Environment

Unit 6

Contents

6.1 Ecosystems

By the end of this section you should be able to:

- Define an ecosystem.
- Explain the abiotic (physical) components of an ecosystem.
- Explain the biotic (biological) components of an ecosystem.

Think about the world around you. If you live in a town or city, think of the parks and gardens, the drains and the rubbish piles. If you live in the countryside, think of the farms, the forests, the mountainsides and the rivers. Wherever you live, you are surrounded by living organisms, from monerans in the air and water, to plants, insects and worms to birds, dogs, cattle and of course people. All of these living things do not live in a vacuum.

The many different species of living things interact with the physical world of rocks, soil and rivers and these interactions make up the **ecology** of the world.

You are going to study what happens in **ecosystems**. An ecosystem is a life-supporting **environment**. It includes all the living organisms, the nutrients which cycle through the system and the physical and chemical environment in which the organisms are living. Ecosystems are huge – the whole world is an ecosystem – but we break them down to look at smaller ecosystems. So we might study a rainforest, a pond or a tree – each of them is an ecosystem!

An ecosystem is the home or **habitat** of the living organisms within it. They are affected by both the **abiotic components** and the **biotic components** of the ecosystem.

KEY WORDS

ecology *science of the relationship between organisms and their environment*

ecosystem *all the animals and plants that live in an area along with the things that affect them*

environment *an organism's home and its surroundings*

habitat *place where an animal or plant lives*

Abiotic components

The abiotic components or factors are the non-living elements of an ecosystem. The climate and weather produce several important abiotic components. They include the amount of sunlight, and the amount of rainfall. Each of these factors will affect which living organisms can survive there. Temperature is an important abiotic component which often affects whether animals and plants can survive in an ecosystem. Other abiotic factors include the type of soil and rocks, the drainage of the soil and the pH (acidity).

If the environment is water, the levels of oxygen dissolved in the water are an important abiotic factor as many animals cannot survive in low oxygen concentrations. The current is another factor – many animals and plants cannot survive in a strong current as they are swept away. The level of wind is also an important abiotic component of an ecosystem – too much wind can make life very difficult for living organisms.

Figure 6.1 *In Ethiopia we have ecosystems with very tough abiotic factors – hot sun, cold temperatures, little water, rocky soils (top) – but we also have ecosystems with plenty of light, warmth and water, which living organisms take advantage of!*

Biotic components

The biotic components (factors) of an ecosystem are the living organisms within an ecosystem which affect the ability of an organism to survive there. The number of predators in an ecosystem is one biotic component that has a big effect on the numbers of other organisms in the area. A pride of lions in an area will affect the numbers of prey animals that survive, and the number of caterpillars will make a difference to the number of plants that survive and reproduce.

The amount of food available is another important biotic factor, which particularly affects animals. The food might be the number of plants growing as food for a plant-eater or the number of prey animals available for a carnivore to eat. Biotic components of an ecosystem also include the numbers of parasites and diseases. High levels of parasites or a serious disease will reduce the numbers of animals or plants in an ecosystem.

KEY WORDS

abiotic components *physical factors in a habitat*

biotic components *components linked to the plants and animals in a habitat*

terrestrial habitats *habitats on land*

aquatic habitats *habitats in water*

marine habitats *habitats in salt water oceans*

freshwater habitats *habitats in fresh water of lakes, rivers, ponds and streams*

camouflage *the ability of an animal to blend its colour into its surroundings to avoid detection*

Figure 6.2 *Ethiopian wolves live in an ecosystem that has harsh abiotic and biotic components. The numbers of rats and wolves in the ecosystem is affected by competition for food by both the rats and the wolves.*

Habitats may be on land – when they are known as **terrestrial habitats** or they may be in water, when they are called **aquatic habitats**. In turn there are two main types of aquatic habitat – the **marine habitat**, which is the salt water of the seas and oceans, and the **freshwater habitat** of lakes, ponds, rivers, and streams.

The final biotic component which has a big effect on ecosystems is competition. There can be competition between different species all trying to get the same food, for example, and there is competition between members of the same species for the best mate, the best nest site or the most sunlight, for example.

Animals compete with each other for food, water, territory and mates. Competition for food is very common. Herbivores (animals that eat plants) sometimes feed on many types of plant, and sometimes on only one or two different sorts. Many different species of herbivores will all eat the same plants – think how many types of animals eat grass! The animals which eat a wide range of plants are most likely to be successful. If you are a picky eater you risk dying out if anything happens to your only food source. An animal with wider tastes will just eat something else for a while!

Competition is common among carnivores (animals that eat meat) – they compete for prey. Wildebeest are hunted by several different predators, for example.

Animals often avoid direct competition with members of other species when they can. It is the competition between members of the same species which is most intense!

Prey animals compete with each other too – to be the one that ISN'T caught! Adaptations like **camouflage** colouring, so you don't get seen, and good hearing, so you pick up a predator approaching, are important for success.

Competition for mates can be fierce. In many species the male animal puts a lot of effort into impressing the females, because it is often the female who chooses her mate. The males compete in different ways to win the privilege of mating with her. In some species – like deer and lions – the males fight between themselves and the winner gets the females. Sometimes the fights are mainly 'mock battles' but in some species the fights can be life-threatening.

Many male animals display to the female to get her attention. Some birds have spectacular adaptations to help them stand out – male peacocks and birds of paradise have the most amazing feathers, which they use for displaying to other males (to warn them off) and to females (to attract them).

Plants might look like peaceful organisms, but in fact the world of plants is full of fierce competition – just like animals! Plants compete with each other for light, for water and for nutrients (minerals) from the soil.

They need light for photosynthesis, when they make food using energy from the sun. They need water for photosynthesis and to keep their tissues rigid and supported. And plants need minerals so they can make all the chemicals they need in their cells.

When seeds from different plants land on the soil and start to grow the plants that grow fastest will win the competition against the slower growing plants. Plants are constantly competing against other plants – which are biotic components of the ecosystem. If you have ever tried to grow food in your garden or on a farm, you will know that the competition between the plants you want to grow and weeds can be fierce. We try to get rid of the weeds to remove the competition for water, light and minerals so our crops can grow as well as possible. And we plant our crop plants apart from each other so they are not competing between themselves.

So the biotic components of an ecosystem have a big effect on the populations of living organisms within it.

Summary

In this section you have learnt that:

- An ecosystem is a life-supporting environment which includes all the living organisms, the nutrients which cycle through the system and the physical and chemical environment in which the organisms are living.
- The abiotic components of an ecosystem are the non-living components of the environment. They include the amount of sunlight, the amount of rainfall, temperature, the type of soil and rocks, the drainage of the soil and the pH (acidity), the levels of oxygen dissolved in the water, the current and the levels of wind.
- The biotic components (factors) of an ecosystem are the living organisms within an ecosystem which affect the ability of an organism to survive there. They include disease, predator numbers, food availability and competition for things such as mates, territory, food, light, etc.

Review questions

Select the correct answer from A to D.

1. Which of the following is not an abiotic component of an ecosystem?

   A sunlight
   B rainfall
   C food
   D wind

2. Which of the following is not a biotic components of an ecosystem?

   A predators
   B rocks
   C parasites
   D diseases

KEY WORDS

phototrophs *organisms that feed off light*

producers *plants*

herbivores *animals that eat plants only*

carnivores *animals that feed on other animals only*

omnivores *animals whose diet includes both plants and animals*

heterotrophs *organisms that rely on eating other organisms*

chemotrophs *organisms that get energy from the breakdown of inorganic chemicals*

Figure 6.3 *Plants are phototrophs – they make their own food using energy from the sun.*

6.2 Food relationships

By the end of this section you should be able to:

- Define phototrophs, heterotrophs and chemotrophs.
- Explain food chains using diagrams.
- Explain food webs using diagrams.
- Explain pyramids of biomass using diagrams.
- Explain pyramids of energy using diagrams.

Plants are vitally important in any ecosystem, because they harness the energy of the sun by photosynthesis and make it available to other organisms in the form of food. They make food from simple inorganic molecules – and without them little else could survive for long. Plants are **phototrophs** (light feeders). Because of their role in making carbohydrates, plants are known as the **producers**. What is more, they absorb carbon dioxide and produce oxygen in the process, maintaining the balance of gases in the atmosphere and providing us all with the oxygen which we need to live.

Plants are the main source of food for many thousands of different species of animals, from the aphids which feed on houseplants to the great herds of wildebeest, zebras and elephants of Africa. Animals that eat plants are known as **herbivores**.

Not all animals eat plants. Many of them feed on other animals and they are known as **carnivores**. And some types of animals, ourselves included, eat a diet that contains both plants and animals. These animals are known as **omnivores**. All animals and fungi are **heterotrophs** – they rely on eating other living organisms.

There are a small number of organisms that can get energy from the breakdown of sulphur-containing chemicals. They are known as **chemotrophs**.

Around the world much of the staple diet for human beings comes from plants. Cereal crops, pulses, nuts, fruits and berries are all the products of plant reproduction, whereas other foodstuffs come from stems, roots, leaves and storage organs. And it doesn't stop there. People don't just eat plants – in many cultures people eat meat as well. Meat comes from animals, but many of those animals eat plants. Cows, sheep, pigs, goats, rabbits, chickens, fish – all of these animals eat plants to provide them with the energy and material they need to grow. Sometimes we eat animals that feed on other animals – for example, many of the fish we eat are carnivores and in some parts of the world dogs, cats and other carnivores are eaten. Even then the animals eaten by the carnivores in their turn eat plants.

It is not only human beings that are dependent on plants and the process of photosynthesis. Almost all living organisms depend on plants as the producers of food from the raw materials of carbon dioxide and water. The way in which living things are linked to each other and to plants can be described by looking at food chains.

Food chains

The first stage of the chain involves converting light energy from the sun into stored chemical energy in plants by photosynthesis. This is always done by plants which are known as producers. Then all of the animals that eat plants or other animals are known as **consumers**.

Some of the energy produced by a plant is passed on to the animal which eats it. This will usually be a herbivore, although it could also be an omnivore. The herbivore (or omnivore) is known as a primary consumer, because it eats plants. Some of the energy within the herbivore is, in turn, passed on to the animal which eats it. Again, this will usually be a carnivore but could be an omnivore. The carnivore (or omnivore) is known as a secondary consumer because it eats the plant eater. This naming continues along the chain. At the end of every food chain are the **decomposers** – the bacteria and fungi which break down the remains of animals and plants and return the mineral nutrients to the soil. They are often not shown in food chains.

Wherever you look you will find food chains which demonstrate time after time the reliance of animals on plants.

Within any habitat living organisms depend on plants – the producers – to provide the food on which all of the rest of the organisms depend. The different levels within a food chain – the producers, primary consumers, secondary consumers, etc. are known as the **trophic levels**. Some of the simplest food chains have only two trophic levels. They come from terrestrial habitats and they describe the food we eat ourselves. For example, bananas photosynthesise and then we eat them in a wide variety of dishes. This food chain is very simple: (In food chains the arrow → means 'is eaten by'.)

banana → human

On the other hand, we often eat meat, and this extends the food chain. For example, if you enjoy chicken, the food chain in which you are taking part may have three trophic levels:

corn → chicken → human

But if you prefer beef the chain would be:

grass → cow → human

Not all food chains involve people however – in fact the great majority of food chains have nothing to do with human beings at all. For example, in the seas around the Horn of Africa coral reefs are a major habitat. Tiny plant-like organisms known as algae grow on the coral, photosynthesising and making food. Parrot fish graze on these algae, before they themselves are eaten by predatory fish such as groupers. But the chain doesn't stop there as groupers in turn are eaten by larger carnivores such as the barracuda.

algae → parrot fish → grouper → barracuda

KEY WORDS

consumers *all of the animals that eat other animals or plants*

decomposers *bacteria and fungi that break down the remains of animals and plants, returning the nutrients to the soil*

trophic levels *levels in a food chain to which an organism belongs*

Figure 6.4 *Bear Island is a very stark environment – very unlike Ethiopia! Yet it was here that Charles Elton first observed food chains in action.*

KEY WORDS

phytoplankton (plant plankton) *microscopic photosynthetic organisms at the beginning of many aquatic food chains*

zooplankton (animal plankton) *microscopic organisms which eat the phytoplankton*

food web *network of food chains*

Figure 6.5 *Coral reefs support a huge variety of life. You can identify many different food chains among the species around a reef!*

Many aquatic food chains start with the microscopic photosynthetic organisms known as **phytoplankton** (**plant plankton**). These tiny organisms are eaten by the equally microscopic **zooplankton** (**animal plankton**) and these two groups of organisms underpin food chains which involve almost every animal in the water, from tiny shrimps to enormous whales.

In Ethiopia we have a wide variety of ecosystems and a rich variety of animals and plants. This gives us some very interesting food chains. Some are simple, some are quite long. Here are some examples:

leaves and flowers → black and white colobus monkeys

leaves → grasshopper → rodent → leopard

grass → zebra → lion

Food chains are a great simplification of the situation in the real world. Very few organisms eat only one type of plant or animal, so many organisms appear in many different food chains. It is possible to draw all these interactions to make a much more complex **food web**.

Activity 6.1: Investigating food chains

Wherever you live or go to school, you will be surrounded by food chains and animals and plants interacting in their habitat. If you look closely in any small area of habitat – it might be a corner of the school field, a garden or a pond – you will find plants and animals linked together in food chains. In this investigation, you are going to see how many you can find.

Remember, you will be capturing and handling living organisms. Treat them with great respect and do not harm them in any way.

You will need:

- trays and containers to store organisms temporarily once you have collected them
- labels for the containers to record where you found the organism and what it is
- hand lens or viewer
- net
- forceps
- pooters (if available) to catch small insects

Method

1. Mark out a small area that you will study (if a land habitat).

2. Collect as many organisms as possible – carefully – and store them in separate containers (to avoid them eating each other). Remember to collect the plants as well – a single leaf or a sketch will do to help you identify them.
3. Observe each organism carefully. Use the hand lens where it will help. Make a sketch of each organism. Identify each one as well as you can and decide if they are herbivores or carnivores.

   Hints: Herbivores are often more slow moving than carnivores.

   Herbivores are often well camouflaged.

   Herbivores are often found on or close to the plants that they feed on.

   Carnivores often have sharper mouthparts than herbivores.
4. Try and build up as many food chains as you can, using the organisms you have found.
5. Then think of several other habitats and try and work out three food chains for each.

Food webs

Food chains are very simple, but in real life things are much more complex. Grass is eaten by insects, by rodents and by many large herbivores. Antelope may be prey for lions, leopards or hyenas. The many interactions between living organisms cannot be shown in simple food chains. So people have developed food webs. In a food web the interactions between many different food chains can be shown. An example based on some of the organisms living on our African savannahs has been prepared for you in figure 6.6.

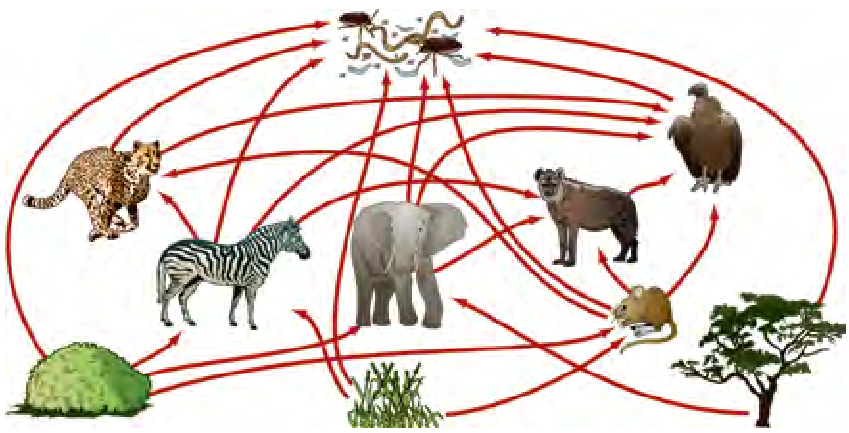


Figure 6.6 *This food web of organisms on the savannah only includes a small number of the organisms that are involved – but already you can see how complicated it is.*

KEY WORD

biomass *all the organic material produced by living organisms*

DID YOU KNOW?

It has been estimated that plants synthesise around 35×10^{15} kg (35 000 000 000 000 000 kg) of NEW biological material each year. That's an awful lot of biomass!

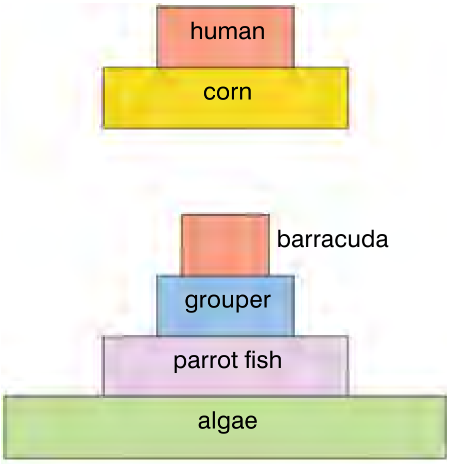


Figure 6.7 *A pyramid of numbers like this seems a sensible way to represent a food chain.*

Energy for life

As you have seen, radiation from the sun is the source of energy for all communities of living organisms. Solar energy pours out continually onto the surface of the earth and a small part of it is captured by the chlorophyll in plants. It is used in photosynthesis and the energy from the sun is stored in the substances which make up the cells of the plant. This new plant material adds to the **biomass**. Biomass is a term that describes all the organic material produced by living organisms. It all comes originally from plants as they photosynthesise at the beginning of all food chains.

This biomass is then passed on through a food chain or web into the animals which eat the plants and then on into the animals which eat other animals. However long the food chain, the original source of all the energy and hence the biomass involved is the sun.

When you look at a food chain, there are usually more producers than primary consumers, and more primary consumers than secondary consumers. This can be shown as a pyramid of numbers.

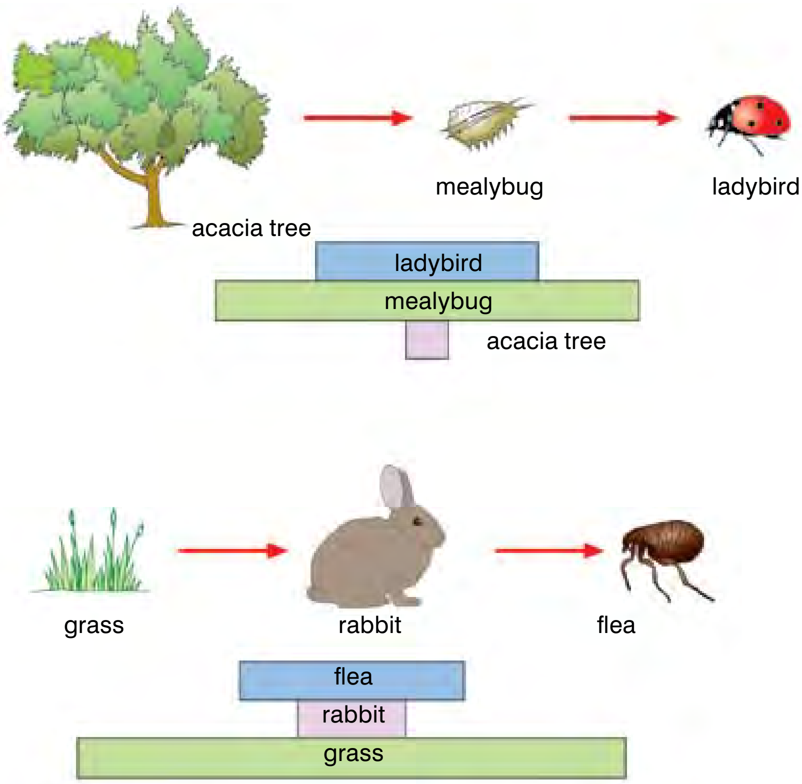


Figure 6.8 *These food chains cannot be accurately represented using a pyramid of numbers.*

However, in many cases a pyramid of numbers does not accurately reflect what is happening. For example, the breadfruit tree can grow to around 20 m tall, yet it can be attacked by mealybugs. They in turn are eaten by ladybirds. However, the pyramid of numbers for this food chain doesn't look like a pyramid at all. And cows eat grass, and people eat cows – and that doesn't make a very good pyramid of numbers either!

To represent what is happening in food chains more accurately we can use biomass. Biomass is the mass of living material in an animal or plant and ultimately all biomass is built up using energy from the sun. The total amount of biomass in the living organisms at each stage of the food chain can be drawn to scale and shown as a pyramid of biomass.

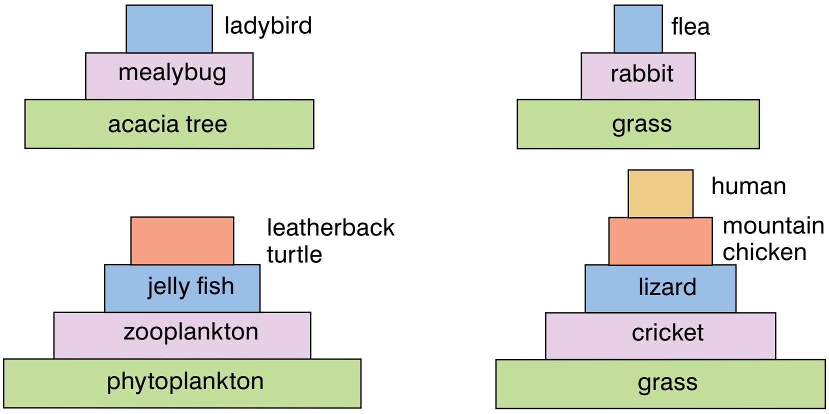


Figure 6.9 *No matter what the numbers of organisms involved in a food chain, when the biomass of the different feeding levels is considered, a pyramid of biomass always results.*

The biomass, and so the energy available at each trophic level of a food chain is less than it was at the previous stage. This is because:

- Not the whole organism at one stage is eaten by the stage above.
- When an herbivore eats a plant, it turns some of the plant material into new herbivore. But much of the biomass from the plant is used by the herbivore to release energy for living and so does not get passed on to the carnivore when the herbivore is eaten.

So at each stage of a food chain the amount of biomass which is passed on is less – a large amount of plant biomass supports a smaller amount of herbivore biomass which in turn supports an even smaller amount of carnivore biomass.

DID YOU KNOW?

Counting the number of living organisms in a food chain can be difficult, but measuring biomass is even harder. If the animals and plants are alive their biomass contains lots of water. Wet biomass is very inaccurate – for example, it is affected by how much water an animal has drunk. Measuring dry biomass is the most accurate measure. Unfortunately to find the dry biomass the organisms have to be killed and dried, which destroys the food chain you are studying!

Figure 6.10 *The amount of biomass in a lion is substantially less than the amount of biomass in the grass which feeds the zebra they prey on. But where does it all go?*

Figure 6.11 Animals like elephants eat vast amounts of biomass, but they also produce very large quantities of dung containing all the material they cannot digest.

DID YOU KNOW?

In a food chain, an animal passes on only about 10% of the energy it receives. The amount of available energy decreases at every trophic level, so each level supports fewer individuals than the one before. The longest food chains are found in the seas and oceans, and even then the number of links is usually limited to about five – unless you can think of a longer one!

Energy reduction between trophic levels and pyramids of energy

An animal like a zebra eats grass and other small plants. It takes in a large amount of plant biomass, and converts it into a smaller amount of zebra biomass. What happens to the rest?

Firstly, not all of the plant material can be digested by the animal, so it is passed out of the body in the faeces. Excess protein which is eaten but not needed in the body is broken down and passed out as urea in the urine. The same is true for carnivores, they often cannot digest hooves, claws and teeth, so some of the biomass that is eaten is always lost in their waste.

Part of the biomass which is eaten by an animal is used for cellular respiration. This supplies all the energy needs for the living processes taking place within the body, including movement which uses a great deal of energy. The muscles use energy to contract, and the more an animal moves about, the more energy (and biomass) it uses from its food.

Much of the energy produced in cellular respiration is eventually lost as heat to the surroundings. These losses are particularly large in mammals and birds, because they are warm-blooded. This means their bodies are kept at a constant temperature regardless of the temperature of the surroundings. They use up energy all the time to keep warm when it's cold or to cool down when it's hot. Because of this warm-blooded animals need to eat far more food than cold-blooded animals like fish and reptiles to get the same increase in biomass.

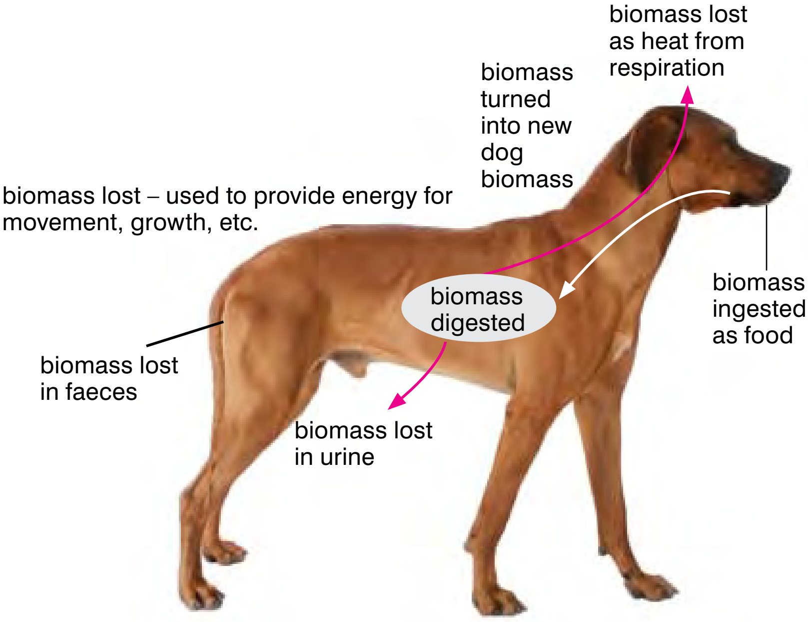


Figure 6.12 Only between 2 and 10% of the biomass eaten by an animal such as this dog will get turned into new dog biomass, the rest will be used or lost in other ways.

If we represent the energy held in each trophic level we get the best possible representation of what is happening in a food chain. A pyramid of energy represents the energy in the producers and how much of that energy is passed on at each stage along the food chain. However, pyramids of energy are very difficult to measure so practically we usually use biomass.

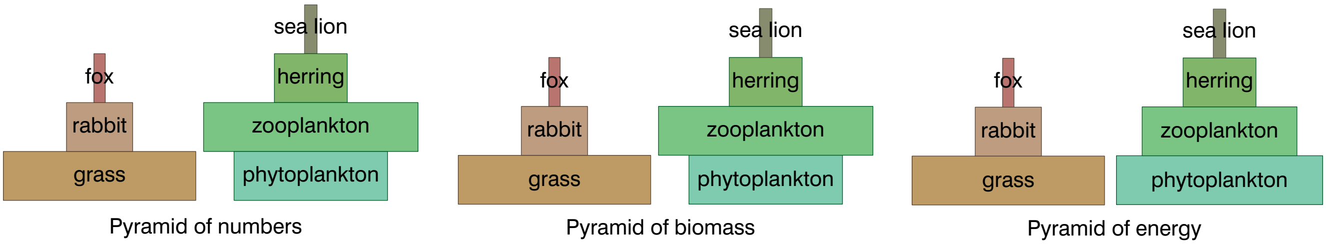


Figure 6.13 *This diagram shows you how pyramids of numbers, biomass and energy compare for two different food chains.*

Summary

In this section you have learnt that:

- Radiation from the sun is the source of energy for all communities of living organisms. It is captured by green plants in photosynthesis. Green plants are known as phototrophs.
- Heterotrophs get their energy by feeding off other organisms and chemotrophs get their energy from chemical reactions which are not related to photosynthesis.
- Food chains and food webs show the feeding relationships between animals and plants.
- The idea of food chains and food webs was developed by Charles Elton in the 1920s from his observations on Bear Island.
- The mass of living material (the biomass) at each stage of a food chain is less than it was at the previous stage because some material is always lost in waste materials and much is used for respiration to supply energy for movement and maintaining the body temperature.
- The biomass at each stage of a food chain can be drawn to scale and shown as a pyramid of biomass.
- Measuring the flow of energy through a system takes place over time. It can be shown in an energy pyramid.

Review questions

1. Why is a pyramid of numbers not always a useful way to represent a food chain?
2. What do pyramids of biomass show about the effect of the number of trophic levels in a food chain on the amount of biomass which is available at the end of the chain?
3. Explain why the biomass from one stage does not all become biomass for the next stage of the pyramid when it is eaten.

6.3 Recycling in nature

By the end of this section you should be able to:

- Describe and illustrate the nitrogen cycle.
- Describe and illustrate the carbon cycle.

Living things are constantly removing materials from the environment. Plants take minerals from the soil and these minerals are then passed on into animals through the food chains and food webs which link all living organisms. If this was a one-way process then the resources of the Earth would have been exhausted long ago. Fortunately the materials are returned to the environment from the waste products of animals and the dead bodies of plants and animals.

The nutrients held in the bodies of dead animals and plants, and in animal droppings, are released back into the soil by the action of a group of organisms known as the decomposers. These are micro-organisms such as bacteria and fungi. They feed on waste droppings and dead organisms. They digest them and use some of the nutrients. They also release waste products, and these are nutrients broken down into a form which plants can use. When we say that things decay they are actually being broken down and digested by these micro-organisms.

The chemical reactions which take place in micro-organisms, like those in most other living things, work faster in warm conditions. But as in other organisms, these reactions are controlled by enzymes, and if the temperature gets too hot, the reactions stop altogether as the enzymes denature. They also stop if conditions are too cold.

Most micro-organisms also grow better in moist conditions which make it easier to dissolve their food and also prevent them from drying out. So the decay of dead plants and animals – and dung – takes place far more rapidly in warm, moist conditions than it does in cold, dry ones.

The majority of decomposers respire like any other organism to release energy to feed and reproduce as rapidly as possible. This means that decay takes place more rapidly when there is plenty of oxygen available.

As people developed an understanding of decomposers they have also developed ways of using them in artificial situations. For example, as the human population has grown, so has the amount of human waste (sewage) produced. Not only is this material unpleasant to live with, it also carries disease. Sewage treatment plants use micro-organisms to break down the sewage and make it harmless enough to be released into rivers or the sea for the breakdown to be completed. They have been designed to provide the bacteria and other micro-organisms with the conditions they

DID YOU KNOW?

Sometimes when an organism dies it freezes rapidly. The decomposers cannot function at these low temperatures and so the organism is preserved with very little decay. Once it begins to warm up, however, the rot will rapidly set in. We have seen mammoths and other prehistoric animals preserved in this way.

Figure 6.14 *Within the natural cycle of life and death in the living world mineral nutrients are cycled between living organisms and the physical environment.*

need, particularly a good supply of oxygen. At the moment we do not treat much of our human waste in Ethiopia.

Another place where the decomposers are useful is in the garden. Many gardeners have a compost heap. This is where they place grass cuttings, sometimes vegetable peelings and bits they cut off plants. Then they leave it to let decomposing micro-organisms break all the plant material down to a fine, rich powdery substance known as compost. The compost produced is full of mineral nutrients released by the decomposers. This compost is then dug into the soil to act as a valuable and completely natural fertiliser.

But it is in the natural world where the role of the decomposers is most important, and where the cycling of resources plays a vital role in maintaining the fertility of our soil and the health of our atmospheres. In a stable community of plants and animals living in an environment, the processes which remove materials from the soil are balanced by processes which return materials. In other words, the materials are constantly cycled through the environment. And by the time the microbes and detritus feeders have broken down the waste products and the dead bodies of organisms in ecosystems, all the energy originally captured by the green plants in photosynthesis has been transferred to other organisms or back into the environment itself as heat or mineral compounds.

The nitrogen cycle

Nitrogen is very important in a wide range of biological molecules. It is a vital part of the structure of amino acids and proteins, and it is also part of the molecules of inheritance, DNA and RNA. Plants can make carbohydrates by photosynthesis – but carbohydrates contain no nitrogen. So where does the nitrogen come from?

Green plants absorb nitrogen in the form of nitrates dissolved in the soil water. They use these nitrates to make proteins, and then this protein is passed along the food chain as herbivores eat plants and are then eaten themselves by carnivores. In this way the nitrogen taken from the soil becomes incorporated into the bodies of all types of living organisms. But almost 80% of the air we breathe is made up of nitrogen – so why don't plants use that? Although it is vital to the formation of proteins and healthy growth, plants cannot use the nitrogen which is in the air around them. It is an inert gas and in that form it is so unreactive that it is no use to them at all.

The nitrates taken out of the soil by plants are returned to it in a number of ways. Urine contains urea, a breakdown product of proteins, and proteins are also passed out in the faeces, so the waste passed out of animals' bodies contains many nitrogen-rich compounds. Similarly when animals and plants die their bodies contain a large proportion of protein. Some of the decomposing or **putrefying** bacteria and fungi which break down the waste products from animals and the bodies of animals and plants act specifically on the proteins. As they break down the protein they form ammonium compounds. These ammonium compounds are

KEY WORD

putrefying *decomposing*

Figure 6.15 *Farmers have been using leguminous plants and the nitrogen-fixing root nodules for centuries to help return fertility to the soil.*

KEY WORDS

nitrogen cycle *cycling of nitrogen compounds between the living and non-living world*

legumes *plants with the ability to fix nitrogen in the soil*

denitrifying bacteria *bacteria that use nitrates as an energy source and breaksthem down again into nitrogen gas*

carbon cycle *cycling of carbon compounds between the living and the non-living world*

then oxidised by nitrifying bacteria which convert them to nitrates which are returned to the soil to be absorbed by plants through their roots again.

Not all of the nitrates in the soil come from the process of decay. Nitrogen-fixing bacteria in the soil can actually convert nitrogen from the soil air into ammonia, which is then converted into nitrates by the nitrifying bacteria of the nitrogen cycle.

There is one group of plants which plays a particularly important role in the **nitrogen cycle**. The **legumes** – that is plants such as peas, beans and clover – have nodules on their roots which are full of nitrogen-fixing bacteria. This is an example of mutualism, where two organisms live together and both benefit. The bacteria get protection and a supply of organic food from the plant, whereas the plant gets ammonia that it can use to form amino acids. The bacteria produce far more ammonia than their host plant needs – and the excess passes into the soil to be used and turned into nitrates by the nitrifying bacteria.

However, not all the bacteria in the soil are helpful in the nitrogen cycle. One group, known as the **denitrifying bacteria**, actually uses nitrates as an energy source and breaks them down again into nitrogen gas. Denitrifying bacteria reduce the amount of nitrates in the soil!

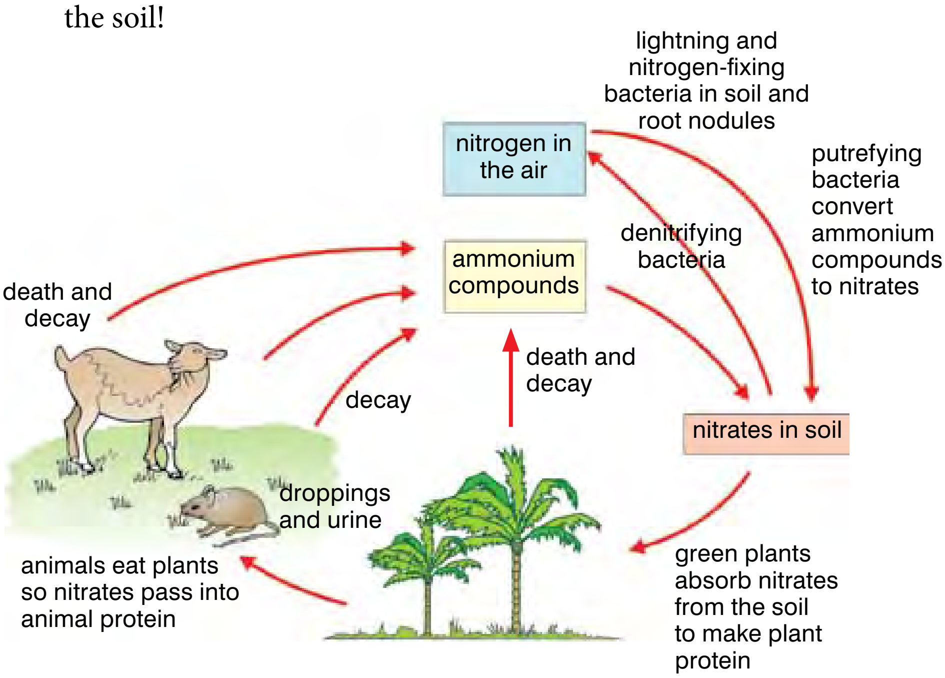


Figure 6.16 *The nitrogen cycle in nature*

The carbon cycle

Another important example of the way minerals are cycled through living organisms and the environment is the **carbon cycle**.

The element carbon is vital for living organisms because all of the main molecules of life are based on carbon atoms. There is a vast pool of carbon in the form of carbon dioxide in the air and dissolved in the water of rivers, lakes and seas. At the same time carbon is constantly recycled between living things and the environment. This is known as the carbon cycle.

Carbon dioxide is removed from the air by green plants in the process of photosynthesis. It is used to make the carbohydrates, proteins and fats which make up the body of the plant. Then when the plants are eaten by animals, and those animals are eaten by predators, the carbon is passed on and becomes part of the animal bodies. This is how carbon is taken out of the environment.

When green plants themselves respire, some carbon dioxide is returned to the atmosphere. Similarly when animals respire they release carbon dioxide as a waste product into the air. Finally when both plants and animals die, their bodies are broken down by the action of decomposers and when these microbes respire, they release carbon into the atmosphere as carbon dioxide, ready to be taken up again by plants in photosynthesis.

In addition to all of these processes, when anything which has been living is burnt – whether wood, straw or fossil fuels made from animals and plants which lived millions of years ago – carbon dioxide is also released into the atmosphere in the process of combustion.

This cycling of carbon can be summarised in a diagram (figure 6.17):

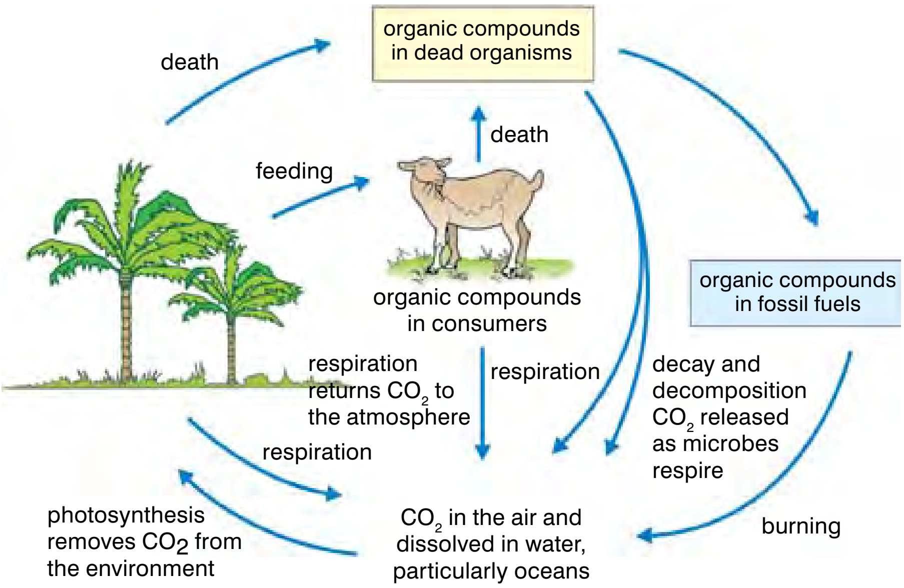


Figure 6.17 The carbon cycle in nature

For millions of years the levels of carbon dioxide released by living things into the atmosphere has been matched by the plants taking it out and the gas dissolving in the seas. As a result the level in the air stayed about the same from year to year.

But now the amount of carbon dioxide produced is increasing fast as the result of human activities. We are burning huge amounts of fossil fuels in our cars, our planes and also in power stations to generate electricity. This speed means that the natural sinks cannot cope, and so the levels of carbon dioxide are building up.

DID YOU KNOW?

At the University of Knoxville in the USA forensic research teams are studying the rate at which the decomposers break down the human body under a range of different conditions. People donate their bodies, which are then deposited in the ways that people most often dispose of murder victims. By monitoring the rate of decomposition in these bodies, the team are collecting information which will help solve murder investigations all over the world.

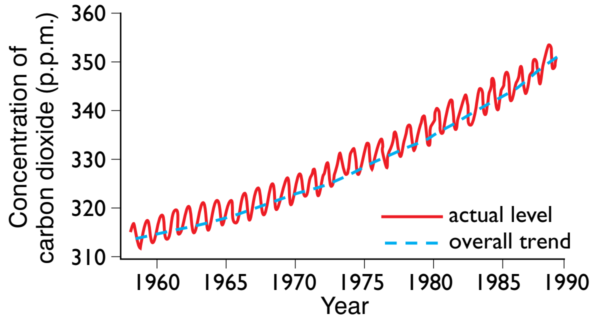


Figure 6.18 *This graph shows how carbon dioxide levels in the air have been steadily increasing. The variations through the year show the difference in the plants taking up carbon dioxide in summer and winter.*

This build-up of carbon dioxide gas in the atmosphere is generally believed to contribute to the **greenhouse effect**, also referred to as **global warming**. Although plants take in carbon dioxide and release oxygen, the release of carbon dioxide from human activities is higher than the plants can process. The situation is made worse because all around the world large-scale **deforestation** is taking place. We are cutting down trees over vast areas of land for timber and to clear the land for farming. In this case, the trees are felled and burned in what is known as 'slash-and-burn' farming. The land produced is only fertile for a short time, after which more forest is destroyed. No trees are planted to replace those cut down.

Deforestation increases the amount of carbon dioxide released into the atmosphere as burning the trees leads to an increase in carbon dioxide levels from combustion. The dead vegetation left behind decays as it is attacked by decomposing micro-organisms which releases more carbon dioxide.

Normally trees and other plants use carbon dioxide in photosynthesis. They take it from the air and it gets locked up in plant material like wood for years. So when we destroy trees we lose a vital carbon dioxide 'sink'. Dead trees don't take carbon dioxide out of the atmosphere.

Methane is another greenhouse gas which causes air pollution and the levels of this gas are rising too. It has two major sources. As rice grows in swampy conditions, known as paddy fields, methane is released. Rice is the staple diet of many countries so as the population of the world has grown so has the farming of rice.

The other source of methane is cattle. Cows produce methane during their digestive processes and release it at regular intervals.

In recent years the number of cattle raised to produce cheap meat for fast food like burgers has grown enormously, and so the levels of methane in the atmosphere are rising. Many of these cattle are raised on farms produced by deforestation.

So as a result of human activities the amount of carbon dioxide (and methane) in the air is continuing to increase. This build-up acts like a blanket and traps heat close to the surface of our earth. This causes the temperature at the surface of the earth to rise. This in turn may have many effects on our climate and health – and it is also thought to contribute to the extreme droughts, strong hurricanes and heavy rains and flooding which are affecting many different parts of the world.

KEY WORDS

greenhouse effect *high levels of greenhouse gases in the atmosphere prevent heat radiating away from Earth's surface and causes the surface temperature to rise*

global warming *another term for greenhouse effect*

deforestation *loss of forests due to the overcutting of trees*

DID YOU KNOW?

Cows produce methane all through the day from both ends! A single cow can release from 100–400 litres of methane per day – that's a lot of greenhouse gas.

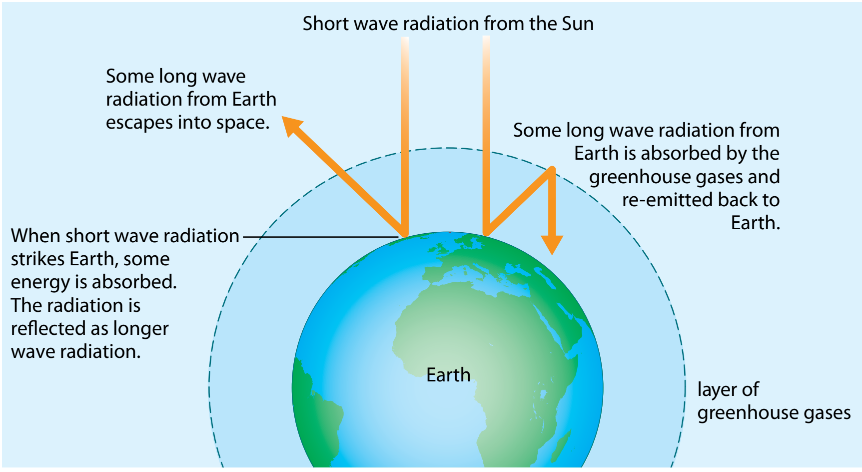


***Figure 6.19** Most scientists believe that global warming is a result of the build-up of air pollutants such as carbon dioxide. The pollution is produced all over the world – but here in Africa we are already feeling the effects.*

We have affected the atmosphere in another way too. Chemicals used as refrigerants in fridges and freezers and in aerosol cans have made the ozone layer around the earth thinner. Over the Antarctic regions there is what is known as an 'ozone hole' where the layer is very thin indeed. **Ozone** protects us from the harmful ultraviolet light in the sun's rays. As the ozone layer thins, more people are getting skin cancers and suffering eye damage from the sun. People need to be very careful with their actions – we can damage our environment without meaning to!

KEY WORD

ozone *layer of the atmosphere that protects the earth from harmful ultraviolet light from the sun*

Summary

In this section you have learnt that:

- Living organisms remove materials from the environment as they grow and return them when they die through the action of the decomposers.
- Dead materials decay because they are broken down by micro-organisms.
- The carbon cycle describes the way carbon is cycled through the environment including plants and animals and carbon sinks.
- The nitrogen cycle describes the way nitrogen is cycled through the environment, including plants and animals and showing how nitrates are returned to the soil.

Review questions

1. Why are the natural recycling processes like the carbon cycle so important for the continuation of life on earth?
2. It can be said that no part of our bodies is truly our own – we have borrowed the materials and at a later date they will be used again elsewhere. How would you explain this statement?

6.4 Adaptations

By the end of this section you should be able to:

- Explain the need for adaptation.
- Describe plant adaptations with examples.
- Describe animal adaptations with examples.

KEY WORD

adaptations *features organisms develop which make it possible for them to survive in particular habitats*

The variety of conditions on the surface of the Earth is huge. Here in our own Ethiopia, altitude can vary from 110 m below sea level to 4620 m above sea level at the highest peak. Rainfall varies from 500 mm to 2800 mm and temperatures in different parts of our country can be as far apart as 35 °C to 0 °C. If you are a living organism, you could find yourself living in the dry heat of a desert or in wastelands of ice and snow. Fortunately living organisms have features (known as **adaptations**) which make it possible for them to survive in their particular habitat – however extreme those conditions might be!

DID YOU KNOW?

Polar bears don't need any camouflage; they don't have any predators on the land – who would dare to attack a polar bear?! They hunt their prey in the sea amongst the ice all year round, so the white colour makes them less visible.

Animals in cold climates

To survive in a cold environment you must be able to keep yourself warm. Arctic animals are adapted to reduce the heat they lose from their bodies as much as possible. Body heat is lost through your body surface (mainly your skin). The amount of heat you lose is closely linked to your surface area:volume (SA/V) ratio. This explains why so many Arctic mammals, such as seals, walruses, whales and polar bears, are relatively large. It keeps their surface area:volume ratio as small as possible and so helps them hold on to their body heat.

Activity 6.2: Calculating surface area:volume ratios

Draw two cubes on a piece of paper. Give one sides of 1 cm, and the other sides of 3 cm.

Calculate the surface area of each cube. Do this by working out the area of one side, and then multiplying your answer by six for the number of sides. Note your answer down beside each cube. The units are cm^2.

Calculate the volume of each cube. Do this by multiplying length x breadth x height. The units are cm^3.

Now work out the surface area to volume ratio for each cube.

What do you notice about the ratio of the larger cube compared to the smaller cube?

Animals in very cold climates have other adaptations as well as a helpful surface area:volume ratio. The surface area of the thin-skinned areas of their bodies – like their ears – is usually very small. This reduces their heat loss. Look at the ears of the polar bear in figure 6.20.

Many Arctic mammals also have plenty of insulation, both inside and out. Blubber – a thick layer of fat that builds up under the skin – and a thick fur coat on the outside will insulate an animal very

Figure 6.20 *The Arctic is a cold and bleak environment. However, the animals that live there are well adapted for survival. Notice the large size, thick fur, small ears and white camouflage of this polar bear.*

effectively. They really reduce the amount of heat lost through the skin.

The fat layer also provides a food supply. Animals often build up their blubber in the summer. Then they can live off their body fat through the winter when there is almost no food.

Camouflage is important both to predators (so their prey doesn't see them coming) and to prey (so they can't be seen). Unfortunately the colours which would camouflage an Arctic animal in summer would stand out against the snow in winter. Many Arctic animals including the Arctic fox, the Arctic hare and the stoat change the greys and browns of their summer coats for pure white in the winter.

Surviving in dry climates

Dry climates are often also hot climates – like deserts! Deserts are very difficult places for animals to live. There is scorching heat during the day followed by bitter cold at night, whilst water is constantly in short supply.

The biggest challenges if you live in a desert are:

- coping with the lack of water
- stopping your body temperature from getting too high

Many desert animals are adapted to need little or no drink – they get the water they need from the food they eat.

Mammals keep their body temperature the same all the time, so as the environment gets hotter they have to find ways of keeping cool. Most mammals rely on sweating to help them cool down, but this means they lose water which is not easy to replace in the desert.

Many animals which live in hot or dry conditions have other adaptations for cooling down. They are often most active in the early morning and late evening, when the temperature is comfortable. During the cold nights and the heat of the day they rest in burrows well below the surface, where the temperature doesn't change much.

Figure 6.21 *Animals like this fennec fox have many adaptations to help them cope with the hot dry conditions, from their large surface area:volume ratio, big ears and thin fur to the way they behave to avoid the heat of the day.*

KEY WORD

stomata *small openings in the leaves of plants*

Figure 6.22 *Not all animals that live in hot, dry climates are small. An elephant is pretty big, but its huge wrinkled skin would cover an animal that was much bigger still. The wrinkles in the skin and the big, thin ears increase the surface area through which heat can be lost.*

DID YOU KNOW?

Animals that live in the deep oceans of the world are adapted to live under enormous pressure, no light and very cold water. But, if these deep water organisms are brought to the surface too quickly, they explode because of the rapid change in pressure.

Many desert animals are quite small, so their surface area is large compared to their volume. This helps them to lose heat through their skin. They often have large, thin ears as well to increase their surface area for losing heat.

Another adaptation of many animals which live in hot areas is that they don't have much fur, and the fur they do have is fine and silky. They also have relatively little body fat stored under the skin. Both of these features make it easier for them to lose heat through the surface of the skin. The animals keep warm during the cold nights by retreating into their burrows.

Plants grow in hot, dry areas around the world – without them there would be no food for the animals. But plants need water both for photosynthesis and to keep their tissues upright – if a plant does not get the water it needs it wilts and eventually dies.

Plants take in water through their roots in the soil. It moves up through the plant and is lost through the leaves in the transpiration stream. Plants lose water all the time through their leaves. There are small openings called **stomata** in the leaves of a plant. These open to allow gases in and out for photosynthesis and respiration. But at the same time water is lost by evaporation. The rate at which a plant loses water is linked to the conditions it is growing in. When it is hot and dry, photosynthesis and respiration take place fast. As a result, plants also lose water very fast. So how do plants that live in dry conditions cope? Most of them either reduce their surface area so they lose less water or they store water in their tissues. Some do both!

Changing surface area

When it comes to stopping water loss through the leaves, the surface area:volume ratio is very important to plants. There are a few desert plants which have broad leaves with a large surface area. These leaves collect the dew which forms in the cold evenings. They then funnel the water towards their shallow roots.

However, most plants that live in dry conditions have reduced the surface area of their leaves. This reduces the area from which water can be lost. They can reduce their surface area in a number of ways. Some desert plants have small fleshy leaves with a thick cuticle to keep water loss down. The cuticle is a waxy covering on the leaf which stops water evaporating away.

Some plants in dry environments have curled leaves; this reduces the surface area of the leaf. It also traps a layer of moist air around the leaf which really cuts back the amount of water they lose by evaporation.

The best-known desert plants are the cacti. Their leaves have been reduced to spines with a very small surface area indeed. This means the cactus only loses a tiny amount of water – and the spines put animals off eating the cactus as well! This adaptation has been very successful. A mature apple tree in England can lose about 100 l of water from its leaves every day. A large saguaro cactus in the desert loses less than one glass of water in the same amount of time!

Storing water

The other main way in which plants can cope with dry conditions is to store water in their tissues. When there is plenty of water available after a period of rain, the plant stores it. Plants which store water in their fleshy leaves, stems or roots are known as **succulents**. Cacti don't just rely on their spiny leaves to help them survive in dry conditions. They are succulents as well. The fat green body of a cactus is its stem, which is full of water-storing tissue. All these adaptations make cacti the most successful plants in a hot dry climate.

Figure 6.23 *These dramatic* Lobelia rynchopetalum *may not be small but they have thick leathery leaves to reduce water loss in their mountain habitat.*

KEY WORD

succulents *plants which store water in their fleshy leaves, stems or roots*

Spreading the seeds

As you saw on page 202, animals and plants compete with each other for resources. To compete successfully a plant has to avoid competition with its own seedlings. The most important adaptation for success in most plants is the way they shed their seeds.

Many plants use the wind to help them. Some produce seeds which are so small that they are carried easily by air currents. Many others produce fruits with special adaptations which carry their seeds as far from home as possible. The fluffy parachutes of the dandelion 'clock' and the winged seeds of trees like the sycamore are common examples of flying fruits. Tumbleweeds, found on the plains and deserts of Northern America, use the whole plant to scatter their seeds! When the seeds are ripe, the plants break off at the roots and are blown away, travelling miles across the plains and scattering seeds as they go.

Figure 6.24 *Tumbleweeds travel a long way to make sure their seedlings don't compete with each other! The whole parent plant is sacrificed to scatter the seeds as far as possible across North America!*

Some plants use mini-explosions to spread their seeds – the pods dry out, twist and pop, flinging the seeds out and away. Others, like the coconut palm, rely on water to carry their seeds away.

A wide variety of plants depend on animals to scatter their seeds for them. They have adaptations which encourage the animals to do this. Juicy berries, fruits and nuts are produced by plants to tempt animals into eating them. Once the fruit gets into the animal's gut, the tough seeds travel right through. They are deposited with the

DID YOU KNOW?

Different types of African dung beetles will feed on the same pile of dung. They avoid competition with each other by attacking the pile at different times of day and in different ways. The most active beetles work in the heat of the day and make balls of dung, which they roll away, whereas if they are quieter tunnellers, the beetles actually live in the dung heaps and work as dusk is falling.

waste material in their own little pile of fertiliser, often miles from where they were eaten! There are even fruits which are sticky or covered in hooks which get caught up in the fur or feathers of a passing animal. They are carried around until they fall off or the animal removes them by grooming hours or even days later.

DID YOU KNOW?

Seeds come in an enormous range of sizes, from the tiny seeds of the rattlesnake plantain, which only weigh 0.000 002 g to the giant seeds of the coconut palm, weighing over 20 000 g (20 kg)! But the roots of some desert plants have a deadly adaptation. They produce a chemical that inhibits (prevents) seeds from germinating. They murder the competition before it has a chance to get growing!

Summary

In this section you have learnt that:

- Living organisms have features (known as adaptations) which make it possible for them to survive in their particular habitat.
- Plants have many adaptations including thick waxy cuticles, water storage tissue, stomata in pits, etc. to help them survive in different conditions.
- Animals have many different adaptations to help them survive in different conditions from very hot, dry deserts to very cold and hostile countries.

Review questions

1. List three ways in which Arctic animals keep warm in winter.
2. Why do many Arctic animals change the colour of their coats between summer and winter?
3. Why do plants often reduce the surface area of their leaves to help them prevent water loss?

6.5 Tree-growing project

By the end of this section you should be able to:

- Explain the importance of planting and growing trees.
- Know how to plant and grow trees in your community.

As you have seen in this unit, Ethiopia is a country with many different ecosystems. However, our country has been changing dramatically. Once, much of the land was covered with forests. Only 100 years ago 40% of Ethiopia was covered with forests – now that is only 3%. This deforestation is causing many problems. Trees produce oxygen and remove carbon dioxide from the air. They help to reduce the effects of air pollution and also reduce global warming. Trees hold the soil in place and without them our soil is becoming unstable and blowing away. Trees also help absorb water – they prevent soil erosion and help to prevent the formation of great areas of deserts.

Figure 6.25 *Tree planting in Ethiopia – a success story!*

In 2007 the Ethiopian Government decided to take action to begin to replace some of the trees and forests we have lost. In 2008 alone 687 million trees were planted as part of the nationwide tree-planting campaign. In fact Ethiopia tops the roll of honour for the most trees planted in a worldwide effort to rebuild some of our lost forests. So far we have planted more than 1.4 billion!

This is where you can help. The idea is to plant two-year-old saplings from five of our indigenous trees, and we need young people to do this. To plant a tree successfully, the soil must be prepared, a big hole must be dug and water must be put into the hole before the tree is planted.

Once the sapling is in place, the soil must be pressed very firmly around it and often a stake is used to support the young tree as it starts to grow and get established. The young trees need to be cared for once they have been planted. For at least the first year they will need extra water if the season is very dry. They may need to be protected from animals that might eat them. But if we can restore some of our lost trees, everyone will benefit, not only in Ethiopia, but across the world.

Activity 6.3: Planning a tree-planting programme

You are going to plan a tree-planting programme for your local area. You may also have the opportunity to go out and plant some young trees and take care of them. Do this activity in groups.

Method

1. Decide where it would be most useful to plant some trees.
2. Decide which type of trees it would be best to grow in your area.
3. Decide how many trees you would like to be able to plant.
4. Investigate how to plant the trees to give them the best chance of surviving and doing well.
5. Make posters to explain your plans to local people and get their support.
6. Make a report for the local media explaining your tree-planting programme and the benefits it will bring to people in the area.

Summary

In this section you have learnt:

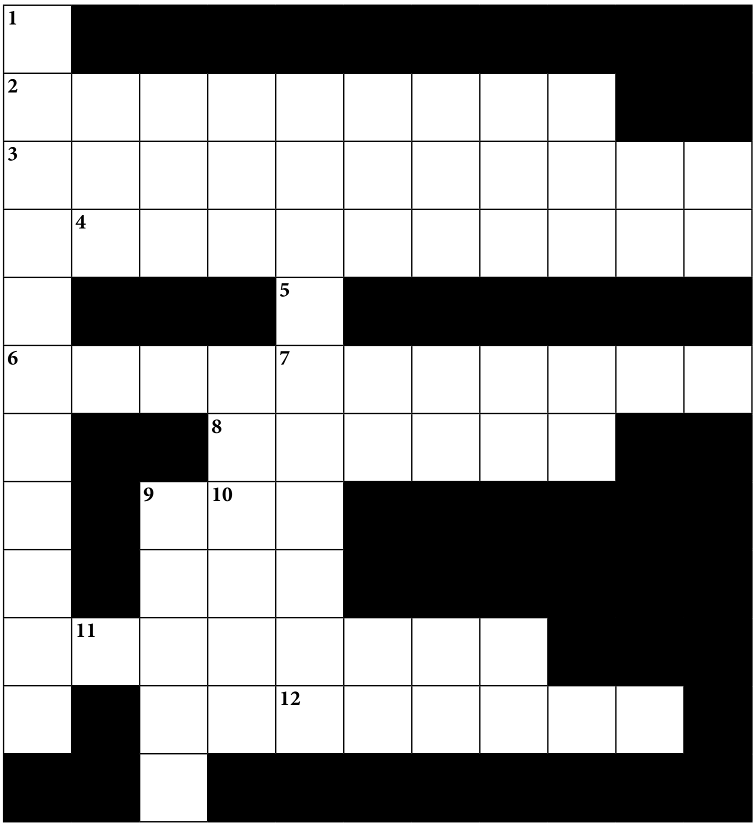
- That it is very important to plant and grow trees in Ethiopia to replace the many forests that have been lost.
- That trees are important for many reasons including taking carbon dioxide out of the atmosphere, holding the soil together and providing us with food and many other products.
- How to plant and grow trees in your community, including how to plan the best place to plant the trees.

End of unit questions

1. a) List the main problems that face animals living in cold conditions like the Arctic.
   b) List the main problems that face animals living in the desert.
2. Give three ways in which animals staying in the Arctic throughout the winter keep warm and explain how the adaptations work.
3. Give three ways in which animals living in a desert manage to keep cool without sweating so they don't lose water.

4. Give three adaptations that help plants living in dry conditions to reduce water loss from their leaves.
5. Give one example of an animal adaptation and one example of a plant adaptation that makes the organism more likely to reproduce successfully.
6. Explain why it is important to plant more trees in Ethiopia.
7. Describe carefully the best way to plant a young tree to make sure that it will survive and grow well.

Copy the crossword puzzle below into your exercise book (or your teacher may give you a photocopy) and solve the numbered clues to complete it.



Across

2 A life-supporting environment (9)

3 The struggle between organisms for resources (11)

4 The special features which allow organisms to survive in difficult conditions (10)

6 Animals which are eaten by predators (4)

7 The biological material made by living organisms (7)

8 The living components of an ecosystem (6)

11 The home of a living organism (7)

12 The greenhouse effect is due to gases such as ****** dioxide in the atmosphere (6)

Down

1 Organisms which break down droppings and dead organisms at the end of a food chain (11)

5 Non-living components of an ecosystem (7)

9 Simple links between organisms which feed off each other are known as a food ***** (5)

10 Complex feeding relationships between organisms are known as food **** (4)

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