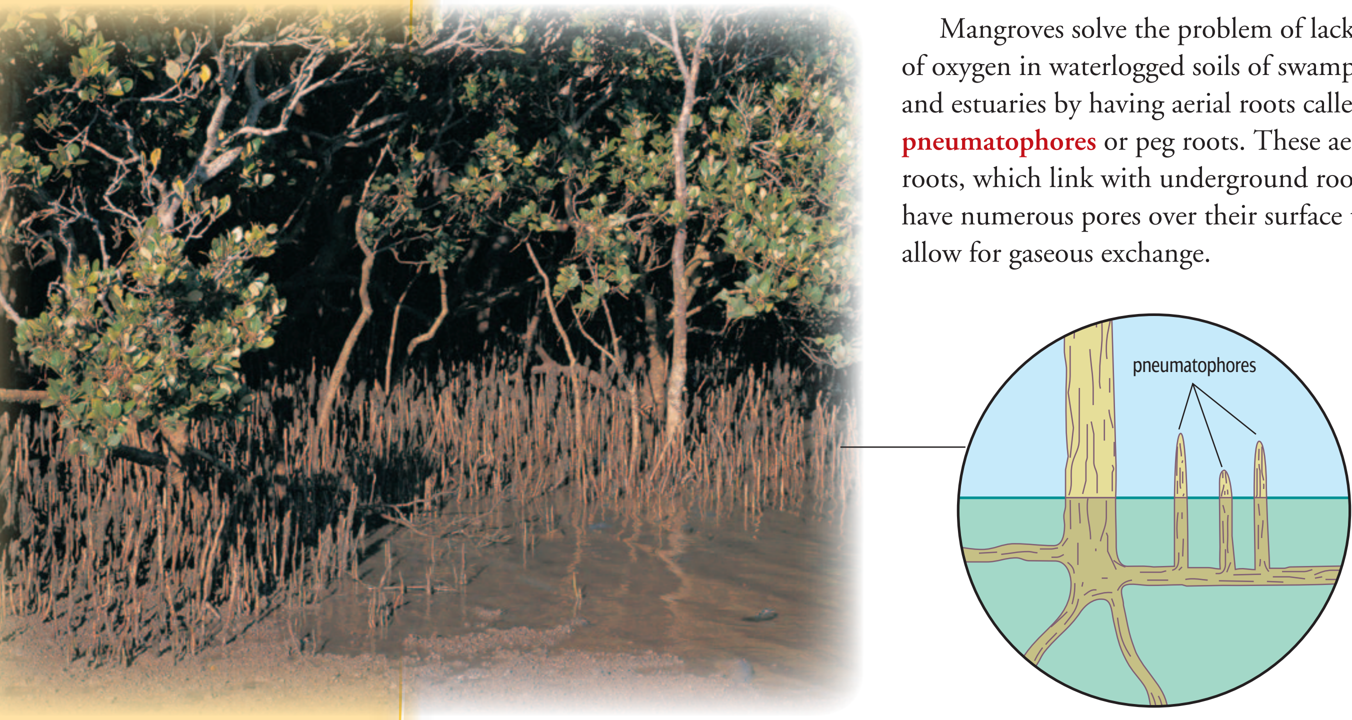
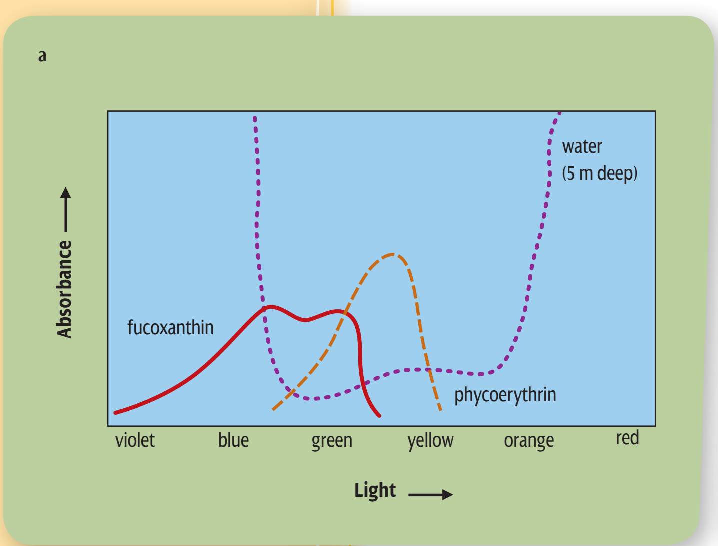


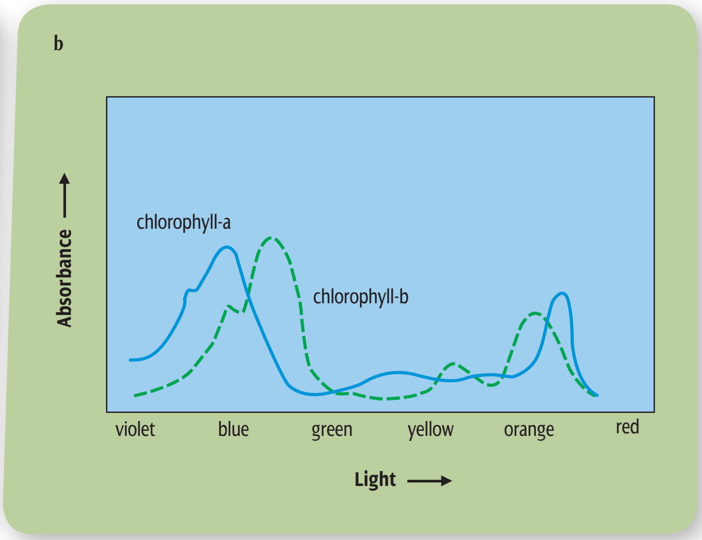
Figure 7.10 Mangroves solve the problem of gaseous exchange. *Avicenna marina*, the Australian white mangrove, has aerial shoots or pneumatophores that obtain oxygen.

Light

On land, light is more readily available than in water although there are variations in intensity from shade to full sun. Aquatic plants are limited in the depth at which they can survive because water absorbs light. About 30% of light striking the surface of water is reflected. Although light can penetrate sea water to about 140 metres, its intensity is about 1% of that at the surface. Water does not absorb all wavelengths of light equally. The red and orange wavelengths of light are absorbed more quickly than the blue, which is why things appear greenish–blue underwater. The degree to which water absorbs light is called the **absorbance spectrum** of water.

Figure 7.11 Absorption of light by pigments in algae.





Vertical stratification of algae is evident as different wavelengths of light are absorbed with increase in depth. Green algae give way to browns and then reds. These algae have additional pigments that are capable of absorbing the predominant colour, which at depth is blue.

Water balance

For plants where the availability of water is not a problem, the opening and closing of stomata are sufficient to control water balance. But many terrestrial plants live in habitats where the challenge is to reduce water loss or to conserve water. High external temperatures, exacerbated by low humidity, increase the rate of evaporation and transpiration and there may be little water available to replace this loss. Plants have evolved structural and physiological adaptations to deal with this problem. Examples are given in Table 7.4.

Marine and freshwater plants, on the other hand, have different challenges. They have to be adapted to control water balance between the internal and external environments if they are to survive. In some marine plants, cells tend to have a slightly lower concentration of salts than the surrounding water. Under these conditions there is a net movement of water molecules out of the cells. In other marine plants, the internal concentration of salts is similar to that of the salt water surrounding them, so there is no overall loss of water.

PRACTICAL ACTIVITY 7.2

BIOLINK Plant adaptations

Support

Root systems of terrestrial plants vary in form, but their general role is to anchor the plant and to absorb water and mineral ions. The roots of plants may be anchored to the ground or, as in case of parasitic plants, to other plants from which they obtain their nutrients. Air is about a thousand times less dense than water so many terrestrial plants, such as the giant mountain ash, have the problem of support as they grow towards the light. Trees and shrubs develop thick, woody stems; some plants, such as vines, depend on climbing on others.

Root systems or their equivalent are less well developed in aquatic plants as water and mineral ions are absorbed directly from the water around them. Water plants rely on the **buoyancy** of the water for support, but anchorage might be a problem in turbulent waters. The **holdfasts** of seaweeds such as kelp and bladderwrack help them to hold on to the **substratum**, whether it is the sea floor, rocks or even the shells of molluscs. Bladderwrack, as its name suggests, has numerous air bladders that keep it buoyant. **Emergent** plants – those that have some parts above the water – need strengthening tissues to give additional support.

bioBYTE

Blubber is less dense than water, so the fatty layer of aquatic animals such as whales and seals keeps them not only insulated but also buoyant. Tiny organisms, such as diatoms, have a large surface area in relation to their volume. They may have spikes and projections that increase their surface area for the upthrust of water to act on. Jellyfish have long, dangly bits that do the same.

bioTERMS

buoyancy
the upward force that allows bodies to float or be suspended

holdfasts
structures that anchor many seaweeds to the substratum, such as the bottom layer or bedrock

substratum
rock layer or bedrock under the organism

emergent
rising above, as in emergent plants rising above water

Biobox 7.4
Plant hardiness zones

Agriculturalists, horticulturalists and hobbyists are interested in advice on what plants should be planted where – and their likelihood of survival. 'Plant hardiness' describes how well a plant survives in different sets of environmen tal conditions.

In 1991 Iain Dawson, then at the Australian National Botanic Gardens, developed an Australian equivalent to the United States Department of Agriculture (USDA) map of plant hardiness zones. He divided Australia into seven zones based on the average annual lowest temperature. Zone 1 is the coldest (–15°C to –10°C) while zone 7 is the warmest (15°C to 20°C). These zones apply only to plants growing out of doors with no protection, but which are provided with adequate water.

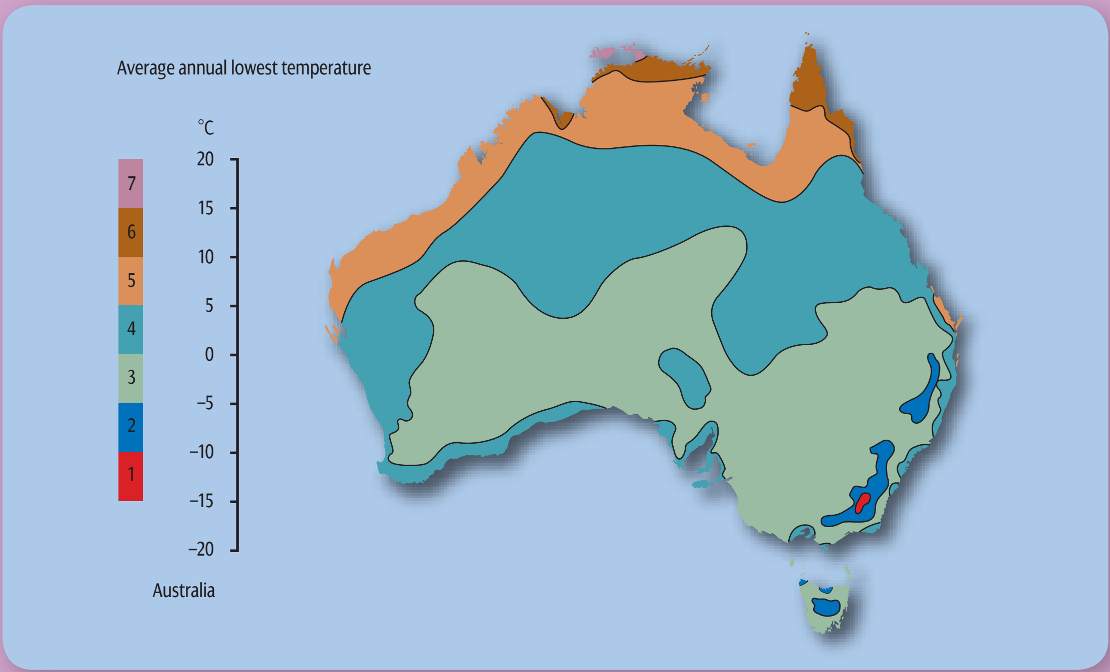


Figure 7.12 Map of plant hardiness zones.

The map can be used as a broad guide only as there are more factors than temperature to take into account. The main factors determining average minimum temperature are altitude, latitude and proximity to the coast. As we all know, different locations in the same city experience different conditions and the scale of the map cannot take into account such variations.

Dawson acknowledges another difficulty – the reliability of the weather information on which the map is based. In Australia there were only 738 stations with a record of more than 10 years on which to base the map. One of them covers nearly 100 000 hectares!

Mt Isa on the other hand has three stations with records of more than 10 years – but based on their data, they have been allocated to different subzones of 4.

Table 7.5 Dawson's plant hardiness zones and their descriptions

Zone	Description
1	Alpine areas of south-eastern Australia
2	Tablelands of south-eastern Queensland, New South Wales and the uplands of central Tasmania
3	Includes much of the southern part of the continent, except coastal regions
4	Places affected by the warming effects of the ocean in winter affects, from coastal Queensland to Shark Bay and Geraldton in the west. Includes the Mornington Peninsula, areas next to Spencer Gulf and Adelaide, the south-western coastal zone, Sydney and the north coast of NSW
5	Some of the Queensland coast, WA north of Shark Bay and across the Top End
6	Queensland coast north of Cairns, Cape York Peninsula and the coast of the Northern Territory
7	Mainly restricted to islands off the north coast of Australia

Source: Adapted from Iain Dawson, *Australian Horticulture* 90(8) 37–39, 1991.

Perhaps using indicator plants would make a better guide for plant hardiness. Common plants with known limits to their range could be used but there is a problem with this too – the same plant may have different common names in different places. Paterson's curse and Salvation Jane, for example, are common names of the same plant. Not everyone is familiar with how this plant is named according to the binomial system: *Echium plantagineum*. However, software programs could be developed to combine all data. Instead of a map a hand-held computer could solve the problem.

Figure 7.13 Evans beach at Cape York Peninsula is in zone 6 of Dawson's plant hardiness zones.

Epiphytes – a special case

Epiphytes (*epi* = above, *phyte* = plant) are aerial plants. They grow on the branches and trunks of other plants, but are not parasitic. They include mosses, lichens, orchids, ferns of many kinds and bromeliads. They gain advantage in competing for light by living high up on rainforest trees. As they have no contact with the soil, their major difficulty is in obtaining nutrients and in holding water that comes their way.

Mosses absorb water and can withstand drying out. In rainforests they have been described as the sponges that sustain life during dry times. They slowly release water absorbed in great quantities during intense periods of rainfall. Bromeliads have tightly rolled leaves that form a funnel in which rainwater and plant debris collect – ideal homes for tiny frogs high up in the trees.

BIOBOX 7.5
DOING IT DIFFERENTLY – PARASITIC AND CARNIVOROUS PLANTS

Where the supply of nutrients is limited, plants have evolved strategies to obtain their nutrients in different ways. Some tap into the organic material that other plants synthesise; these are parasites.

Mistletoe can be seen in the canopy of eucalypt or casuarina trees where they produce root-like structures that penetrate the branches. The leaves of the mistletoe can photosynthesise, but they withdraw water and minerals from the host. Where heavy infestation occurs the damage to trees can be so great that they die.

Figure 7.14 Tree damaged by mistletoe.

Cherry ballarts can be mistaken for independent trees. They grow alongside their host and absorb nutrients and water from their roots. They too photosynthesise.

Pitcher plants, as their name suggests, are shaped in such a way that they trap unwary insects that climb over the lip of the pitcher, attracted by the colour and the sweet substances secreted by special cells. The lip might be waxy or have downwardly directed hairs that speed the insects on their way. The bottom of the pitcher is filled with a pool of fluid that contains digestive enzymes secreted by the lining cells.

The pitcher plant and other ‘carnivorous plants’ that grow in nutrient-poor soils supplement their intake of mineral nutrients, particularly nitrogen, by digesting the small insects and spiders that fall in the pitcher or are trapped by other mechanisms.

Figure 7.15 A pitcher plant.

Plants and water

Some of the most striking adaptations of plants relate to water availability. Table 7.6 summarises examples of adaptations possessed by plants.

Table 7.6 Adaptations of plants to water availability.

Category	General description	Examples of characteristics
Mesophytes	Plants in areas with adequate water	Water loss via stomata is usually made up for by the available supply; if excessive, stomata close; water is replaced during the night. Some plants exude excess water from their tips (guttation). Many woody mesophytes shed their leaves under adverse conditions; **perennial** shrubs die down and survive as underground organs, e.g. bulbs, tubers. **Annuals** survive as dormant seeds.
Hydrophytes	Aquatic plants	Grow submerged or partially submerged in water. Stems and leaves have little or no cuticle. Have large continuous air spaces forming a reservoir for gases and providing buoyancy.
Halophytes	Salt-tolerant plants	Store water in special tissues Extensive air spaces throughout roots and stems. Water storage tissues (succulent) Reduced leaves Halophytic mangroves have pneumatophores. Some plants concentrate and **exude** salt through special glands on their leaves.
Xerophytes	Plants in areas where water is scarce	Xerophytic plants have a variety of structural adaptations that reduce water loss or conserve water. Many are to do with adaptations of leaves (Biobox 7.3). Other **xeromorphic** adaptations include the **habit** (shape or form of the plant as a whole). For example, the angle of the branches of the mulga ensure water is channelled to the roots. The height of some shrubs is low, reducing exposure to drying winds. **Ephemerals** are 'opportunistic' with short life cycles that take advantage of favourable conditions. Reversal of stomatal opening and closure (CAM – **crassulacean acid metabolism** – plants). Stomata are open at night allowing for entry of CO_2, which is 'fixed' in malic acid. Stomata are closed during the day, reducing water loss. Malic acid releases CO_2 for photosynthesis.

Plants and fire

Fire is a feature of much of Australia. At its worst it damages homes, properties, and human and other life. At its best it rejuvenates vegetation. Grass trees (*Xanthorrhoea*) will flower abundantly after fire. Many species of orchid are fire-dependent and sprout from bulbs that may have lain dormant for 20 years. Banksias begin to age without producing seed unless subject to frequent fires, and eucalypt forests rely on occasional fires as part of their regeneration process. Many grasses regrow quickly, their growing tips protected from being severely burnt by old stubble or soil.

Survival depends on the intensity and scope of the fire and the adaptations that plants have to particular fire regimes. Plants have developed two broad strategies, and use them either alone or in combination.

The first strategy is producing extremely large numbers of seeds that accumulate in the soils or in woody fruit, such as that produced by banksias and hakeas, and germinate after fire. The entire population of adults may be destroyed in the fire so survival depends on the germination and growth of the seeds. Mountain ash is an example of such a species. Seedlings have the advantage of the increased mineral content of the soil because of the ash. One disadvantage is that if the time between one fire and the next is not long enough for the seedlings to grow to maturity and produce the next lot of seed, further generations will not be produced.

Figure 7.16 Some plant adaptations to fire.

The second strategy of fire-tolerant species is to have structures and mechanisms that allow for survival and regeneration. Many species of trees have thick insulating bark and **epicormic buds** just beneath it that sprout after fire; large woody rootstocks called **lignotubers** at the base of the tree produce new growth. Some plants combine these strategies.

bioTERMS

epicormic buds
buds that lie under the bark of some plants

REVIEW

15 Draw up a table that compares environmental factors in a terrestrial habitat with those in an aquatic habitat. For each factor give an example of an adaptation possessed by a named organism.

16 Explain why there is a limit to the depth at which aquatic plants can live.

17 Explain why there is such colour variation in algae.

18 The leaves of a shrub are small, hairy underneath and curled over at the edges. What description, in terms of adaptations to water availability, best fits the shrub? Explain its features in terms of adaptation.

19 Small drops of water were seen at the tips of some leaves of a house plant. Account for this observation.

20 Draw a sketch diagram of a hypothetical tree that shows all possible adaptations for surviving fire. Annotate the features. Would all of these features be possessed by a single plant? Explain.

Timing it right – regulating activity

Structural adaptations that plants have in relation to their environment are diverse. In part this can be accounted for because they are sessile – they cannot escape adverse conditions or move to more favourable ones.

Stages in the life cycle of a plant are largely timed to coincide with environmental conditions that are favourable to the organism. Their physiological adaptations are also in tune with their environment. Germination, growth, flowering, seed setting and budding are signalled by changes in abiotic factors such as temperature, rainfall, length of daylight and the availability of water and nutrients. Patterns of activity may be daily or seasonal and different species of plant may follow different rhythms. Plant activities are coordinated to maximise environmental opportunities. How do external cues produce such responses?

It seems that there is an interplay between what is happening in the external environment and the internal environment – something that cues responses that are to the plant's advantage. Being able to detect and respond appropriately to changes in external conditions ensures a plant's viability. Whether they be simple diatoms, mosses or such multicellular and complex species as eucalypts or a Wollemi pine, plants require a means of coordinating and regulating their activities. It is as important for plants to maintain a relatively stable internal environment as it is for animals. With some notable exceptions such as photosynthesis, the kinds of biochemical processes that take place in plant cells are much the same as those in other life forms. But unlike complex animals, plants do not have a nervous system that coordinates activity. Plant responses tend to be less immediately evident than those of animals but they are just as important. Plants tend to adapt to new situations by modifying their growth.

Figure 7.17 Sturt desert pea.

What makes shoots grow upwards instead of downwards and roots grow downwards instead of upwards? Why do plants flower in particular seasons and not in others? These phenomena do not just happen. Seeds of the Sturt desert pea germinate only when there is water and seeds of some acacias will germinate only after being exposed to fire. Without these conditions the plant will not flourish. How are these activities regulated?

Phytohormones

The solution to the coordination and regulation of the enormous range of processes and activities that maintain life lies with growth regulators, commonly called hormones, **phytohormones** (*phyto* = plant), and pigments such as phytochrome (see page 221). The range of plant regulators is not as great as in animals and they cannot collectively be called an endocrine system, but there are similarities as well as differences in the way they function. Animal hormones are produced by particular tissues or glands in the body, but plant growth regulators may be produced by any growing tissue; the type and amount vary according to the stage in the plant's life cycle.

There are five groups of plant regulators, classified according to their chemical structure.

bioTERMS

phytohormones
plant growth substances

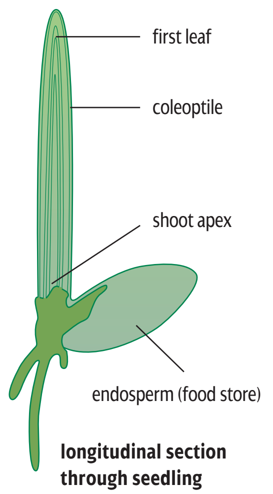


Figure 7.18 The coleoptile is a specialised leaf originating from the first point on the stem (node). It sheaths the tip in the plant's seedling stage, protecting it until it emerges from the ground. Coleoptiles have played a significant role in our understanding of aspects of plant physiology.

Figure 7.19 Busy Lizzie: adventitious roots sprouting from the cut stem – an auxin-induced response.

bioTERMS

adventitious
relates to roots that grow from stems

vascular
relates to having specialised conducting or transport tissues

How do plant regulators 'work'?

Plant hormones are thought to work by changing the permeability of membranes. This affects cellular activity by controlling inputs and therefore the processing of materials inside cells. In this way plant hormones can promote or inhibit growth. Some plant hormones affect the production of certain enzymes, therefore affecting cellular processes.

The combined effect of the various groups of hormones is to coordinate the growth and development of plants. But environmental conditions have a part to play; they are thought to determine the amount of hormones that are synthesised and the sensitivity of tissues to them. This is another example of the interplay between external and internal environments.

Auxins

Auxins were the first plant hormones discovered. Charles Darwin and his son, Francis, were among the first scientists to investigate what might be controlling plant growth. In his book *The Power of Movement in Plants*, published in 1880, Charles Darwin describes the effects of light on movement of canary grass (*Phalaris canariensis*) **coleoptiles**, the sheath-like covering of the young growing tips of grasses.

Darwin's experiments supported his hypothesis that the tip of the coleoptile was the tissue responsible for detecting the light. It was also responsible for producing some substance that travelled to the lower part of the coleoptile where the physiological response of bending occurred. Further experiments in which he cut off the tip of the coleoptile and exposed the rest of it to light from one direction did not produce bending. This confirmed the results of his first experiment.

Since then, much experimental work has been done by various scientists to discover the action of plant growth substances.

Auxins (*indole*-*acetic*-*acids* or IAA) derive their name from the Greek *auxe*, to increase. In a sense an auxin is the master hormone as its effect is widespread and it often works in conjunction with other hormones. Though primarily involved in promoting plant cell elongation (cell expansion), auxins regulate other activities such as the ripening of fruit and the growth of shoot tips (apical buds). Their presence inhibits the growth of lateral buds, but promotes the growth of **adventitious** roots from stems.

Auxins stimulate cells to divide particularly in the cambium of **vascular** plants. The cambium is a ring of meristematic tissue, made up of cells that readily divide, increasing the girth (circumference) of the stem or trunk. Meristematic tissue (meristem) is found elsewhere in plants: the growing tips of buds, roots and shoots.

There is some evidence to suggest that auxins can act as inhibitors.

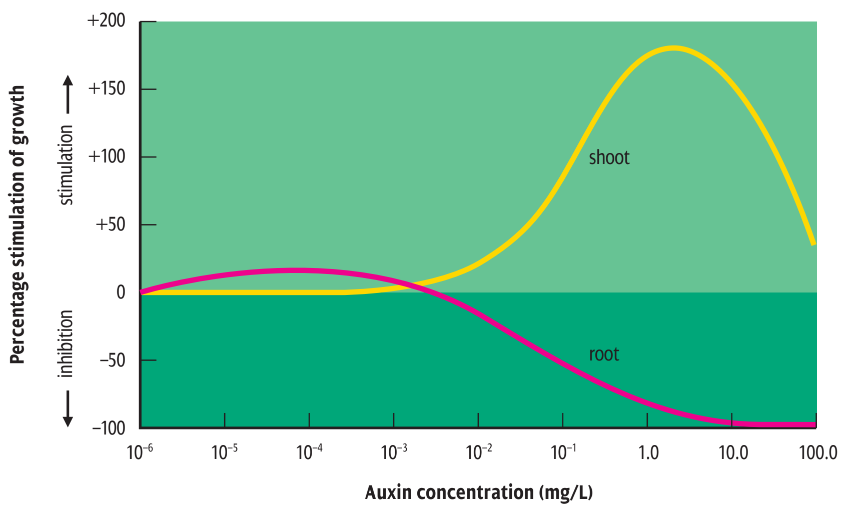


Figure 7.20 (right) The effect on growth of applying different concentrations of auxin to the shoots and roots of oat seedlings. The concentration that produces maximum growth in the shoot inhibits growth in the root.

Biobox 7.6

Discovery of plant growth substances and their effects

Charles Darwin carried out one of the earliest investigations into phototropism. In 1880, shortly before his death, Darwin produced a book called *The Power of Movement in Plants*, in which he described an experiment that he did with his son, Francis.

The experiment examined the effect of light on grass seedlings. They found that a coleoptile failed to bend towards light if its tip was covered with a light-proof cap. However, if a coleoptile was covered completely except for the tip, it bent towards light. The Darwins concluded that the stimulus of light was detected by the tip of the coleoptile, and that some kind of stimulus was transmitted to the lower part, where it caused the bending to occur.

The idea that this influence might be a chemical is suggested by the two experiments performed in 1913 by Boysen-Jensen (see Figure 7.21).

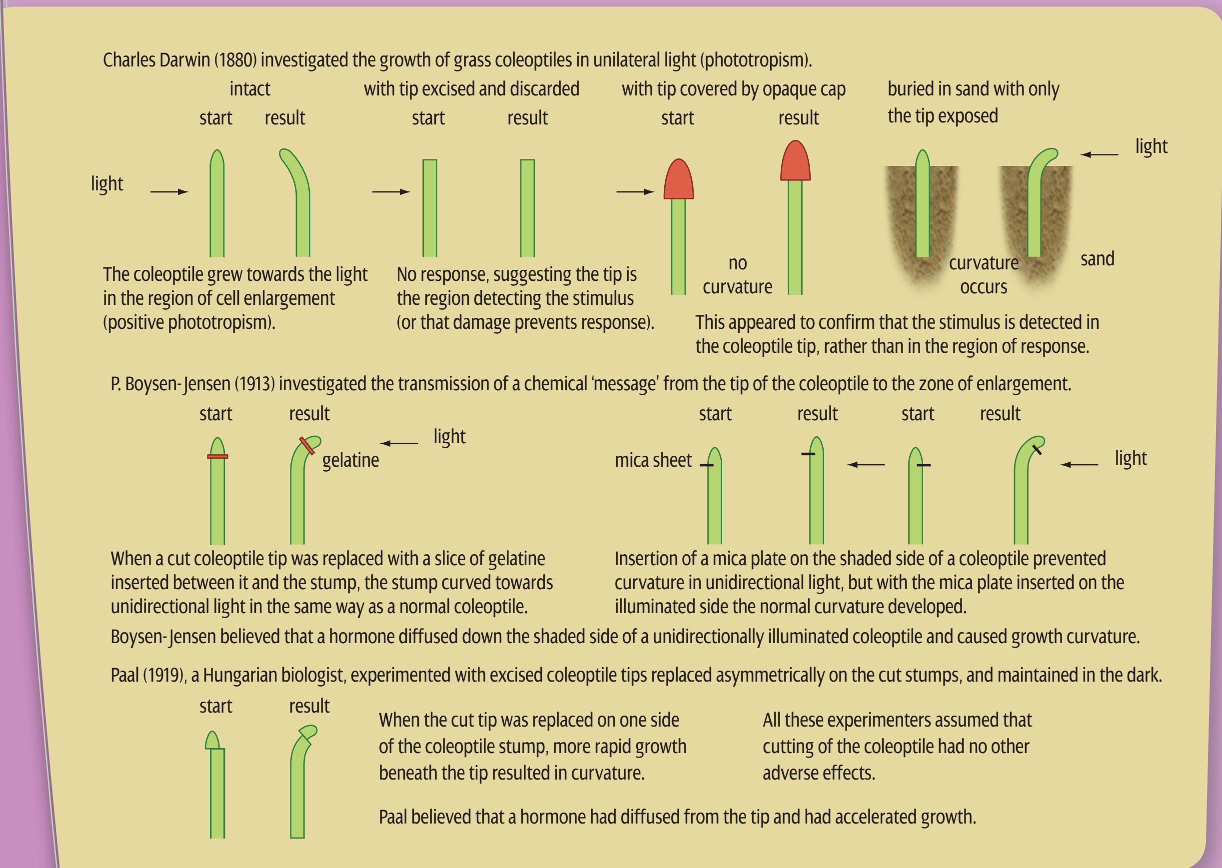


Figure 7.21 The discovery of plant growth substances and their effects.

In the first experiment a thin piece of mica was inserted into the side of a coleoptile just behind the tip. The mica created a barrier, preventing any chemicals from passing back from the tip, but not affecting the surrounding tissues. It was found that if the mica barrier was inserted into the coleoptile on the shaded side, the coleoptile failed to bend towards the light. However, if the mica was inserted on the illuminated side, bending occurred in the usual way. It seems that the mica prevented a substance (later described as an auxin) passing back from the tip only on the shaded side of the coleoptile.

The second experiment supported this idea. The tip of a coleoptile was cut off. The decapitated coleoptile not only did not bend towards light, but was completely unresponsive and did not grow at all. However, if an agar block was inserted between the tip and the lower part of the coleoptile, the latter bent towards light in the usual way. It was concluded that a chemical from the tip diffused through the agar into the lower part of the coleoptile, where it accelerated growth on the shaded side, thus bringing about the bending response.

Auxins are also responsible for the fall of leaves and fruit. These are usually seasonal events and support the concept of the interplay between internal and external environments in plant regulation.

Synthetic auxins are used widely as **herbicides** to kill unwanted weeds. How can a substance that regulates growth and development of plants be a killer? Stimulating rapid growth of cells means that cells use up reserves of energy (carbohydrates) faster than they can be replenished. Auxins stimulate the unwanted plants to grow so rapidly that they outstrip their supplies – the plants starve!

bioTERMS

herbicides
chemicals that kill plants

Sharing control

Four other groups of phytohormones – gibberellins, cytokinins (*cyto* = cell), abscisic acid (ABE) and ethylene – work together to regulate growth and development in plants. Their particular effects are due to their presence in various combinations and in varying proportions.

Figure 7.22 Bolting cabbages. The three plants on the right were treated with 0.1 μg of giberellic acid weekly. The control pair on the left received no treatment. Cabbages do not normally flower until the second year. The treated first year plants are elongated and produce flowers.

Table 7.7 Phytohormones and their effects.

Phytohormones	Effect
Gibberellins	Promote cell division and elongation in plant shoots; extend internodes and can raise flower heads (bolting).
Cytokinins	Stimulate cell division and the middle layer of cells (mesophyll) in leaves. They tend to be concentrated in the starchy material in seeds (endosperm) and in young fruit.
Abscisic acid	Generally acts as an inhibitor. It promotes closure of stomata particularly during times of water stress; stimulates dormancy in seeds and buds.
Ethylene	In gaseous state, it is significant in ripening fruits by stimulating the conversion of starch to sugars, increasing the sweetness of the fruit. Ethylene also stimulates colour change and softening of tissues of ripening fruit as in tomatoes and bananas.

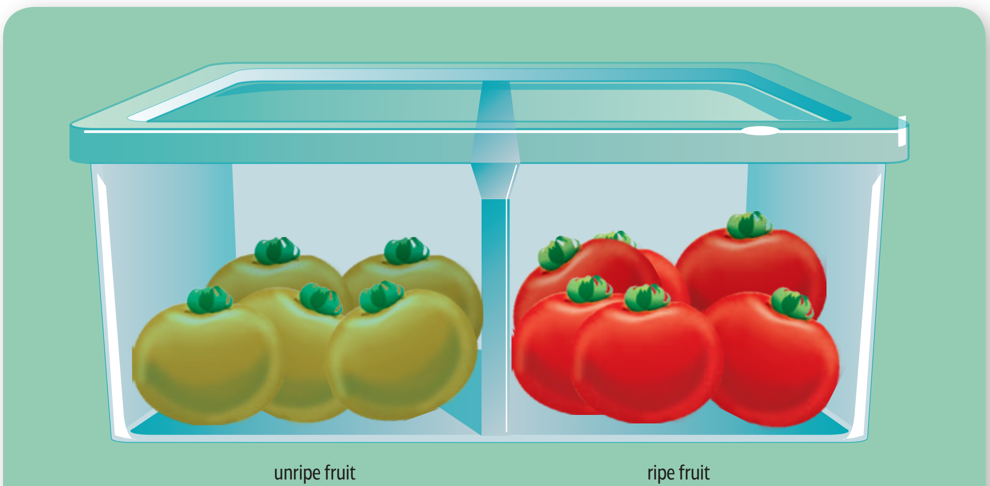


Figure 7.23 The effect of ethylene on ripening fruit.

bioBYTE

Citrus farmers used to 'cure' citrus plants such as lemons, limes and oranges by using kerosene stoves. They believed that heat brought on ripening of the fruit, but it was found that non-kerosene heaters did not have the same effect. It was a by-product of burning kerosene that did it – ethylene.

Phytochromes

An interesting aspect of control of growth was discovered through investigating the germination of seeds. Seeds of some plants will germinate only if they are exposed to light – even a short flash is enough. A series of experiments in the 1950s on a kind of lettuce found that red light is absorbed by a photoreceptor given the name **phytochrome** (*phyto* = plant, *chrome* = colour). Further experiments found that phytochrome, in extremely small quantities of about 1 part in 10 million, was involved in stem elongation, expansion of leaves, the growth of lateral roots and leaf fall. These responses were found to be stimulated by light.

Photoperiodism

One of the most significant discoveries about phytochrome was its role in regulating cycles of flowering of plants according to the length of daylight (photoperiod), a phenomenon known as **photoperiodism**. Phytochrome, a blue–green pigment, has two forms; the inactive form can be converted readily to the active form in the presence of light. The amount of the two forms relative to each other is the signal for a physiological response such as flowering, germination or dormancy.

The relative lengths of daylight and darkness stimulate the timing of flowering. Different plants react differently to the photoperiod; some plants are described as '**short-day**' plants and others as '**long-day**' plants. Poinsettias, chrysanthemums and potatoes are examples of short-day plants. Short-day plants are really long-night plants because if a dark period is introduced into the light period, flowering still occurs. If a dark period is interrupted by a light flash, no flowering occurs.

Spinach, lettuce, clover and winter wheat are examples of long-day plants that make up most of the summer flowering plants in temperate latitudes. The plants require long summer days to trigger flowering. Long-day plants really are long-day plants. If a dark period is introduced into the light period, no flowering takes place. If the dark period is replaced by continuous illumination for 3 to 5 days, then flowing does occur.

Day-neutral plants, such as geraniums, tomatoes, cucumbers and snapdragon, flower irrespective of the relative lengths of daylight or darkness.

In some species, the young plant cannot flower unless it is exposed to a period of low temperatures before spring growth; a 'cold snap' is needed. This is referred to as **vernalisation** (*vernal* = spring).

Perhaps you know someone who puts their bulbs in the fridge for a time before planting them. The importation of many plants from temperate climates means that your plant may flower one year, but not the next.

Horticulturalists manipulate conditions in glasshouses and other enclosed areas to create artificial environments. They can stimulate flowering, fruiting and particular growth patterns in commercial plants by controlling abiotic factors:

bioTERMS

photoperiodism
refers to the physiological reaction of organisms to the length of day or night

phytochrome
a pigment that plants use to detect light (a plant photoreceptor) in the red region of the spectrum

short-day
describes plants that flower after a long period of darkness (better described as long-night plants)

long-day
describes plants that require long periods of daylight before flowering

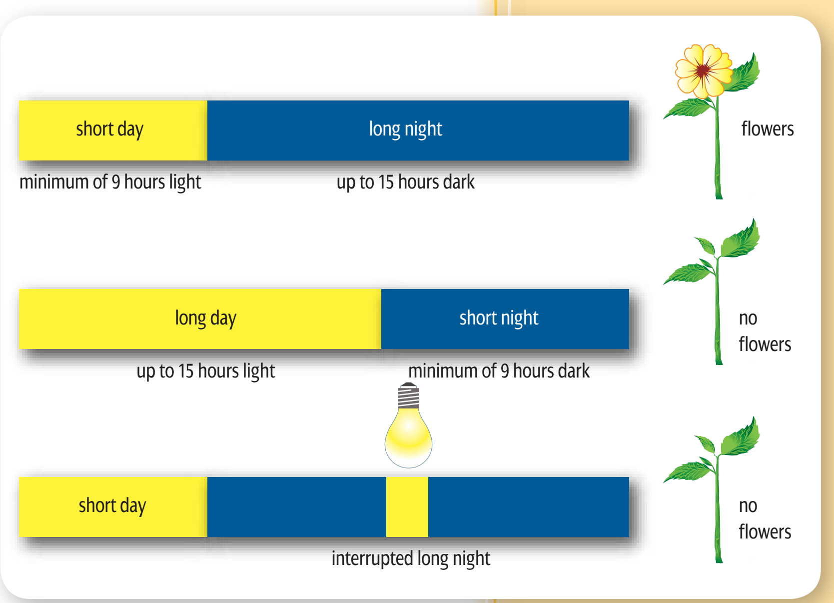


Figure 7.24 Day length and plant flowering.

temperature, soil nutrients, humidity, the length that plants are exposed to light, and even the concentration of carbon dioxide. Horticulturalists are adept at using environmental cues to stimulate particular physiological activities of plants; they also use synthetic hormones.

Dormancy

Just as many animals slow or shut down some of their activities in unfavourable conditions, many plants do, too. A plant may go into a state of dormancy *imposed* by such external conditions. Energy requirements are lowered to a minimum when temperatures are low or water is scarce. When favourable conditions return, the combination of different environmental cues triggers renewed activity.

When growth is slowed for a period, regardless of external conditions, dormancy is described as *innate*. Most plants of temperate regions pass through a period of innate dormancy at some stage in their life cycle. This period tends to coincide with unfavourable seasons that occur on a regular basis; seeds and buds lie dormant 'over winter' or during periods when rainfall is scarce.

Figure 7.25 Greening of the interior: ephemeral plants. Desert-dwelling plants such as parakeelya (purple), bellybuttons (yellow scattered flowers) and perennial sunray (yellow bush) flower only after the first large downpour of rain.

REVIEW

21 Distinguish between phytochrome and photoperiodism. What do the prefixes 'photo' and 'phyto' mean?

22 Distinguish between short-day flowering and long-day flowering.

23 Make three generalisations about the action of plant growth substances.

24 Distinguish between vernalisation and dormancy.

Response by plants: taxes, tropisms, nastics and others

Sessile plants are able to respond to directional stimuli by growth responses that can be negative (away from the stimulus) or positive (towards the stimulus). These responses are called tropisms, from the Greek *trópos*, meaning 'turn', and are significant in increasing the chances of survival of the plant.

Plant movements in response to external stimuli can be grouped into several categories:

- **taxis** (plural, taxes): movement of a whole organism in response, such as a unicellular alga towards a light source (positive phototaxis) or away from a high concentration of a particular chemical in solution (negative chemotaxis)
- **tropism**: growth movement in response to an external stimulus in which the direction of the stimulus determines the direction of the response (referred to as a unilateral or unidirectional stimulus)

bioTERMS

tropism
the growth movement in response to a unidirectional stimulus

- **nastic**: movement of a plant organ that is not determined by the direction of the stimulus (non-directional), such as the opening and closing of flowers in 'sleep' movements. Nastic responses are due to localised growth or expansion of cells in response to light or change in temperature (photonasty and thermonasty). Rapid responses can be included in this category.

Up, down or sideways?

The tropisms that sessile plants exhibit increase the plant's chance of functioning effectively (see Table 7.8). Roots grow towards water supplies, shoots towards light, and some plants such as lianas and vines use the support of structures they come in contact with. This helps them with the competition for light.

Table 7.8 Plant tropisms.

Tropism	Stimulus	Response
Phototropism	Light	Positive: shoots grow towards the light Negative: roots (if responsive) grow away
Geotropism	Gravity	Positive: roots grow downwards Negative: shoots grow upwards
Hydrotropism	Water	Roots grow towards water
Thigmotropism	Touch, contact	Stems and tendrils grow round or against points of contact with solid objects such as stems of other plants
Chemotropism	Chemicals	Positive: pollen tubes of some plants are attracted to the stigma of the same species, enabling fertilisation. The ovary releases chemicals that produce a positive response.

Figure 7.26 Thigmotropism: the hop vine responding to contact with the support string.

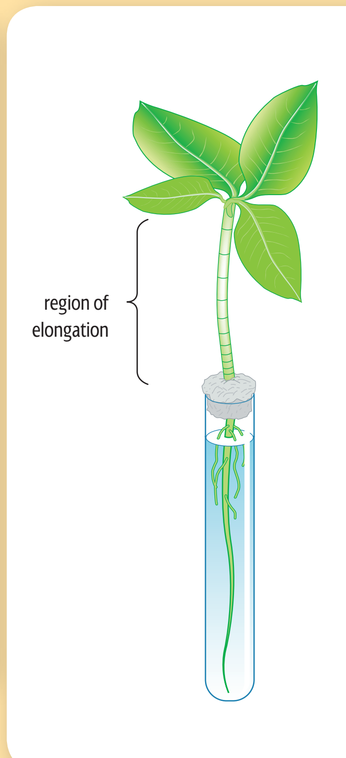


Figure 7.27 Region of elongation of a seedling.

Tropic responses of plants to external stimuli can be explained by the action of hormones on the zone or region of elongation (cell enlargement) of stem and root.

STUDENT CD
Phototropism

Figure 7.28 Positive tropism: shoots of cress seedlings were illuminated from the right.

bioTERMS

statolith
starch grains in cells near the root and shoot tips

PRACTICAL ACTIVITY 7.3

Response to light

When a shoot is illuminated from one side, an auxin is transported across to the shaded side. Cells away from the light respond by growing and elongating, causing the shoot to grow differentially. In doing so, it curves over towards the source of light. The actual bending occurs behind the tip or apex, in the zone of elongation. The higher the concentration of the auxin on the shaded side, the greater the elongation and the greater the curvature or bending. Experiments have shown that strong light of short duration generally produces the same degree of curvature as weak light of longer duration.

Response to gravity

There is some evidence that the redistribution of auxins may play a part in geotropism. Slightly greater amounts of auxin have been found in the lower side of horizontally held organs placed horizontally, but the evidence is not convincing. An alternative explanation has more credence: growth inhibitors, including abscisic acid, have been found in the tissues of stems and roots responding to gravity (see Figure 7.29).

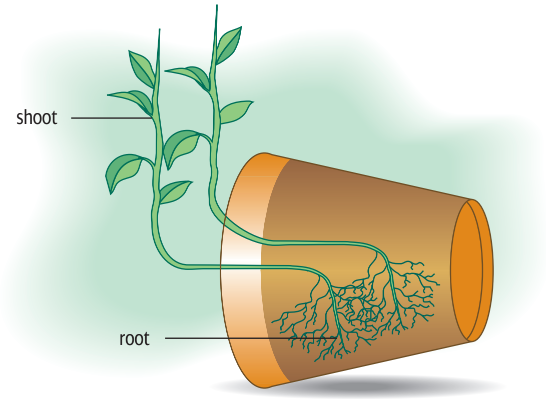


Figure 7.29 Response to gravity.

According to the **statolith** hypothesis of geotropism (see Figure 7.30), the pull of gravity is detected by cells near the stem or root tip (apex). These cells contain starch grains that change their location in the cell if the plant is moved from a vertical to a horizontal position. This change in location is thought to activate enzyme systems in the cell resulting in growth.

Evidence for this hypothesis comes from the observation that if a vertically growing seedling is placed in a horizontal position, it bends upwards as it continues to grow.

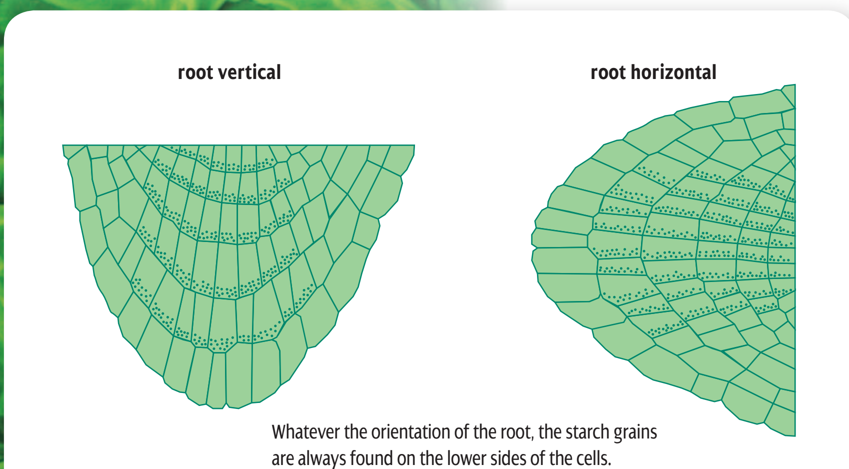


Figure 7.30 Detecting gravity: the statolith hypothesis.

Nastics

Nastic movements can be relatively slow, but more rapid responses are evident in some plants. The Venus flytrap and sundew close rapidly when catching the small animal such as a fly that alights on them.

Trigger plants, members of the genus *Stylidium*, are a diverse group of over 250 kinds that use insects as their agents of pollination. When an insect visits a flower a catapult-like trigger, made from fused stamens, flips rapidly over in response, catching the insect. The trigger picks up or transfers pollen in the process.

Mimosa pudica, the 'sensitive' plant introduced from South America as a house plant, has become a pest across many areas of northern Australia. During the day its compound leaves are expanded but as darkness falls all the leaflets fold up. This also happens if a leaflet is touched or damaged. This is possibly because of rapid loss of water from pad-like swellings at the base of each leaflet and the petiole (leaf stalk). The loss of **turgor** causes the cells to become **flaccid** or limp and lose support. The effect of the stimulus is conducted rapidly, rather like the transmission of nerve impulses, to other parts of the plant that respond by folding.

Figure 7.31 Rapid response: **(a)** Venus flytrap and **(b)** trigger plant.

Figure 7.32 The 'sensitive' mimosa plant, *Mimosa pudica*, responds to touch. **(a)** The pen touches the leaf causing **(b)** the leaf to close up.

Other movements

Nutation describes movements of plant structures that are in response to internal rather than external stimuli. Slow, upward, helical growth movements of seedlings have been caught by time-lapse photography. Seemingly random movements of climbing plant stems increase the chance of making contact with a supporting structure.

Figure 7.33 Growth movements of seedlings by time-lapse photography.

Review

25 Refer to Table 7.6. Draw up a similar table with an additional column headed 'Survival value'. For each example of a tropism describe the advantage that the particular tropism conveys to a plant. Provide examples where possible.

26 Draw simple annotated diagrams that explain the mechanisms of phototropism and geotropism.

Putting it together

All living things have to obtain resources from their environment if they are to survive. Environmental factors, abiotic and biotic, together with the characteristics of the organism itself, affect an organism's ability to obtain its requirements. The range and distribution of species are limited by one or more of these factors.

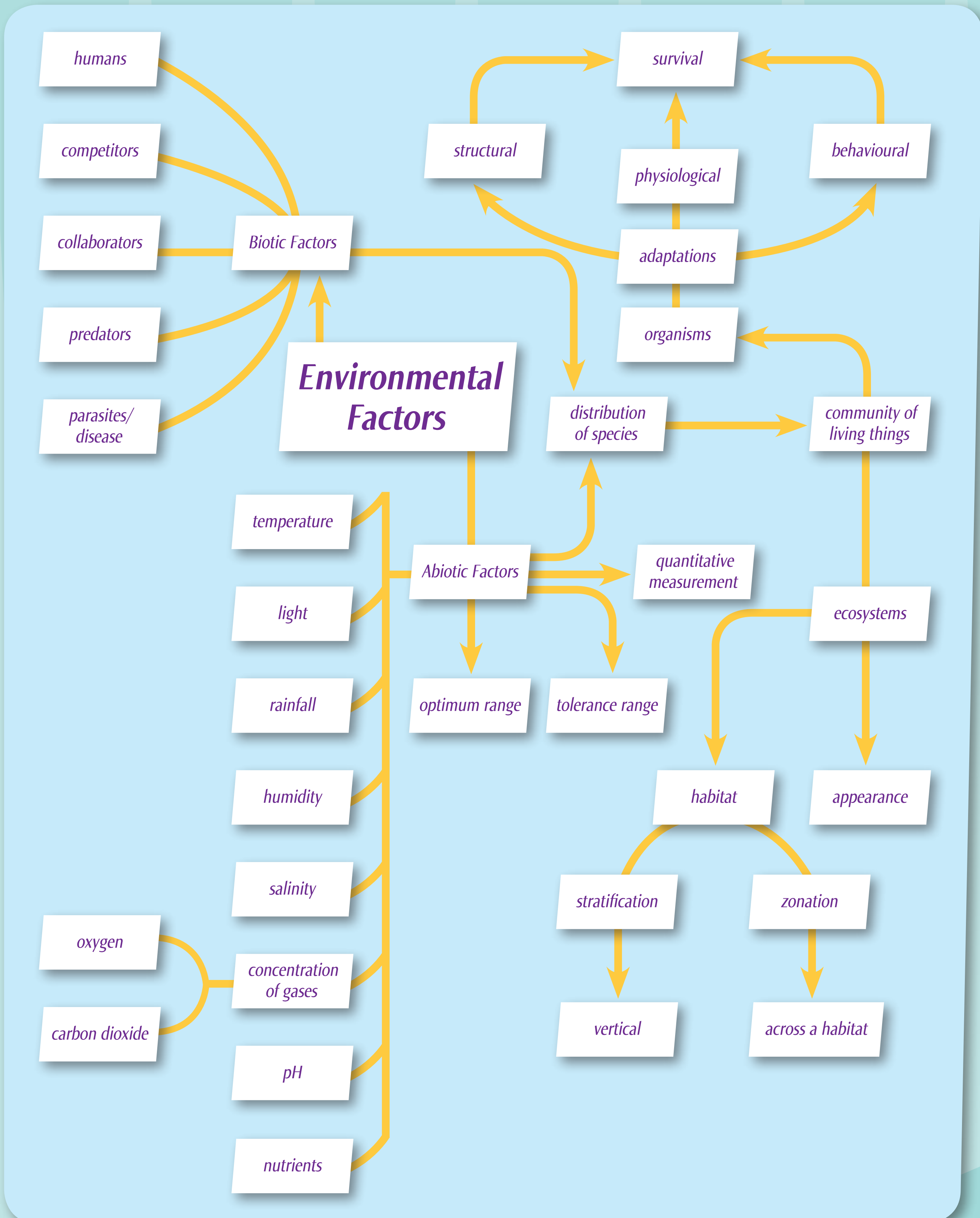
Organisms show a great range of structural and physiological adaptations that suit them to particular sets of environmental conditions. Complex plants have diverse adaptations to their sessile way of life, whether in water or on land.

Plants are responsive to cues in their environment that signal change in the stages of growth and development in their life cycle. Other kinds of responses and plant activities are coordinated to maximise environmental opportunities. Being able to detect and respond appropriately to changes in external conditions ensures a plant's viability.

Measuring and monitoring environmental factors in ecosystems, with increasingly sophisticated technologies, contributes to our understanding of how these factors affect the distribution and viability of living things. The information gathered can help us to understand the holistic nature of ecosystems and analyse the way that human activity is affecting their sustainability.

The next chapters investigate more particularly the way animals are adapted to their habitat.

Visual summary



Key terms

abiotic	exude	pneumatophores
absorbance spectrum	flaccid	qualitative
abundance	geotropism	quantitative
adaptations	habit	range
adventitious	habitat	sessile
annuals	herbicides	short-day
bioinformatics	holdfasts	shrub
biomes	holistic	statolith
biosphere	hydrotropism	stratification
biota	lignotubers	substratum
biotic	limiting factor	taxis
buoyancy	long-day	thigmotropism
canopy	nastic	transect
chemotropism	nutation	tree
coleoptiles	optimum range	tropism
day-neutral	perennial	turgor
distribution	photoperiodism	vascular
emergent	phototropism	vernalisation
ephemerals	physiological stress	xeromorphic
epicormic buds	phytochrome	zonation
epiphytes	phytohormones	

Apply understandings

1. Refer to the maps of vegetation types and climate (Figure 7.5). Draw a line transect from Darwin to Melbourne. Name the major vegetation types along the transect. Make generalisations about the relationship between vegetation and climate, supported by examples.
2. How do some plants in dry conditions balance the need for CO_2 with loss of water by evaporation?
3. Draw the outline of a 'typical' plant. Add labels to the drawing that summarise the action of the main groups of growth substances.
4. Why is it critical to consider the length of the growing season when selecting food plants and the length of daylight when selecting plants for growing for their flowers?
5. A horticulturalist turned on lights briefly in her glasshouse during the night. Her crop was ruined. Explain this result.

Investigate and inquire

1. Many plants, including species of *Goodenia* and saltbush, grow along coastal areas of southern Australia. They are subject to strong winds and salty spray.
   - a Predict what adaptations you would expect them to have.
   - b Analyse and evaluate your prediction by investigating the characteristic features of these plants. Sketch an example of each plant and annotate. Present your findings as a poster, electronic or print.
2. Choose a particular habitat to investigate, such as a rainforest, rock pool, alpine meadow, scrub, woodland or other of your choice.
   - a Describe the environmental factors that operate in the named habitat.
   - b Describe the plants that live in the habitat and analyse the adaptations they have that enable them to obtain their requirements.
   - c Create a transect of the area that shows the distribution of the named plants.
   - d Present your findings as a poster or electronic presentation. Use techniques of communication appropriate to the medium and the audience.
3. Roots (radicles) of young seedlings show positive geotropism. Design an experiment to test this hypothesis. Predict the results of your experiment that would:
   - a support the hypothesis, and
   - b disprove the hypothesis.
4. Investigate the use of synthetic plant hormones. Survey a plant nursery or gardening supply store to provide you with information you require to complete the investigation. Design a table in which to record the results of your findings. Graph results, analyse your findings and report your conclusions.
5. New technologies are being developed to reduce the amount of nutrients in run-off from agricultural, mining and industrial activities. Emergent plants that grow in marshes and wetlands and along shorelines often grow very rapidly, removing large quantities of nutrients from the soil.
   - a Investigate the possibility of using them to clean up polluted soil and water, a process called phytoremediation.
   - b Give the advantages and disadvantages of using this technology.