Ecology

Unit 2

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Section	Learning competencies
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2.1 Cycling matter through ecosystems

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

- Explain the need for the recycling of materials through ecosystems.
- Illustrate the nutrient cycle.
- Describe and diagram the water, carbon, nitrogen, sulphur and phosphorus cycles.
- State that materials do not always remain within an ecosystem.

Why is it important that materials are recycled?

We have studied the flow of energy through ecosystems and seen how energy is continually lost as heat from the ecosystem and has to be replaced as light. Nutrients, however, are recycled. Figure 2.1 illustrates this difference.

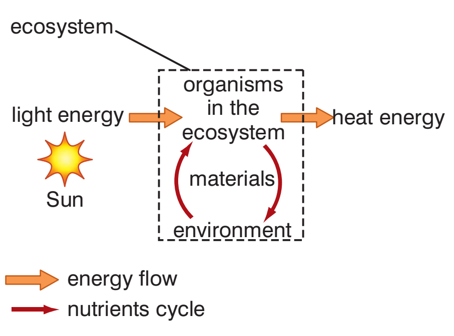


Figure 2.1 The recycling of nutrients in an ecosystem.

Did you ever consider … just how second-hand our bodies are?

Have you ever thought that some of the carbon atoms in the carbon dioxide from Julius Caesar's last breath as he was murdered 2000 years ago might have ended up in the potato you ate the other day and are now part of you? Or that carbon dioxide that Haile Gebreselassie breathed out during a race perhaps ended up in some sugar cane and the carbon atoms are now part of you? Every atom in your body has been in many other bodies before it was in you. We are very much second-hand!

Figure 2.2 *Caesar's dying breath*

There is a finite amount of each nutrient in an ecosystem and so the same atoms must constantly be re-used, over and over again. This happens at the ecosystem level and also globally. Ecosystems look unchanging, but they are in fact always changing. Materials are always being 'moved around' within an ecosystem. Nutrients are always being taken in by organisms and materials are lost when they breathe and excrete. What is a waste product to one organism becomes a vital nutrient to another. All the organisms in the ecosystem are interdependent and interact with their physical environment. Materials are moved around an ecosystem when organisms:

- feed
- excrete
- respire and breathe
- die and are decomposed

The molecules that are moved around, particularly the organic molecules, store large amounts of energy in the bonds holding the atoms together. So, as materials are moved, energy is transferred also. But, as noted earlier, energy is eventually lost from the ecosystem as heat and must be replaced as light. The nutrients just keep on being recycled …

As you can see from Figure 2.3, **decomposers** (bacteria and fungi) are key in returning nutrients to the ecosystem. Important mineral elements such as nitrogen and phosphorus are returned to plants as a result of the action of decomposers.

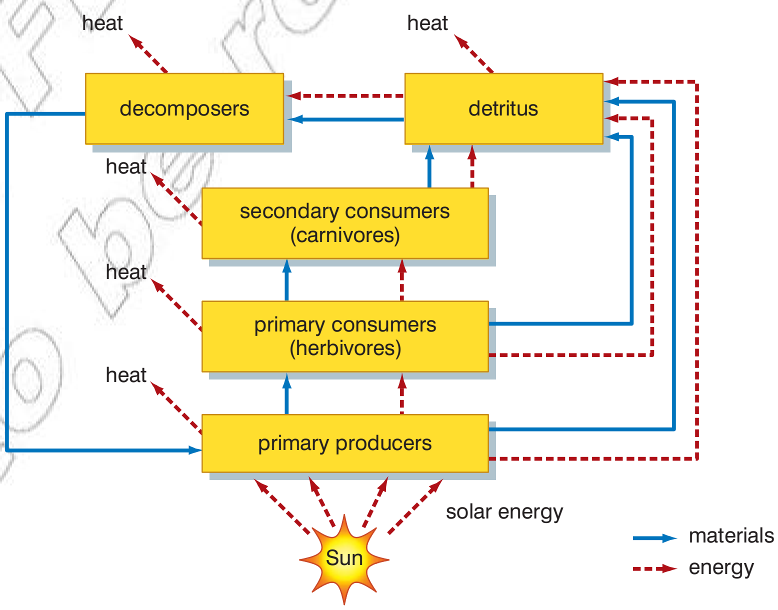


Figure 2.3 *Energy and materials are moved around in an ecosystem*

Decomposers feed by a method known as **saprobiotic nutrition**. They feed on dead matter – and so do you. You digest the parts of dead animals and plants that you eat and so must the decomposers. To do this, they secrete enzymes onto the dead matter. The enzymes digest the complex organic molecules into simpler, smaller ones and the micro-organisms absorb these products of digestion (just like you). But, unlike you, their **extracellular digestion** does not take place in a gut, it takes place in the soil, or wherever the dead matter happens to be.

DID YOU KNOW?

Decomposers release many mineral elements, nitrogen, phosphorus and others from organic compounds in dead bodies. These are then absorbed from the soil by plants. However, carbon is released into the air as carbon dioxide when the decomposers respire – just as with all other organisms.

However, besides hydrolytic enzymes that break down complex organic molecules many micro-organisms have enzymes for other purposes. For example, many of the decomposers have an enzyme that releases the amino group from amino acids and converts it to ammonia. This is known as ammonification and is important in the nitrogen cycle. But that is not why it takes place. Ammonification is carried out by a range of bacteria and fungi as a way of obtaining energy from organic, nitrogen-containing compounds. The ammonia, vital to the nitrogen cycle, is just a useless by-product to these micro-organisms. This is typical of many of the chemical reactions that take place in all the nutrient cycles. The reactions are primarily energy-releasing reactions for a particular type of micro-organism. It is a 'happy chance' that the reactions produce a by-product that can be processed in the next stage of the nutrient cycle.

***Figure 2.4** Fungi (moulds) decomposing bread using extracellular digestion*

What are the main stages in the carbon cycle?

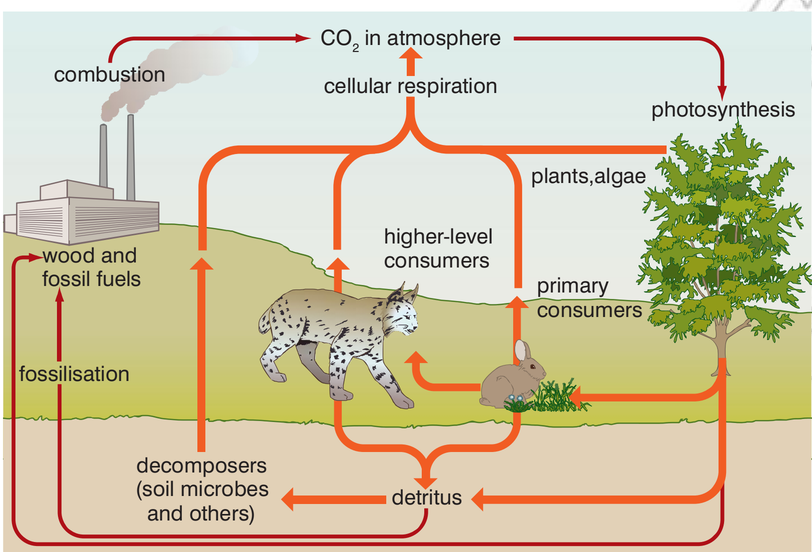


***Figure 2.5** The carbon cycle*

The main processes involved in cycling carbon through ecosystems are:

- photosynthesis – the process that fixes carbon atoms from an inorganic source (carbon dioxide) into organic compounds (for example, glucose)
- feeding and assimilation – feeding passes carbon atoms already in complex molecules to the next trophic level in the food chain where they are assimilated into (become part of) the body of that organism
- respiration – this releases inorganic carbon dioxide from organic compounds
- fossilisation – sometimes living things do not decay fully when they die due to the conditions in the soil, and fossil fuels (for example, coal, oil and peat) are formed
- combustion – fossil fuels are burned, releasing carbon dioxide into the atmosphere

KEY WORDS

decomposer *an organism that breaks down dead organic matter and recycles it*

saprobiotic nutrition *used by organisms such as fungi to obtain nutrients from non-living organic matter using extracellular digestion*

extracellular digestion *organisms excrete enzymes to release nutrients from food and then absorb these nutrients through their cell walls*

Activity 2.1: Poster

Farmers add fertilisers containing nitrates to the soil to replace the nutrients which crops remove. Excess fertilisers can be washed into lakes and rivers. This is called leaching. In the lakes and rivers, these fertilisers cause a process called eutrophication. In this process:

- the fertilisers cause algae in the river to grow faster
- they grow so much that they block out the light for plants underneath them, which die (due to competition for light)
- eventually the algae die also as they run out of nutrients
- the dead algae and dead plants become food for bacteria, which breed rapidly.
- the large population of bacteria respires, using up oxygen from the water.
- there is not enough oxygen left for organisms such as fish, which have to move to another area or die.

Use the information above to make a poster explaining the dangers of the overuse of fertilisers.

KEY WORD

redox reaction *in a redox reaction, one chemical (called an oxidising agent) is reduced, and another chemical (called a reducing agent) is oxidised*

Cycling carbon is essential to the living world as all the organic molecules found in living organisms are based on carbon. We often talk about the Earth having 'carbon-based life forms'.

What are the main stages in the nitrogen cycle?

Nitrogen is found in many biological compounds. It is present in proteins, amino acids, DNA, RNA (all kinds) and adenosine triphosphate (ATP) as well as ADP.

Without nitrogen, organisms could not synthesise:

- their genetic material (DNA)
- their principal structural materials (proteins)
- their principal energy transfer molecule (ATP)

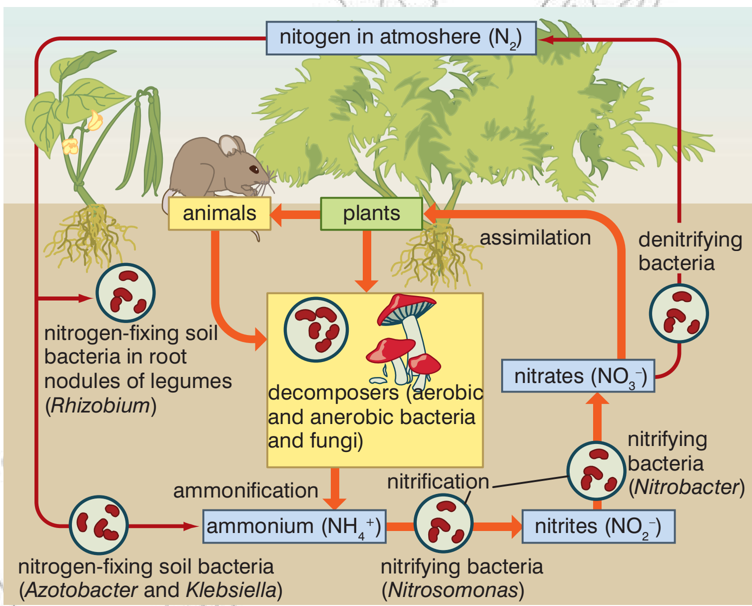


***Figure 2.6** The nitrogen cycle*

The main processes in the cycle are:

- plants absorb nitrates from the soil
- the nitrates are then used to form amino acids, which are used to synthesise proteins
- the plants are eaten by animals, the proteins digested and the amino acids absorbed and assimilated into animal proteins
- both plants and animals die, leaving a collection of dead materials (detritus) which contain the nitrogen still fixed in organic molecules; in addition, excretory products such as urea also contain nitrogen
- decomposers decay the excretory products and detritus, releasing ammonium ions (NH_4^+) into the soil; this process is often referred to as ammonification
- nitrifying bacteria oxidise the ammonium ions to nitrates (NO_3^-) (which are taken up by the plants) in a process called nitrification; in this process there is an intermediate product called nitrite (NO_2^-)

Remember redox reactions?

The conversion of ammonium ions to nitrite ions is an oxidative process involving redox reactions, because the nitrogen atoms in the original ammonium ion:

- gain oxygen atoms and
- lose hydrogen ions

as the simple equation below shows

$$\underset{\text{ammonium}}{NH_4^+} \longrightarrow \underset{\text{nitrite}}{NO_2^-}$$

The hydrogen ions lost must go somewhere and the oxygen atoms must have come from somewhere, so something else is being reduced.

In actual fact, it is a much more complex reaction as the next equation shows! You will not have to remember this equation; it is just to illustrate how complex the reactions are and where the oxygen atoms come from and where the hydrogen ions go to.

$$55NH_4^+ + 76O_2 + 109HCO_3^- \longrightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3$$

The hydrogen ions reduce hydrogen carbonate ions to carbonic acid. The oxygen atoms that join the nitrogen atom are themselves reduced in the reaction.

Reduction and oxidation always occur together.

These processes recycle nitrogen that is already in biological molecules of one kind or another. But besides this, two other processes, denitrification and nitrogen fixation, decrease or increase, respectively, the amount of nitrogen in circulation.

Denitrifying bacteria reduce nitrate to nitrogen gas that escapes from the soil. This decreases the total amount of nitrogen available to the plants, and, therefore, to all the other organisms also.

Nitrogen-fixing bacteria 'fix' nitrogen gas into ammonium ions. This happens in two main situations:

- Nitrogen-fixing bacteria free in the soil (belonging to the genera *Azotobacter* and *Klebsiella*) reduce nitrogen gas into ammonium ions in the soil. These ammonium ions can be oxidised immediately into nitrates by nitrifying bacteria, adding to the amount of nitrogen available to the plants and, therefore, the other organisms also.
- Nitrogen-fixing bacteria in nodules on the roots of legumes (belonging to the genus *Rhizobium*) form ammonium ions that are passed to the legumes and used by them to synthesise amino acids. The extra nitrogen only becomes available to other organisms when the legumes die and are decomposed.

Figure 2.7A shows the root system of a legume with nodules containing *Rhizobium*. Figure 2.7B is a micrograph of a section through the nodule showing the bacteria (stained purple).

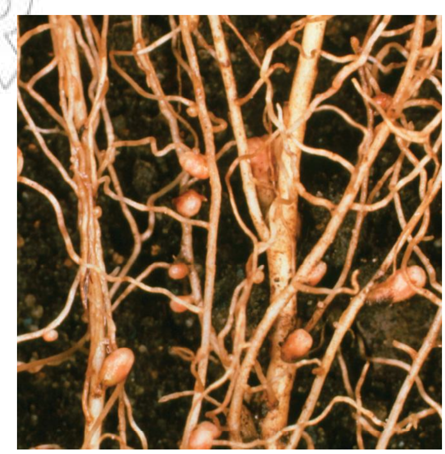


***Figure 2.7A** Root nodules*

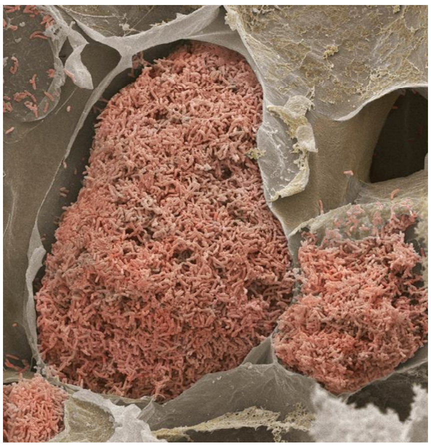


***Figure 2.7B** The bacteria in a root nodule*

DID YOU KNOW?

Legumes are often used in crop rotation systems by organic farmers. They can be used in one of two ways. They can be grown as a crop (for example, peas or beans) and the peas or beans harvested; then the remains of the plants are ploughed into the soil. Alternatively a non-crop legume such as clover can be grown and ploughed in at the end of the year. In this second method, all of the nitrogen fixed is added to the soil; none is lost in a crop.

KEY WORD

legumes *(also called pulses) are food plants such as beans, lentils and peas*

At the moment an immense amount of research into the genetics of nitrogen fixation is being carried out. The aim is to isolate the genes that control nitrogen fixation and transfer them by genetic engineering into other cells. Or persuading bacteria like *Rhizobium* to form symbiotic associations with other species of crop plants. If all the cereal plants that are grown in the world had nitrogen-fixing bacteria in their roots or if their own cells could fix nitrogen, crop yields in countries with extreme food shortages would be hugely increased. And the plants would not need nitrogen fertiliser – they would make their own! Transferring this ability to other plants would have a huge impact on our ability to feed the planet.

How is phosphorus recycled?

The core phosphorus cycle is much the same as the core nitrogen cycle. Phosphorus is present in organisms in the form of phosphates.

- phosphate is absorbed from the soil (or water) by plants
- these are passed along food chains to various herbivores and carnivores
- on death, their bodies are decomposed and phosphate ions are released from compounds like phospholipids, ATP, DNA and RNA and are returned to the soil or water
- phosphates also enter the soil (or water) as a result of the weathering of rocks and in the form of fertilisers, which, themselves, contain phosphates that have been obtained from rocks
- over millions of years, phosphate ions can leach into the seas and become part of newly forming sedimentary rock.

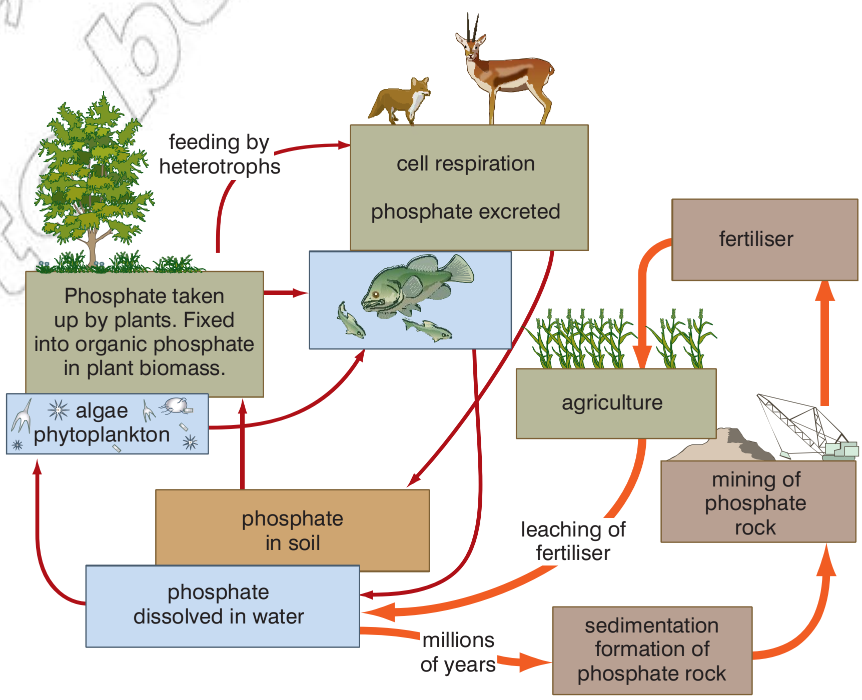


***Figure 2.8** The phosphorus cycle*

How is sulphur recycled?

As with the other cycles, the core cycle is between the soil, plants, animals and special decomposers. There are also components that relate to long-term rock formation and weathering as well as the formation of sulphur dioxide when fossil fuels are burned.

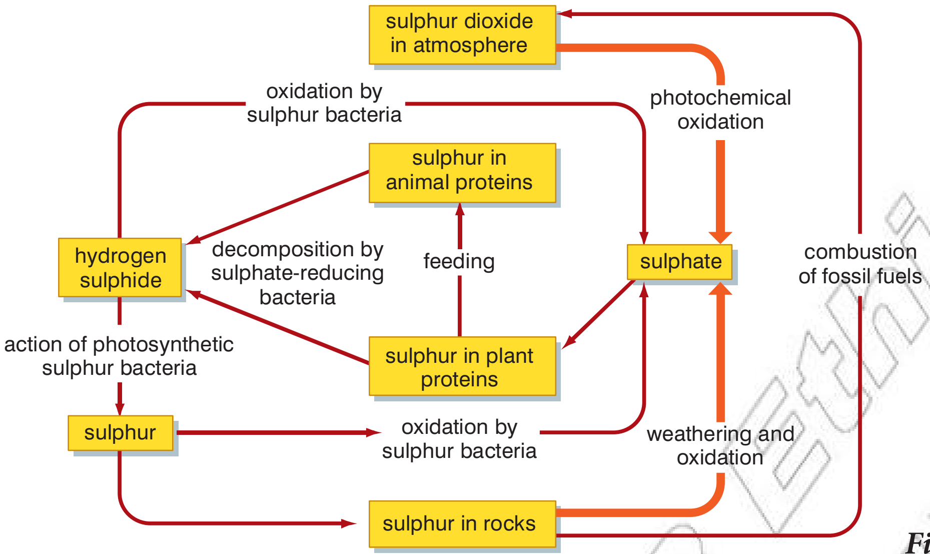


Figure 2.9 *The sulphur cycle*

- sulphate ions in the soil are taken up by plants and incorporated in plant tissue (many proteins include some sulphur-containing amino acids, such as methionine and cysteine)
- these are passed to animals by feeding and digestion
- on death of the plants and animals, sulphate-reducing bacteria release the sulphur in the proteins in the form of hydrogen sulphide (with the smell of 'bad eggs'); the most important genus of bacteria involved in this process is *Desulphovibrio*; this process requires anaerobic conditions
- in some aquatic environments the hydrogen sulphide is oxidised to sulphur by photosynthetic sulphur bacteria; this reaction is the equivalent of the photolysis of water in the photosynthesis of higher plants
- sulphur bacteria, mainly of the genus *Thiobacillus*, then oxidise the hydrogen sulphide (or sulphur) to sulphate (SO_4^{2-}), with sulphite (SO_3^{2-}) as an intermediate step; this is an oxygen-requiring process that needs aerobic conditions and makes sulphate ions available once again to be taken up by plant roots from the soil
- sulphur can also become incorporated in rocks, including those that yield fossil fuels
- combustion of fossil fuels oxidises the sulphur to sulphur dioxide (SO_2); this is a serious pollutant of the atmosphere and a major contributor to the formation of acid rain
- in the atmosphere, the sulphur dioxide becomes further oxidised to sulphite and sulphate which dissolve in rainwater to form a mixture of sulphurous and sulphuric acid: acid rain

Activity 2.2

Work in groups to make a big display of natural cycles. Each group should make a big poster on one of the natural cycles which can then all be arranged on the walls of the classroom as an aid to learning!

Activity 2.3

Prepare a report for the class on the importance of recycling in nature. You can investigate and add something about how people can recycle their resources too.

What about the water cycle?

Water is essential to all living organisms in all kinds of ways:

- it makes up 70% of all cells
- it is an essential requirement of photosynthesis
- it is the basis of all transport systems in organisms
- it provides a means of removing excretory products

In addition, we use water in many ways in our daily lives:

- to wash our clothes, our dirty dishes and our dirty selves
- to flush away waste
- to make products such as paper, steel and beer
- to generate electricity using a range of devices that convert the motion of water into electrical energy
- in a system, called 'hydroponics', to grow plants in a soil-free medium

Figure 2.10 summarises the main stages of the water cycle.

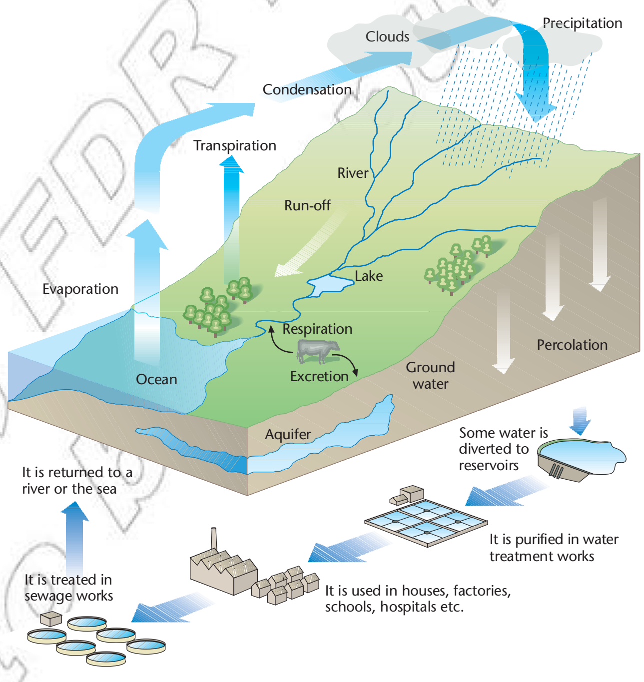


***Figure 2.10** The water cycle*

Review questions

Choose the correct answer from A to D.

1. Which of the following statements about the nitrogen cycle is true?

   A Plants fix nitrates into atmospheric nitrogen.

   B All the nitrogen obtained by animals came from plants.

   C Nitrogen is consumed by bacteria and removed from the soil.

   D Nitrogen-fixing bacteria reduce the total amount of available nitrogen in the nitrogen cycle.

2. The micro-organisms that break down dead matter are:
   A herbivores
   B detritivores
   C decomposers
   D nitrogen-fixing bacteria
3. Carbon dioxide is removed from the atmosphere when
   A animals respire
   B plants respire
   C plants photosynthesise
   D Plants and animals respire
4. Decomposers feed by:
   A parasitic nutrition
   B saprobiotic nutrition
   C intracellular digestion
   D autotrophic nutrition
5. In the nitrogen cycle, nitrogen gas is returned to the atmosphere by:
   A nitrogen-fixing bacteria
   B ammonifying bacteria/decomposers
   C nitrifying bacteria
   D denitrifying bacteria
6. In the sulphur cycle, hydrogen sulphide is oxidised to sulphur by:
   A photosynthetic sulphur bacteria
   B *Desulphovibrio*
   C *Thiobacillus*
   D none of the above
7. Which of the following comparisons of the phosphorus *and* carbon cycles is true?
   A The biological components of the cycles involve recycling through the atmosphere.
   B The non-biological components involve the use of fossil fuels by humans.
   C The non-biological components involve the agriculture industry.
   D The biological components involve feeding, death and decomposition.

8. Which of the following statements concerning the water cycle are true?
   - A Aquifers are large underground natural reservoirs.
   - B Evaporation uses energy from the sun to vaporise liquid water.
   - C Run-off is the movement of water along the surface.
   - D All of the above.
9. Which of the following is the best explanation for the fact that decomposers are found in the carbon, nitrogen, sulphur and phosphorus cycles?
   - A They digest organic molecules.
   - B They feed on dead materials.
   - C They release mineral ions that are combined in complex organic molecules.
   - D They decay dead materials.
10. In the nitrogen cycle, it is accurate to describe the conversion of ammonium ions to nitrate ions as an oxidation because the nitrogen atom in the ammonium ion:
    - A loses oxygen and gains hydrogen ions
    - B loses oxygen and loses hydrogen ions
    - C gains oxygen and gains hydrogen ions
    - D gains oxygen and loses hydrogen ions

KEY WORDS

ecology *the branch of science that describes and explains how organisms belonging to different species interact with each other and with the non-living environment.*

ecosystem *a community of organisms along with their habitat*

succession *the process where one ecosystem replaces another ecosystem*

2.2 Ecological succession

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

- Explain what is meant by the term succession.
- Describe the natural process by which bare land turns out to be productive by succession.
- Describe primary and secondary succession.
- Give examples of primary and secondary successions.

What is a succession?

The **ecosystems** that exist today did not always exist. They have developed from other previous systems by **succession**. And many of them began on completely bare ground. Bare rock does not remain bare for long. Very soon, lichens can be seen growing on the surface of the rock. These extremely resilient organisms are able to colonise harsh environments and reproduce there. They are pioneer species.

***Figure 2.11** Lichens growing on bare rock*

Through the natural recycling processes we have discussed in section 2.1, the very presence of the lichens must change the **abiotic** conditions, making them less harsh. The living lichens grow into the rock causing it to crumble. When the lichens die, decomposers act on the remains to release mineral ions into the crumbled rock.

The mixture of dead remains, crumbled rock and mineral ions forms a primitive soil. This less harsh environment is suitable for mosses (provided that there is sufficient water). So, spores of mosses that land there can now 'germinate' and the mosses grow, outcompeting the lichens in the changed environment.

This is the essence of succession:

- Organisms colonise an area.
- They change the abiotic (physical) conditions in the area.
- The changed abiotic conditions allow other species to colonise the area.
- The new species compete with the ones there before and become dominant.
- They also then change the abiotic conditions, more species enter and the process continues.

The various stages in a succession are called seres.

As successive producers colonise the area, they create more and different habitats and niches for other organisms to occupy. As a consequence, succession usually involves an increase in the complexity of food webs. The final, most complex, state of a succession is the **climax community**.

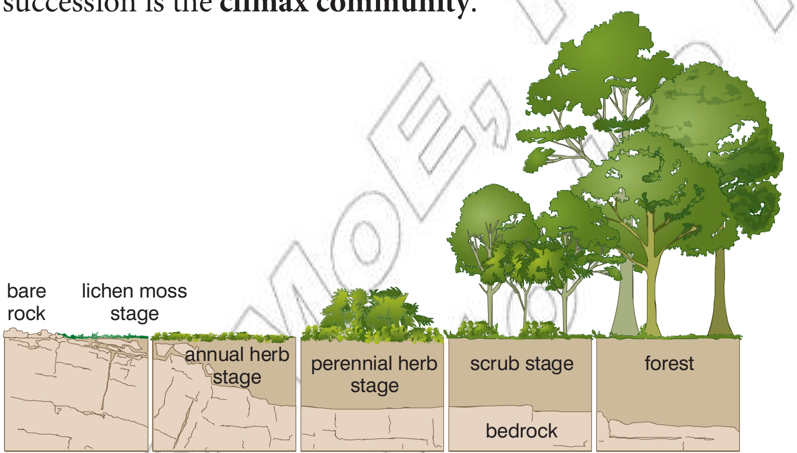


Figure 2.13 *A succession from bare rock to a woodland climax*

In the example shown in figure 2.13, you can see that as different types of vegetation enter the area, they affect the amount and depth of soil. This, in turn, allows other types of plant with more complex root systems to enter. The increasing complexity of the plant community will create more and more ecological niches and so more animals will also enter the area. The species diversity will rise through the succession, until the climax is reached. The climax is the most complex community that can exist under the prevailing environmental conditions.

Figure 2.12 *Mosses have succeeded lichens in some areas*

KEY WORDS

abiotic *describes the non-living part of an ecosystem*

climax community *the most complex community that can exist under the prevailing environmental conditions*

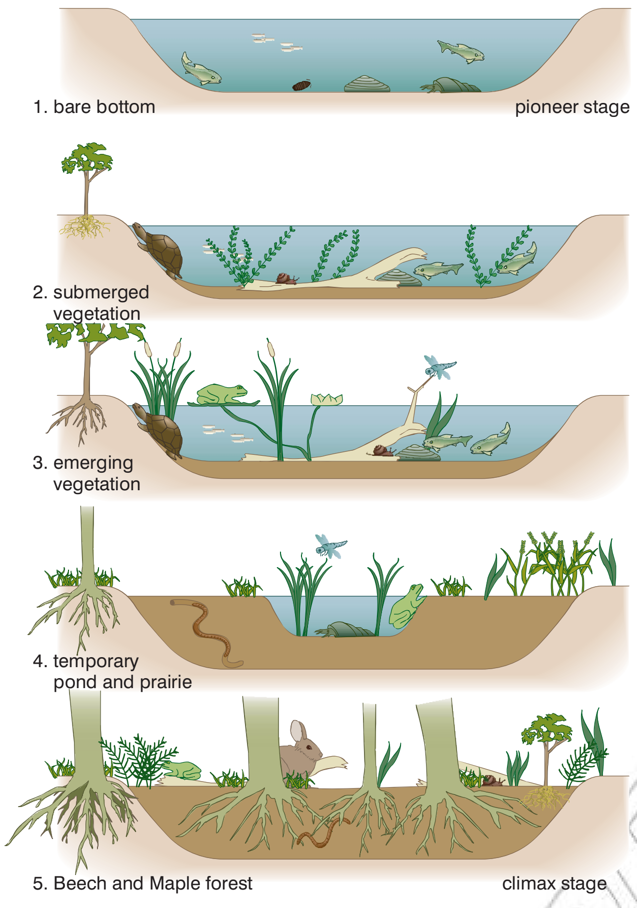


***Figure 2.14** A succession from open water to woodland*

The following trends occur in any succession:

- The total biomass of the community increases.
- The species diversity increases.
- The number of ecological niches increases.
- Food webs become more complex.
- The community becomes more stable – can accommodate small changes/losses more easily.

A woodland climax can arise through a totally different succession. A lake or pond can undergo a succession that results in the water being replaced by sediments allowing land plants to grow and giving rise to a succession that results in woodland. Figure 2.14 shows how.

An open water area with little obvious vegetation can support animal life because of plankton in the water and smaller animals in the mud at the bottom.

Submerged plants become established in the sediment formed by the dead animals. They increase the amount of sediment as they die and larger plants become established.

As time passes, more and more sediment fills the lake and larger 'emerging' plants become established. Eventually there is sufficient sediment to support deep-rooted trees and the climax woodland stage of the succession is reached.

Both successions end with the same climax. Because the first takes place from rock it is called a xerosere. The second, starting from water, is a hydrosere.

The ecological impact of humanitarian acts

Ethiopia has housed millions of refugees from other African countries. Many of these lived in large, specially created settlement areas. They are now, in most cases, being successfully repatriated to their native countries. But areas up to 40 km from the settlements have been deforested. They will probably revert, by a secondary succession, to the original native climax forest if left unmanaged.

Why do different areas have different climax communities?

Forest climax communities in Europe do not become as complex as tropical rainforest because of the climate. Because of this, they are said to be climatic climax communities.

Grassland in many areas would revert to woodland or forest if it were not grazed. The grazing animals nip off the growing points at the tips of young tree shoots, preventing them from growing. Grasses grow from ground level, not from the tips of shoots, and so can regrow. These grasslands are grazing climaxes. Other factors that could influence the type of climax community formed include:

- temperature
- precipitation (rainfall)
- soil type
- soil depth

Where a succession starts from bare, previously uncolonised ground, or from a newly formed pond with no life, the succession is a primary succession. Sometimes, communities are destroyed by fire or by a farmer ploughing a field or by some other human intervention. When a new succession begins in such an area it is a secondary succession. This may result in the same climax as was originally present or in a very different one. Although the process is still essentially the same (with pioneers colonising and then being succeeded), secondary successions to the original climax are usually much quicker than primary successions because:

- the succession is not starting from bare rock/open water
- there is a seed bank of many of the climax plant types available in remaining undamaged plants
- the soil is already present

Review questions

Choose the correct answer from A to D.

1. In an ecological succession:
   - A pioneer species are the first to colonise an area
   - B the most complex community to develop is the climax community
   - C each stage in the succession alters the environment so that other species can enter
   - D all of the above
2. Which of the following factors does not affect the type of climax community that develops?
   - A temperature
   - B the presence of grazing animals
   - C thunderstorms
   - D soil type
3. A secondary succession differs from a primary succession to the same climax in that:
   - A it usually takes a greater period of time
   - B it requires no pioneer species
   - C there is an existing seed bank to draw on
   - D it starts from ground that has never been colonised
4. The stages in a succession are referred to as:
   - A pioneers
   - B seres
   - C climaxes
   - D communities

Activity 2.4: Debate

Some people believe that clearing forests to create space for agriculture is always acceptable. Other people disagree with this because they believe it can reduce biodiversity. In this activity you will debate this issue.

Your teacher will divide the class into three groups:

- Group 1 – this group will present arguments to support the idea that clearing forests is always acceptable
- Group 2 – this group will present arguments to support the idea that clearing forests will reduce biodiversity
- Group 3 – this group will form the 'audience' who will:
- question the members of each of the other groups after their presentation
- vote to decide the outcome of the debate

The debate will follow the following procedure:

- Group 1 will present their case (2 minutes)
- Group 2 will present their case (2 minutes)
- Groups 1 and 2 can question the other group and try to disprove their ideas (2 minutes)
- Group 3 (the audience) can question any members of any group (4 minutes)
- Group 3 votes on the issue

5. All successions share which of the following features?
   - A Each stage changes the abiotic conditions.
   - B The community becomes more complex as the succession progresses.
   - C More ecological niches are created as the succession progresses.
   - D All of the above.

2.3 Biomes

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

- Define the term biome.
- Name the major terrestrial and aquatic biomes.
- Describe the main features of each biome.
- Give examples of the flora and fauna of each biome.
- Appreciate the duty of care we have for the flora and fauna of the biomes.

KEY WORDS

biosphere *all those parts of the Earth, including the Earth's crust, the seas and the atmosphere, where living organisms can be found*

biome *a climatically and geographically limited ecological area that consists of organisms that are adapted in similar ways*

What is a biome?

In 1875, the geologist Eduard Suess first coined the term **biosphere**. He used this to describe the layer of the Earth's surface where life is found.

Today we also think of the biosphere as the integration of all the world's ecosystems. It is now evident that the biosphere is more extensive than we ever realised. From bacteria at hot sulphur vents miles beneath the sea surface to geese flying at heights of over 8000 metres (5 miles), vultures at heights of 11 000 metres (7 miles) and fish living at depths of 8000 metres (5 miles), the biosphere is a lot thicker than we once thought.

We divide the biosphere into a number of **biomes**. The concept of a biome brings together several ideas. A biome is a geographical or regional area with:

- a specific climate, and
- a specific soil type, and
- specific animals and plants that are adapted in similar ways to the abiotic conditions within the area.

Temperature and precipitation (rainfall) are the most significant climatic factors in determining biome type. These, in turn, are determined to a very large extent by geographical location.

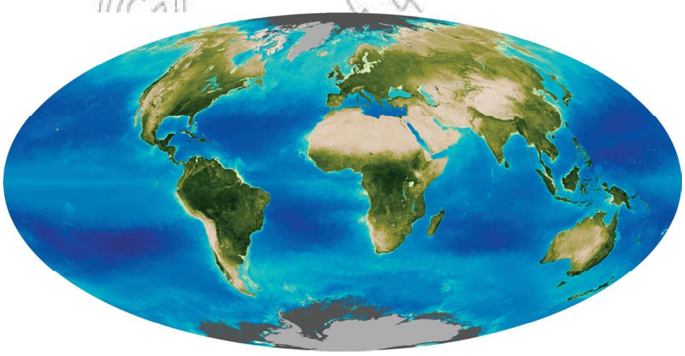


Figure 2.15 *The biosphere*

For example, it is never anything but cold at the poles, and these areas also receive little precipitation. It is never anything but hot at the equator and equatorial regions receive high precipitation.

Figure 2.16 shows how different combinations of temperature and precipitation result in different biomes.

Figure 2.17 shows how the main biome types are influenced by wind patterns, which are the main factors that drive the climate.

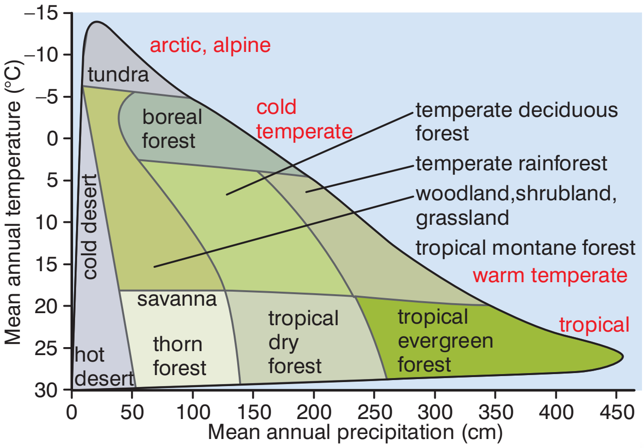


Figure 2.16 *Temperature and precipitation are large factors in determining biomes*

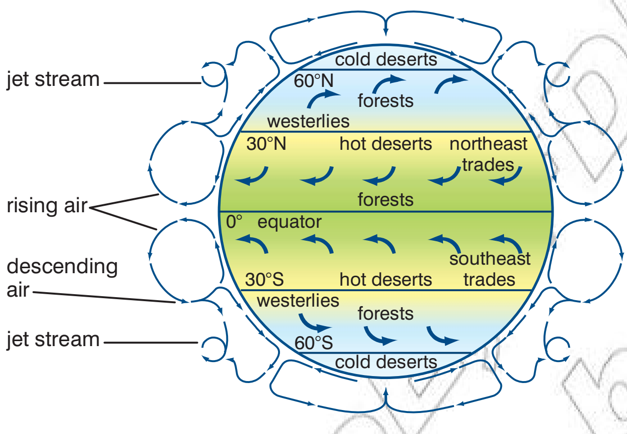


Figure 2.17 *Biomes and their relation to the Earth's pattern of winds*

What types of biomes are there?

There have been many classifications of the different biomes and scientists are still refining their ideas but we can classify the biomes into two main types:

- terrestrial
- aquatic

Each can then be further subdivided to give the distinct biomes.

What are the main types of terrestrial biomes?

A **terrestrial biome** is defined by temperature, rainfall, soil type, flora and fauna (plants and animals). Table 2.1 overleaf gives the features of the major terrestrial biomes.

KEY WORD

terrestrial biome *a biome consisting of an area of land*

Table 2.1 The characteristics of the major terrestrial biomes

Biome	Precipitation	Temp.	Soil	Plants	Animals
Desert (hot)	Almost none	Hot	Poor	Sparse – succulents (like cactus), sage brush	Sparse – insects, arachnids, reptiles and birds
Desert (cold)	Almost none	Cold	Poor	Sparse – micro-organisms and some lichens	Sparse – polar bears, seals
Thorn forest (scrub)	Dry summer, rainy winter	Hot summer, cool winter	Poor	Shrubs, some woodland (like scrub oak)	Drought- and fire-adapted animals
Tundra	Dry	Cold	Permafrost (frozen soil)	Lichens and mosses	Migrating animals
Boreal forest (Taiga)	Adequate	Cool year-round	Poor, rocky soil	Conifers	Many mammals, birds, insects, arachnids, etc.
Temperate deciduous forest	Adequate	Cool season and warm season	Fertile soil	Deciduous trees	Many mammals, birds, reptiles, insects, etc.
Tropical montane forest	8–9 wet months, air always humid	Always warm	Fertile soil	Ferns, tree ferns, large deciduous trees, epiphytes	Many animals
Tropical rainforest	Very wet	Always warm	Poor, thin soil	Many plants, epiphytes common	Many animals

There are several biomes to be found within Ethiopia. Wetter portions of the western highlands consist of tropical montane vegetation with dense, luxuriant forests and rich undergrowth.

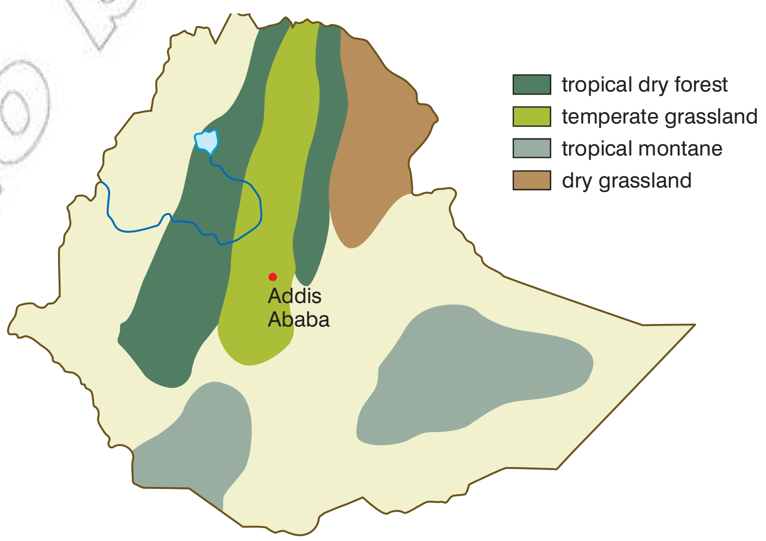


Figure 2.18 The main biomes in Ethiopia

Activity 2.5

Write the word biome on the centre of a piece of paper or of the chalk board. Build up a concept map or a spider diagram showing everything you know about the major biomes.

Drier sections at lower elevations of the western and eastern highlands contain tropical montane forest mixed with grassland. Temperate grasslands cover the higher altitudes of the western and eastern highlands. Tropical dry forest is found in the Rift Valley and eastern lowlands together with some dry grassland areas. Dry grassland also covers portions of the Denakil Plain.

KEY WORDS

aquatic biome *a marine biome or a freshwater biome*

freshwater biome *a biome consisting of a river, a lake or a pond*

marine biome *a biome consisting of a part of the sea*

What types of aquatic biomes are there?

We can subdivide the **aquatic biomes** into two main types:

- **marine biomes**
- **freshwater biomes**

There are several biomes in each category. Table 2.2 gives some of the features of each category.

Table 2.2 *The main features of the aquatic biomes*

Biome	Salt content	Moving or standing	Other feature	Animals and plants
Marine:				
Oceanic, pelagic	High	Moving	The region of the ocean where light penetrates	Many fish, mammals and plankton
Oceanic, abyssal	High	Less movement	The region of the ocean where no light penetrates	Angler fish, sulphur bacteria at vents
Coral reef	High	Moving	Most diverse of all marine habitats. Has many strata like a rainforest.	Corals, many fish, many seaweeds
Estuarine	Intermediate	Extreme movement	Unique habitat due to mixing of saltwater and freshwater	Shore birds, fish, crabs, mangroves, kelps, sea grass
Freshwater:				
Ponds and lakes	Freshwater	Standing	Are stratified as top layer absorbs more heat and light	Large numbers of plankton, plants and animals in top layer
Streams and rivers	Freshwater	Moving	Water is highly oxygenated	Algae, plankton, plants and fish
Wetlands	Freshwater	Standing	Water is very nutrient rich	Many plants and animals – highest of all aquatic biomes

Figure 2.19 shows the distribution of some of these aquatic biomes. It is clearly not possible to show the location of most lakes, ponds, rivers and estuaries.

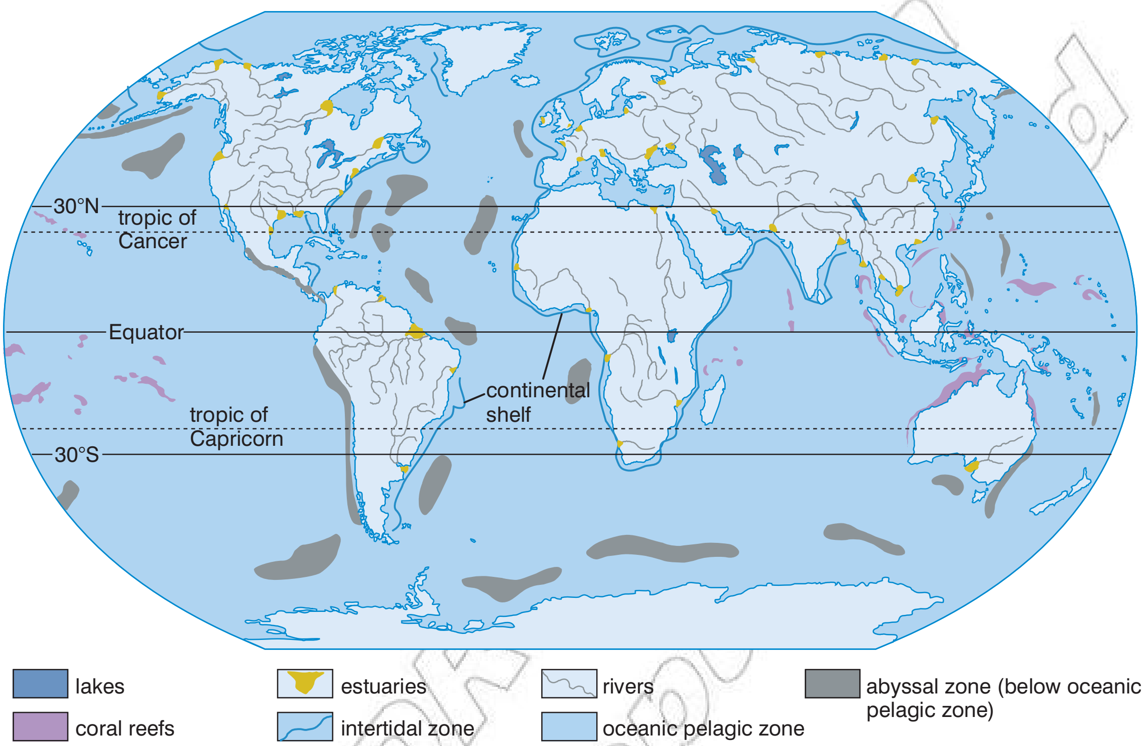


Figure 2.19 The distribution of the major aquatic biomes

Activity 2.6

Investigate a local biome – it may be terrestrial or aquatic. Find out as much as you can about your chosen biome. You can collect and present material from the biome such as soil, specimen plants etc. Prepare a short talk on your local biome and explain how it fits in with the ecology of Ethiopia as a whole.

Review questions

Choose the correct answer from A to D.

1. A biome can best be defined as:
   - A a geographically defined region
   - B a group of ecologically similar organisms in a geographically defined region
   - C a geographically and climatically defined region
   - D a group of ecologically similar organisms in a geographically and climatically defined region
2. Terrestrial biomes are largely defined by:
   - A wind and temperature
   - B temperature and light
   - C rainfall and wind
   - D rainfall and temperature

3. Tropical rainforest is characterised by:
   - A low rainfall and low temperature
   - B high rainfall and low temperature
   - C low rainfall and high temperature
   - D high rainfall and high temperature
4. Freshwater biomes include:
   - A ponds and lakes, rivers and wetlands
   - B wetlands, estuaries and rivers
   - C estuaries, ponds and lakes, and rivers
   - D pelagic zones, wetlands and estuaries
5. When compared with tropical dry forest, tropical montane forests have:.
   - A a higher annual rainfall but a lower temperature
   - B a lower annual rainfall but a higher temperature
   - C the same annual rainfall but a higher temperature
   - D a lower annual rainfall but the same temperature

2.4 Biodiversity

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

- Explain what is meant by the term biodiversity.
- Appreciate the significance of biodiversity, both globally and locally.
- Explain how biodiversity is threatened in many areas of the world.
- Explain the status of biodiversity in Ethiopia.
- Describe the principles of conservation.
- Reflect a concern towards biodiversity and the need for its conservation.
- Appreciate the interdependence of plant and animal biodiversity.
- Engage in a tree-growing project.
- Express willingness to participate in tree-growing activities in your locality.

KEY WORDS

biodiversity *the extent to which an ecosystem contains different species. Greater biodiversity makes an ecosystem less vulnerable.*

index of diversity *a number indicating an ecosystem's biodiversity*

What is biodiversity?

The most usual way to think of **biodiversity** is in terms of species richness. This is quite simply the number of different species that are present in an ecosystem. However, if only one or two individuals of a particular species are present in an ecosystem, they won't be contributing a great deal to the biodiversity of the ecosystem. A more useful concept is species diversity. This takes into account, not just how many different species are present, but the success of each species in the ecosystem. An **index of diversity** can be calculated and this can be used to give a picture of the ecosystem as a whole.

Look at the examples in table 2.3 below. They are, of course, made up, but the figures serve to illustrate a point. Each area contains the same six species and the same total number of organisms (100) yet the areas are clearly very different.

- In area 1, only species A is really successful and dominates the area.
- In area 2, all the species are more or less equally successful.
- In area 3, three of the six species dominate the area.

***Table 2.3** Three 'invented' ecosystems*

Species	Number of organisms of each species		
	Area 1	Area 2	Area 3
A	86	16	23
B	5	17	25
C	2	16	27
D	3	17	5
E	1	17	12
F	3	17	8

One **index of diversity** is Simpson's index of diversity and is calculated from the formula:

$$d = \frac{N(N-1)}{\Sigma n(n-1)}$$

In this formula, d is the index of diversity, N is the total number of organisms in the area and n is the total number of organisms of each species.

For area 1:

$d = (100 \times 99) / [(86 \times 85) + (5 \times 4) + (2 \times 1) + (3 \times 2) + (1 \times 0) + (3 \times 2)] = 1.348$

For area 2:

$d = (100 \times 99) / [(16 \times 15) + (17 \times 16) + (16 \times 15) + (17 \times 16) + (17 \times 16) + (17 \times 16)] = 6.314$

For area 3:

$d = (100 \times 99) / [(23 \times 22) + (25 \times 24) + (27 \times 26) + (5 \times 4) + (12 \times 11) + (8 \times 7)] = 4.911$

A low value for the index of diversity suggests an area dominated by one or just a few species. If there are more successful species with no species completely dominating the area, the value for the index of diversity will be higher.

A low value for the index of diversity, suggesting only a few successful species, could be the result of a hostile environment with only a few organisms being really well adapted to that environment. Change in the environment would probably have quite serious effects. If those few species that can survive are seriously affected, then the whole ecosystem may be disrupted.

Think back to section 2.2 and our study of succession. At the pioneer stage, when lichens are colonising bare rock, there are no other organisms present.

There will be a very low index of diversity because of this hostile environment. If, due to some environmental change, the lichens do not survive, the fledgling ecosystem will be lost; nothing else is going to colonise the bare rock.

There might be only a few types of organisms because they outcompete other similar types that could survive in that environment. Rhododendron bushes very effectively prevent any other plant from growing in the same area by shading them so completely that they cannot photosynthesise; they also secrete chemicals into the soil that inhibit the germination of other seeds. As a result, rhododendron bushes completely dominate the areas in which they grow and the areas have a very low index of diversity.

A higher diversity index suggests a number of successful species and a more stable ecosystem. More ecological niches are available and the environment is likely to be less hostile. Environmental change is likely to be less damaging to the ecosystem as a whole unless it affects all the plants present. Tropical rainforests provide an example of a stable ecosystem with high species diversity.

Figure 2.20 *Lichens growing on bare rock*

Figure 2.21 *Tropical rainforest has a high species diversity*

KEY WORD

tropical rainforest *a biome at a low elevation above sea-level, high rainfall and warm temperatures all year round*

However, biodiversity isn't just about the numbers of different species and how well they are doing. It is also about the diverse ways in which these different species are found. So we must also consider:

- the ecological diversity of each species – how many different ecological niches has it managed to colonise?
- the genetic diversity of each species – is there just one strain of the species with essentially one set of genes (the gene pool) or are there several different (but related) gene pools because there are several different (but related) populations of the species living in different areas?

So, biodiversity is a measure of the overall variability of life on the planet (or a local area) and it includes:

- the species richness and species diversity of the planet (or the local area)
- the ecological variability of each species
- the genetic variability of each species

How have humans influenced biodiversity?

Only for the worse. We humans have influenced our environment much more than any other species. This is one of the key features of human evolution. We have not so much adapted to our environment by natural selection, as changed the environment to suit us. Until relatively recently, because of the small numbers of humans, this has not been too much of a problem. However, the rate of this change has accelerated with the huge increase in our population and the development of our technology. We have reduced biodiversity in many ways, but two important activities have been:

- deforestation, and
- the impact of agriculture.

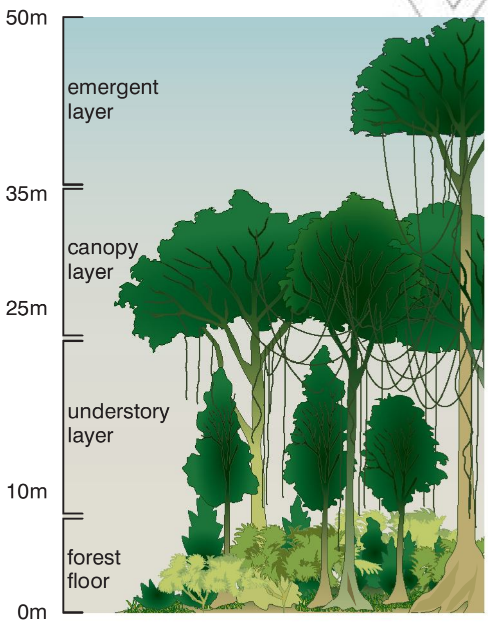


***Figure 2.22** The structure of rainforest*

How has deforestation affected biodiversity?

Where have all the trees gone? Gone for timber every one. Well, not quite; some have gone to be pulped to make the paper for biology textbooks, or simply to make room for ever more humans.

Deforestation is usually carried out for one of two main reasons:

- to clear land for human activities, such as mining, agriculture or house building, or
- to obtain timber to make products such as paper, charcoal, furniture, or to use as a building material.

Tropical rainforest is one of the most complex and species-rich ecosystems in the world. Rainforest covers about 7% of the Earth's surface and contains 25% of the known species.

Although many of the trees are very tall, the root systems are shallow and trees can easily fall. The shallow root systems grow in shallow, nutrient-poor soils. The soils are nutrient poor because many of the minerals from the soil remain 'locked up' in the huge trees. The only recycling of nutrients that occurs on a regular basis takes place when leaves fall. There is no accumulation of detritus as decomposers rapidly break down the leaves and release the mineral ions they contain. The roots take these up, leaving few mineral ions in the soil. As a result, when the forest is cleared for agriculture, crop yields are often poor after the first year and more forest must be cleared. Tropical rainforest is the most productive of natural land ecosystems. The net primary production (biomass produced allowing for losses due to respiration) is 2.2 kg m^{-2} y^{-1}, nearly twice that of temperate forests.

Felling tropical rainforest has far-reaching effects.

- There is a serious reduction in species diversity. Many ecological niches are destroyed when trees are felled and the species that fill these niches are lost. This reduces the biodiversity of the area.
- There is a reduction in the rate at which carbon dioxide is removed from the atmosphere. In addition, if the trees are burned, then carbon dioxide is added to the atmosphere. The local and global cycling of carbon is therefore affected.
- There is a reduction in the amount of nitrogen returned to the soil. The nitrogen fixed in the proteins and other compounds in the massive tree trunks remains fixed in a table in London, New York or Addis Ababa. Any tree trunks not removed from the area are slow to decay and the soil is depleted in nitrate for many years.
- A secondary succession will take place. If the felled area is allowed to regenerate, then seeds of many species of plant from the shrub layer will germinate. Ordinarily, the shrub layer is limited because the canopy prevents much of the light from reaching lower levels. If the shrub layer is allowed to dominate, this could give rise to a less complex ecosystem with a lower biodiversity.

The felling of trees need not be totally destructive and the practice need not be halted. However, the rainforests must be conserved and felling and replanting in a planned cycle over a number of years can do this. This could give a sustainable yield of timber, without endangering the species diversity of the rainforests.

One practice that has been adopted is to fell a strip of forest approximately 20 m wide and take the felled trunks to the sawmill for processing. This strip of land is not touched again for 20 years. In those 20 years, a secondary succession will have produced 'secondary forest' and the 20-year-old trees can be felled. For the intervening 19 years, other strips of forest are felled. Some areas are left completely untouched and act as a seed bank and core area, maintaining all ecological niches for the whole area.

What are the effects of agriculture on biodiversity?

The effects of large-scale agriculture often follow the same pattern. Large areas of land are given over to the production of just one crop plant, such as maize or another cereal. This inevitably brings a reduction in biodiversity for several reasons, including:

DID YOU KNOW?

It is estimated that, currently, 20% of the Amazon rainforest has been felled since 1970. This is expected to rise to 40% by 2025, leaving only 60% of the rainforest that was present in 1970. We're getting through it at an alarming rate!

Figure 2.23 *Strip felling is one form of sustainable felling*

DID YOU KNOW?

When anyone eats a quarter-pounder, they should bear in mind that to make that one burger using South American beef, it took:

- the clearing of 5 m^2 of rainforest (to create the grazing land for the cattle)
- the destruction of 75 kg of living matter, including 20–30 different plant species, up to 100 insect species and dozens of bird, mammal and reptile species.

Figure 2.24 *A quarter-pounder*

- the area is dominated by just one species, drastically reducing the number of niches for other organisms to fill
- organisms that might live there are regarded as pests, as they reduce the crop yield and so they are controlled by the use of pesticides, and
- hedgerows are removed to create bigger and more productive fields; this reduces still further the number of habitats and niches and, therefore, reduces the biodiversity of the area.

Other changes in agricultural practices have also had major effects on biodiversity. Traditionally, crops were 'rotated' so that in a field one year a cereal would be grown, another year perhaps a root crop such as carrots, then in another year a legume such as beans and perhaps one year 'fallow' (just grass, no crop).

The rotation would be carried out with different timings in different fields, so that all crops were always available. This meant that different animals could find different habitats. However, the intensive farming of just one crop year after year, keeping pests at bay with herbicides and pesticides, reduces the habitats available. Such practices have been blamed for the decline and, in some cases, the local extinction of species.

What is the status of biodiversity in Africa?

Figures 2.25A and B show the mammal species richness and plant species richness in Africa, respectively.

You can clearly see that the two are related. Areas that have high plant species richness often also have high mammal species richness – and vice versa. The reason for this is not difficult to work out. We have just been talking about the way in which plants provide habitats and niches for animals. So the more different plants there are, the more different habitats and niches for animals (including mammals) there will be.

There is one important exception. Parts of South Africa have a very high plant species richness, but do not have a correspondingly high mammal species richness. This is the Fynbos of South Africa. Fynbos has one of the highest concentrations of plant species anywhere in the world. But the plants grow on very nutrient-poor soils. So there just isn't the protein in the plants to support a large number of mammals. Some other facts concerning African biodiversity include:

- a quarter (1229 species) of the world's approximately 4700 mammal species occur in Africa, including about 960 species in sub-Saharan Africa (SSA) and 137 species in Madagascar. The eastern and southern savannahs host large populations of mammals, including at least 79 species of antelope
- more than a fifth of the approximately 10 000 bird species in the world are found in Africa; about 1600 bird species are endemic to SSA

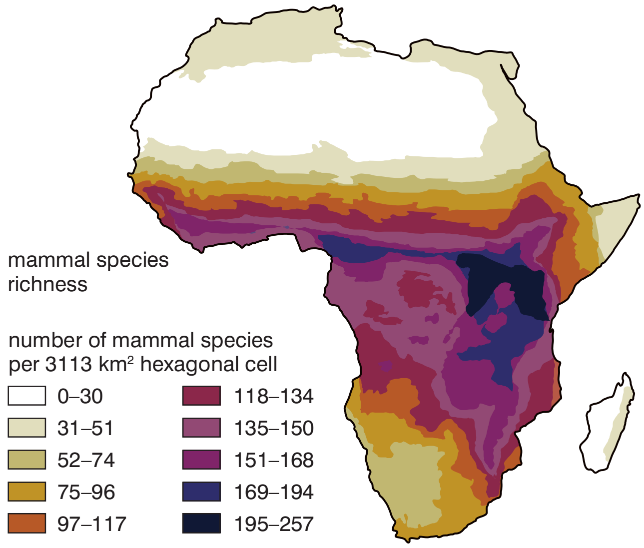


Figure 2.25A *Mammal species richness in Africa*

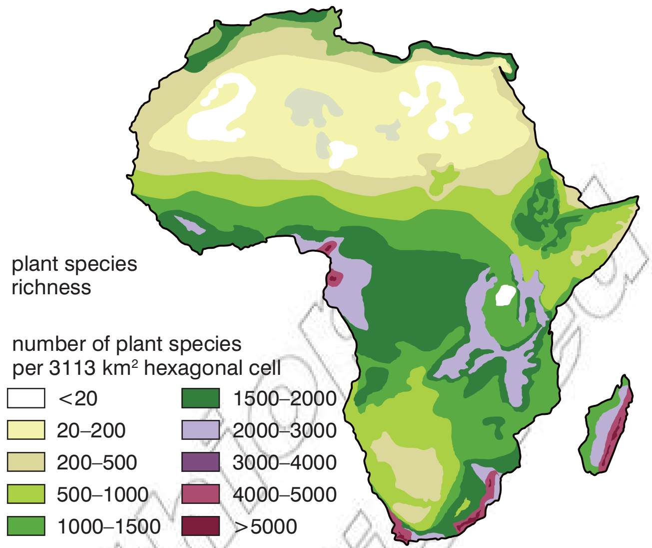


Figure 2.25B *Plant species richness in Africa*

- about 950 species of amphibians are found in Africa, making Africa (together with South America) the continent with the highest number of amphibians.

What about – biodiversity in Ethiopia?

You can see from figures 2.25 A and B that biodiversity in parts of Ethiopia, compared to other African countries, is better than most, although not as high as in some nearby countries, such as Kenya.

Ethiopia is an important regional centre of biological diversity. The wide range in altitude and climate, the isolation of the highlands of Ethiopia, and the fact that there are so many different biomes present in the country, are some of the reasons for its high biodiversity. One estimate suggests that there are between 6500 and 6700 plant species in the country. This represents the fifth most diverse flora in Africa. About 10–12% of these plant species are endemic to Ethiopia (approximately 1150 plant species).

And the story of plant species richness doesn't end with wild plants in Ethiopia. Ethiopia is one of the 12 centres of origin (Vavilov centres) of cultivated crops. There are 11 cultivated crops, which have their centre of genetic diversity in Ethiopia. These are:

- *Coffea arabica* – Coffee
- *Eragrostis tef* – Tef
- *Ensete ventriculum* – Ensete
- *Coccinia abyssinica* – Anchote
- *Guizotia abyssinica* – Niger seed (Nug)
- *Brassica carinata* – Ethiopian rape (Gomenzer)
- *Carthamus tinctures* – Safflower (Suf)
- *Sorghum* Spp. – Sorghum
- *Hordeum* Spp. – Barley

Figure 2.26 *Different varieties of coffee in Ethiopia*

KEY WORD

forage plant *a plant that is grown for animal feed*

- *Linum usitatissimum* – Linseed (Telba)
- *Ricinus communis* – Castor bean (Gulo)

It is the efforts of the farmers of Ethiopia that have generated and maintained the diversity of crop plants in the country.

Ethiopia is also an important centre of genetic diversity of **forage plants**. About 46 legumes are endemic to Ethiopia. They include species of *Trifolium* (clover), *Vigna* (a type of bean) and *Lablab* (all parts of the plant are edible). These plants, used as animal feed, are important because they add nitrogen to the soil in which they grow as they have nitrogen-fixing bacteria living symbiotically in their roots.

The high species richness creates many diverse ecological zones with many ecological niches for animals to fill. Every group of vertebrate animals is well represented in Ethiopia as table 2.4 illustrates.

Table 2.4 *A summary of the vertebrate biodiversity of Ethiopia*

Vertebrate group	Number of orders	Number of families	Number of genera	Number of species	Endemic to Ethiopia
Mammals	12	40	144	277	22
Birds	24	87	306	861	27
Reptiles	4	15	36	78	3
Amphibians	5	7	19	63	17
Fish	5	14	33	101	4

KEY WORDS

species *a group of organisms that can interbreed to produce viable and fertile offspring*

genus *a group of closely related species (e.g. the genus* Felis *contains all species of small cats)*

family *a group of related genera (e.g., the family Felidae contains all cat-like animals, large and small)*

order *a group of genera that may differ but share some important attribute (e.g., the order Carnivora contains all carnivorous mammals, including the various cat-like mammals and dog-like mammals)*

endemic *an organism that is endemic to an area is always present and numerous in that area*

There are other estimates of the numbers of orders/families/genera and species that differ slightly from that given in table 2.4.

In terms of the biodiversity of its avifauna (birds), Ethiopia is one of the most significant countries in mainland Africa. Again, Ethiopia's diverse ecology contributes to the tremendously diverse bird life. Over 861 species are found in Ethiopia. At present, 69 Important Bird Areas (which are also important for large numbers of other groups of animals) are identified by the Ethiopian Wildlife & Natural History Society (EWNHS). These include already existing protected areas and many other additional sites.

Such protection is necessary as the diverse bird life of Ethiopia is threatened, along with the overall biodiversity of the country as a result of a number of practices. Some of the effects of these practices have been direct, others have been indirect.

Practices with direct effects on biodiversity:

- deforestation – conversion of forests, woodlands and savannas to agricultural lands (for cultivation and grazing) and other land-use systems reduce the area available to native species
- fuelwood collection and illegal logging
- overgrazing by stock animals – reduces the availability of forage and woody plant species for other animals
- introduction of improved crop varieties – reduce the genetic

diversity of the particular crop plant as only the ‘improved’ variety is used

- overhunting (poaching) – directly reduces the numbers of the species hunted
- introduction of alien invasive species – these often outcompete native species for the available resources, sometimes making native species locally extinct

Practices with indirect effects on biodiversity:

- high population growth – the more people there are, the bigger the demand for resources of all kinds, which puts pressure on land to be used for supporting humans, rather than other species
- undervaluation of the biodiversity resources – if biodiversity is not seen as important at all levels of government, then attempts to maintain biodiversity will not receive a high enough priority, this results in a lack of incentives for communities to conserve their local biodiversity
- legal and institutional systems that promote unsustainable exploitation – this results in big companies being able to make big profits from exploiting Ethiopian resources in a non-sustainable way; the resources won’t be there in the future as a result of these practices
- disregard of traditional communal (range) land management systems – traditional methods of land management conserved the species present and used them to support the community; these are at risk as more communities are encouraged to use more high-yielding, intensive practices

It is all too easy to paint a picture of doom and gloom with no hope on the horizon. But this would not be accurate. The Ethiopian government has been party to a number of initiatives relating to biodiversity. The eastern tropical montane forests of Ethiopia have been recognised as a hotspot for biodiversity conservation because of the exceptionally high concentration of endemic species and habitat loss. In 2005, the Ethiopian Insititute of Biodiversity Conservation in Addis Ababa put forward a National Biodiversity Action Plan. This is a significant document running to 115 pages, which reviews the current situation and makes numerous recommendations. Some of these recommendations are listed below in two categories – those based on ecological considerations and those based on socioeconomic considerations.

Ecological considerations

- Accelerate recovery by enrichment planting of target species in degraded remnant forests.
- Establish corridors to enhance the biodiversity and eventually the viability of fragmented forests, particularly in the central and northern highlands.

DID YOU KNOW?

- About 87% of the highlands were once covered by forest, this was reduced to 40% by 1950 and 5.6% by 1980; more recent estimates suggest that there is now just 3% covered by forest.
- There have been local extinctions of several species as a result.
- The viability of fragmented, small populations of the forests remaining is questionable.

- Establishment of buffer zones (through tree planting) to stop further degradation of isolated forest fragments.
- Planting native woody species may be necessary on sites lacking of vegetation (for example, steep slopes).
- Establishment of tree plantations, which can serve as nurse crops, on highly degraded sites.
- Establishing area enclosures may be necessary to enhance natural regeneration and diversity of the native flora, particularly in arid and semi-arid regions.
- Control or eradicate (where possible) alien invasive species using integrated pest management.

Activity 2.7: What should Ethiopia do?

Consider each of the recommendations in the 'socioeconomic considerations' section. Write a short paragraph explaining how each of these might address some of the issues listed in the 'practices that affect biodiversity' section.

Socioeconomic considerations

- Allow meaningful participation by all stakeholders (people who have any interest in a particular course of action), including in decision making and implementation.
- Consider local socioeconomic needs in choices of approaches and options in matters impacting on local biodiversity.
- Strengthen local organisations.
- Make land and tree tenure completely secure.
- Formulate policies that promote sustainable utilisation and conservation of biodiversity.

Why is biodiversity loss a concern?

In the years leading up to the millennium (2000) a global assessment of many aspects of biodiversity was made. It was called the Millennium Assessment (MA). The MA findings suggest that biodiversity loss contributes to:

- worsening health
- increasing insecurity of food supply
- increasing vulnerability
- lower material wealth
- worsening social relations
- less freedom for choice and action

Food security

Biological diversity (the availability of many food sources) is used by many rural communities directly as an insurance and coping mechanism to increase flexibility and spread or reduce risk in the face of increasing uncertainty, shocks and surprises in the food supply. In a world where fluctuating commodity prices are more the norm than the exception, economic entitlements of the poor are increasingly becoming precarious. The availability of this food security net provides an important insurance program. Coping mechanisms based on indigenous plants are particularly important for the most vulnerable people, who have little access to formal employment opportunities.

Increasing vulnerability

Biodiversity can help with physical protection. Mangrove forests and coral reefs – a rich source of biodiversity – are excellent natural buffers against floods and storms. Their loss or reduction in coverage has increased the severity of flooding on coastal communities.

A common finding from the various assessments was that many people living in rural areas cherish ecosystem variability and diversity as a way of not being caught out by ecological shocks and surprises.

Health

An important component of health is a varied and balanced diet. Thousands of species of plants and several hundred species of animals have been used for human food at one time or another. Some indigenous and traditional communities currently consume 200 or more species. Wild sources of food remain particularly important for the poor and landless to provide a balanced diet. Overexploitation of marine fisheries worldwide, and of bushmeat in many areas of the tropics, has led to a reduction in the availability of wild-caught animal protein, with obvious consequences in many countries for human health.

Social relations

Many cultures attach spiritual and religious values to ecosystems or their components such as a tree, hill, river or grove. Thus loss or damage to these components can harm social relations – for example, by impeding religious and social ceremonies that normally bind people. Damage to ecosystems, highly valued for their aesthetic, recreational or spiritual values, can damage social relations, both by reducing the bonding value of shared experience as well as by causing resentment towards groups that profit from their damage.

Freedom of choice and action

Freedom of choice and action within the MA context refers to individuals having control over what happens and being able to achieve what they value. Loss of biodiversity often means a loss of choices. For example, local fishers may depend on mangroves as breeding grounds for local fish populations. Loss of mangroves therefore leads to a loss in control over the local fish stock and a livelihood they may have been pursuing for many generations and one that they value. They may be forced into something else. Another example is high-diversity agricultural systems. These systems normally produce less cash than monoculture cash crops, but farmers have some control over their entitlements because

Activity 2.8

In areas of biodiversity you will find lots of living organisms which are interdependent in a food web. EITHER chose a local environment which has a lot of biodiversity OR research a rich environment. Draw out a food web (like the one in fig 2.30) showing as many organisms as possible from your chosen environment.

of spreading risk through diversity. The loss of biodiversity is sometimes irreversible, and the value placed on keeping biodiversity for future generations can be significant. The notion of having choices available is an essential constituent of the freedom of choice aspect of well-being.

These benefits that humans gain from biodiversity are collectively known as ecosystem services. A loss of biodiversity will reduce ecosystem benefits locally and globally.

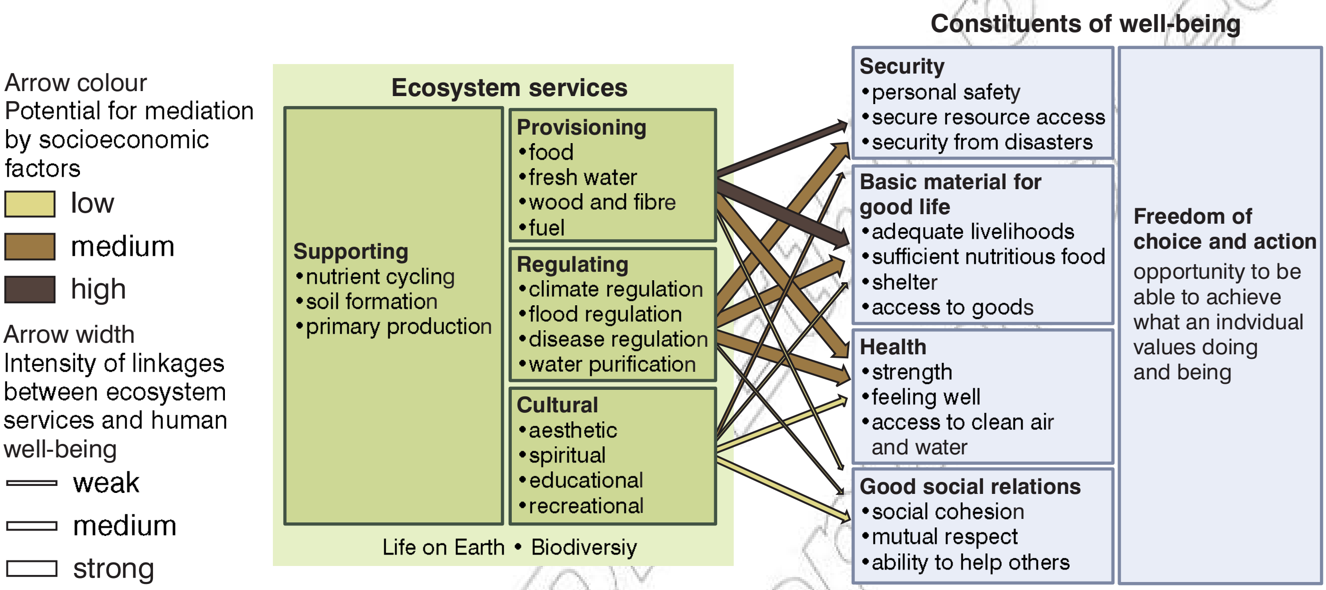


Figure 2.27 *Ecosystem services and human well-being*

In addition to reduction in the ecosystem services described above, and summarised in figure 2.27, there are other dangers that result from the loss of biodiversity. The list is huge, but here are some examples:

- continued felling of forests in some countries leads to increased flooding
- many medicines have been derived from plants; the oldest painkiller – aspirin – is derived from the willow tree – how many more are waiting to be discovered in plants we have not yet even named?
- the same holds true for animals; some sheep from South America produce anti-cancer drugs – again what other aids could there be in the millions of insects yet to be discovered?

Finally, we discussed biodiversity in the context of species diversity at the start of this section. If the number of species continues to be reduced, then this will ultimately lead to less complex ecosystems. Less complex ecosystems are less stable and more prone to 'collapse'. Ecosystems will function less well if there are fewer species making them up.

What can we do about it?

Is there still time? Can I have any effect at all? To answer that, you must understand the cost of doing nothing.

Figure 2.28 shows that, if we do nothing, and allow species extinctions to continue at the present rate, then there will be a serious reduction in biodiversity by 2050.

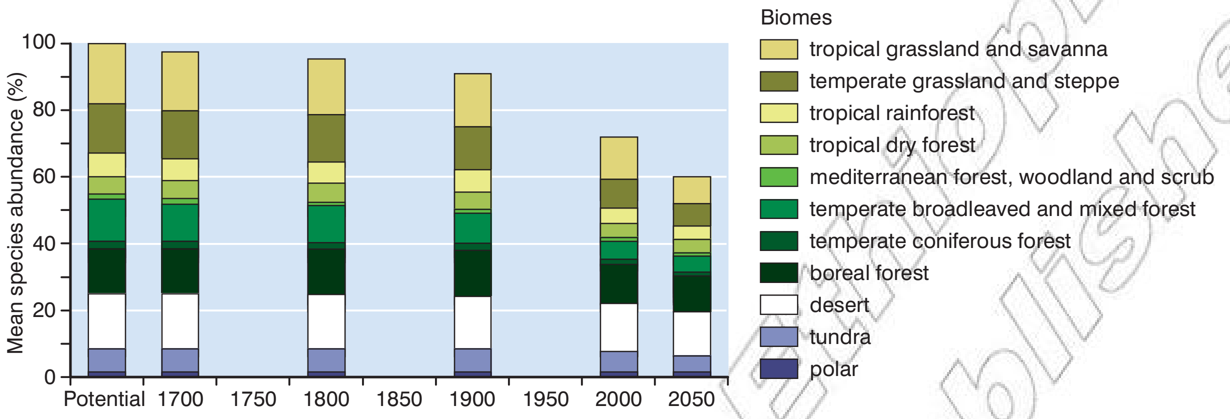


Figure 2.28 *The future of our biodiversity*

When you look at any particular biome, there doesn't seem to be any huge projected change, and so it is easy to believe that we can just continue to do nothing. But look at the overall trend. Our biodiversity has fallen from 90% of its potential in 1900, to 70% in 2000 and it is projected to fall to 60% by 2050 and, carrying on the projection, to 50% by 2100, with most of this biodiversity in areas such as desert and tundra that are difficult to exploit. We are losing 10% of our biodiversity every 50 years. To help visualise this, if this loss of biodiversity were concentrated in just one place, it would represent an area just larger than all of the USA. And this is assuming that things don't get any worse – just that we continue to lose our biodiversity at the same alarming rate that we are losing it now. However, there is considerable evidence to suggest that the rate of species loss (and therefore loss of biodiversity) will actually increase in the future, as figure 2.29 shows.

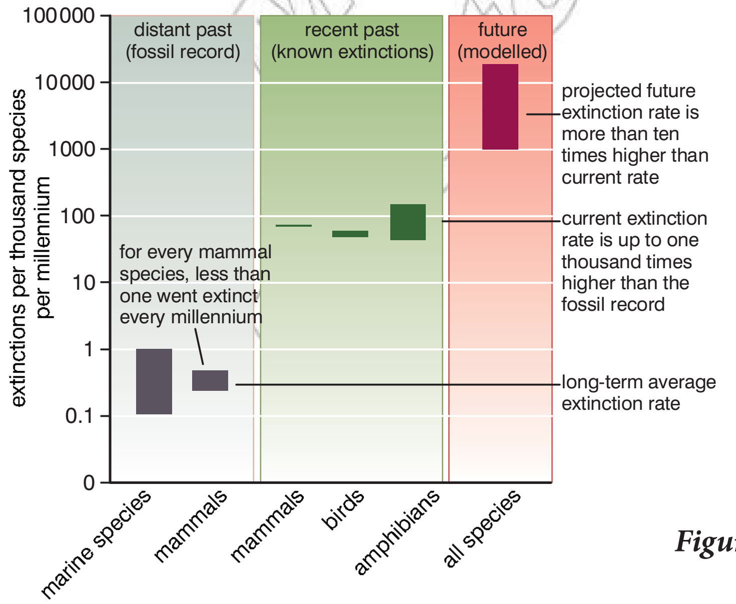


Figure 2.29 *Past, present and future extinction rates*

KEY WORD

conservation *the measures taken by people to preserve or restore an ecosystem*

We cannot allow this to continue. We must **conserve** our biodiversity for future generations and appreciate that we have a duty of care to do so. Every future generation of humans has the right to enjoy and make use of the biological resources of the planet that are available to us today. This is the core principle of conservation. Conservation does not preach that we should not make use of the biological resources available, in fact it encourages us to make use of as many as possible. However, conservation demands that we use the resources in a sustainable manner so that future generations may do the same. Action is needed at individual, local, national and international levels to achieve this.

There are three guiding ideas of conservation:

- research – we must know what we are doing
- minimum intervention – the balances within and between ecosystems are delicate and can easily be upset, and
- repair rather than replace – it is always better to try to help an ecosystem to repair any damage rather than try to replace it.

The ecological principles that form the basis of conservation of biodiversity are:

- any protection of species and varieties of species will support biodiversity
- maintaining habitats is fundamental to conserving species
- large areas usually contain more species than smaller areas with similar habitats
- disturbances to habitats shape the characteristics of populations, communities and ecosystems, and
- climate change will increasingly influence all types of ecosystems.

Activity 2.9

Identify an area near your school or home where the environment has become damaged or polluted. Plan how your community could clear up the area to allow as much biodiversity as possible to return. Think carefully about what needs to be removed, what can be left, how to protect the area as it recovers and how to prevent the same problems happening again.

The key to maintaining biodiversity will be to maintain habitats. If we can maintain habitats, the organisms will continue to visit them and live there. This will become increasingly difficult because of climate change, but, where possible, we should not allow existing habitats to become eroded and, if at all possible, should extend them.

To help conserve our biodiversity, we should also use our resources in a sustainable way. This means that we must not continue to:

- overfish the oceans; we must take only an agreed quota each year – but the types of fish eaten must become more diverse to provide the sheer tonnage demanded
- fell rainforest in the current manner; it must be felled sustainably, by strip-felling, for example
- reduce the genetic diversity of stock animals and crop plants by breeding only those that produce certain desired traits (lean meat, high milk yield, high grain yield)
- grow vast areas of cereals in monoculture

The above are examples only. You should try to think of other areas of our actions that need modification.

What can I do for Ethiopia?

You can plant a tree. Now. Not next year – now. If you plant a tree now, and ensure that it grows, then in 20 years time there will be a mature plant that provides a habitat for a whole range of other organisms. You will see birds feeding and maybe nesting in your tree – but that is the very least of the increase in biodiversity that you will have encouraged. A complex **food web** in the soil will begin to develop because you planted the tree.

If you don't really believe the extent of it – give your tree a couple of years, and then carefully examine some of the soil from around it. You'll be amazed at what you find.

KEY WORD

food web *an interconnected collection of food chains*

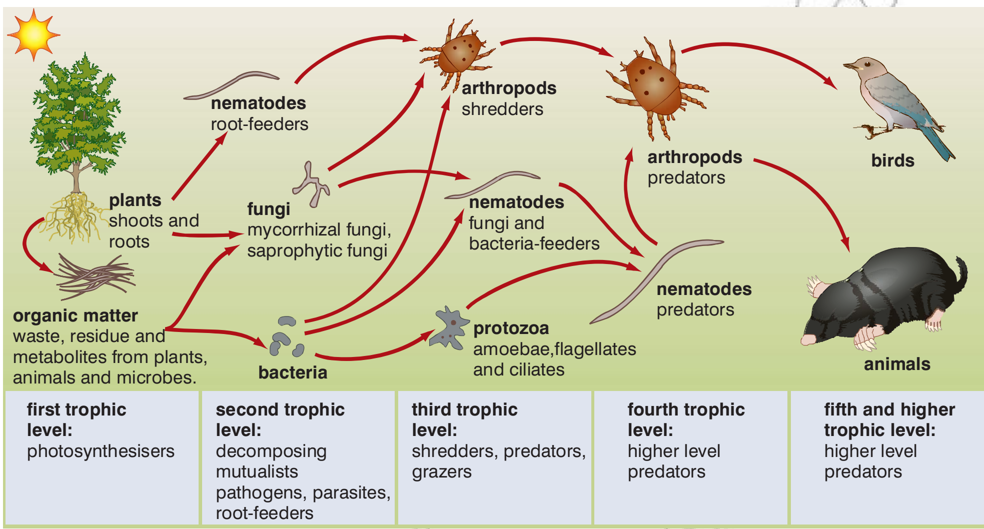


Figure 2.30 *The soil food web.*

If you want to do more, several of you could plant a little 'copse', but make sure that you do not plant the trees too closely together – they have to grow. If you were all to plant a tree a year, then in 20

Figure 2.31 *Professor Legesse Negash, seen here planting a keystone indigenous tree, species* Ficus vasta Forssk, *at his Center for Indigenous Trees Propagation and Biodiversity Development in Ethiopia.*

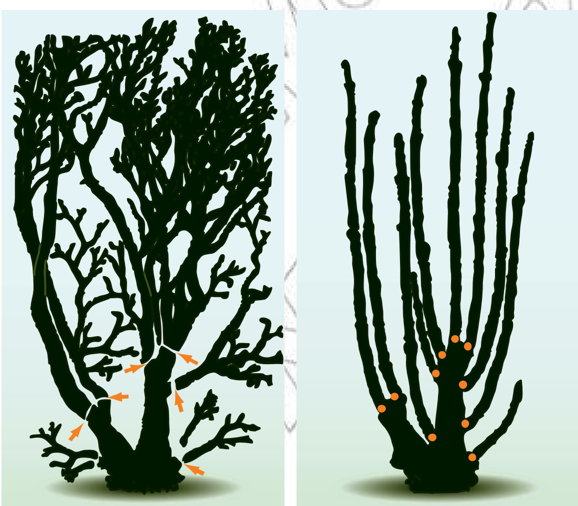


Figure 2.32 *Coppicing trees for timber*

years, you would have the makings of a sustainable woodland that could be coppiced every year for timber. Coppicing involves cutting back the shoots of the plant to about 10–15 cm above ground and allowing the stump to regrow. If you have this in mind, you must research which local trees are best for coppicing.

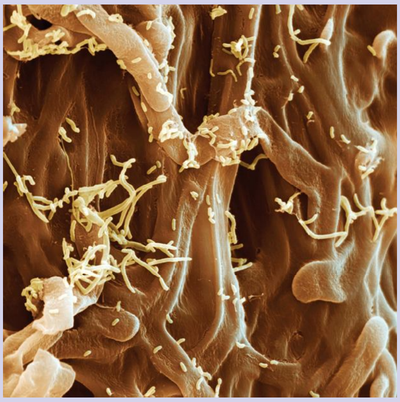


Figure 2.33 *A young tree seedling with an already extensive mycorrhizal network.*

DID YOU KNOW?

Mycorrhizae are symbiotic associations that form between the roots of most plant species and fungi. Organic molecules like sugars and amino acids pass to the fungus and inorganic nutrients move to the plant, thereby providing a critical linkage between the plant root and soil. The hyphae (threads) of the fungi grow around the root, greatly extending the area available for nutrient uptake, with some hyphae penetrating the root and, in some cases, individual cells. In infertile soils, nutrients taken up by the mycorrhizal fungi can lead to improved plant growth and reproduction. As a result, mycorrhizal plants are often better able to tolerate environmental stresses than are non-mycorrhizal plants.

Activity 2.10: What can I do for Ethiopia?

You can organise a small group of friends to plant trees in your locality and see that they are regularly looked after until they are established. This will involve:

- regular watering
- checking for pest damage
- feeding the young trees (organic fertilizers are best) regularly

Review questions

Choose the correct answer from A to D.

1. Increasing biodiversity could include increasing:
   - A species richness
   - B genetic variability
   - C ecological variability
   - D all of the above
2. Environmental change is likely to have most impact on:
   - A pioneer stages of successions because they have complex ecosystems
   - B climax stages of successions because they have complex ecosystems
   - C climax stages of successions because they have simple ecosystems
   - D pioneer stages of successions because they have simple ecosystems

3. A loss of biodiversity may affect well-being of rural communities in which of the following ways? It may:
   A reduce food security
   B reduce freedom of choice
   C reduce physical protection
   D all of the above
4. What percentage of our potential biodiversity is being lost every 50 years, at current rates?
   A 5%
   B 7%
   C 10%
   D 20%
5. Planting trees now could help conserve biodiversity in which of the following ways? It could:
   A encourage the development of a soil ecosystem in the area
   B encourage birds to feed and nest
   C reduce timber taken from wild sources in the future
   D all of the above
6. The high species richness of plants and mammals in Ethiopia is due largely to:
   A the lack of disturbance
   B the presence of several different biomes within the country
   C efficient ecological management
   D lack of predators
7. The key to conserving biodiversity is:
   A using hardly any of the current biodiversity
   B replacing any of the animals or plants we use
   C maintaining habitats where at all possible
   D using only specially bred stock animals and crop plants
8. Using a wide variety of food sources is beneficial to rural communities and the practice should be encouraged because:
   A it is more likely to provide a balanced diet than using only a few
   B it reduces the overall impact on each food species
   C it is less likely to lead to shortages in food supply than depending on just a few sources
   D all of the above

9. When compared to present rates of extinction, future rates are predicted to be:
   A the same
   B one-tenth as great
   C ten times as great
   D none of the above
10. Continued felling of forest can:
   A reduce the biodiversity of an area
   B increase the amount of flooding in an area
   C allow erosion of the soil
   D all of the above

2.5 Populations

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

- Compare and contrast arithmetic and exponential growth.
- Compare intra-specific and inter-specific competition.
- Describe and explain the factors that influence the rate of population growth, including natality (birth rate) and mortality (death rate).
- Interpret a population growth rate curve.
- Define the term carrying capacity and appreciate the importance of the concept.
- Describe and explain the impact of rapid population growth on development.
- Describe measures that could and should be undertaken to control population growth.

What is a population?

It's a much-used word – we talk of the world population, the population of Ethiopia, the population of Addis Ababa and so on. How can we use the same word in all these different contexts?

When biologists speak of a population, they have a specific meaning in mind.

A population is all the individuals of a particular species in a particular habitat at a particular time.

Populations are not static. Like ecosystems they are constantly changing. The cheetah population of Africa was once that – one extensive population. It suffered a 'population crash' about 10 000 years ago and is now effectively fragmented into several smaller populations (the high-density regions in figure 2.34). Cheetahs live in open grassland or savannah (their **habitat**) within a large **geographical range**.

And like ecosystems, the populations that are there now have not been there all the time. Remember the idea of succession? As the environment is modified (abiotic factors change) by plants present in an area, new species of plants colonise the area, establish themselves and outcompete the organisms that were there before and brought about the change.

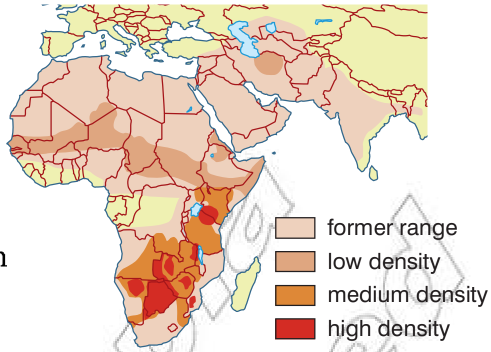


Figure 2.34 *The changing cheetah population.*

How can several populations live in the same area?

In a pond, there are populations of many different organisms. They are able to live in the same area because each exploits a different habitat in that area. For example:

- plankton exploit the open water regions of the pond
- decomposers inhabit the detritus found at the bottom of the pond
- snails browse the surface of the sediment at the bottom of the pond and graze small organisms

A habitat is an area where a population lives and finds the nutrients, water, living space and other essential resources it needs to survive.

Sometimes, different organisms can share the same habitat. However, they make different demands on that habitat. This combination of habitat and the demands made is called the ecological niche.

The ecological niche of an organism describes its role within a habitat.

For example, both floating plants and tadpoles are found in the open water habitat. But the plants use sunlight, carbon dioxide, water and minerals from the water, whereas the tadpoles feed on the larvae of insects. They have different ecological niches.

In another example, both blue tits and great tits spend much of their time foraging in trees for insects and insect larvae. When one or the other species is present, they forage at about the same height. However, if both species are present in the same trees, they forage at different heights and so avoid competing for the same niche.

DID YOU KNOW?

Research shows that two species cannot normally occupy the same niche. If two species are present initially, they will compete for the same available resources in the niche. One will be more successful and the other will be made locally extinct. This is called the **competitive exclusion principle**.

KEY WORDS

habitat *the part of an ecosystem where members of a particular species live*

geographical range *the part of the Earth's surface where members of a particular species live*

What factors influence the sizes of populations?

As we have said, a population is all the individuals of a certain species in a certain habitat at a certain time. Anything which influences these numbers clearly affects the size of the population. There are three factors that directly affect numbers:

- natality – birth rate
- mortality – death rate
- migration – movement into (immigration) and out of (emigration) the area

Activity 2.11

In ideal conditions populations simply grow. For example, bacteria reproduce by splitting in two. If they have everything they need, they can reproduce every 20 minutes. Calculate the number of bacteria there will be in 24 hours. However bacteria do not continue to grow at their optimum rate, otherwise they would take over the world. What factors do you think would stop them growing and eventually cause the death of the population?

Natality and mortality are clearly linked in their influences:

- if natality exceeds mortality (more are born than die), the population numbers will increase
- if mortality exceeds natality (more die than are born), the population numbers will decrease
- if mortality and natality are equal, the population numbers will remain the same

In a similar way, emigration and immigration are linked in their influences:

- if immigration exceeds emigration (more enter than leave), the population numbers will increase
- if emigration exceeds immigration (more leave than enter), the population numbers will decrease
- if emigration and immigration are equal, the population numbers will remain the same

Other factors influence mortality and natality. They influence how quickly a population increases in size or decreases in size. These factors can be divided into two main categories:

- **biotic factors** – the effects of other organisms of the same species or of a different species
- **abiotic factors** – the effects of factors in the physical environment (light, temperature, carbon dioxide concentration, oxygen concentration, physical space, etc.)

Biotic factors

Some of the main biotic factors are:

- **predation** – the presence of a carnivore (predator) or herbivore, in the case of plants
- **disease** – infection by micro-organisms can reduce productivity and may be fatal
- **intra-specific competition** – competition between members of the same species
- **inter-specific competition** – competition between members of different species.

The ways in which biotic factors can affect population growth are summarised in table 2.5.

Intra-specific competition

Intra-specific competition is the competition between members of the same species for some resource (often food) in the same habitat. In one example, gypsy moth caterpillars infested much of southern New England (on the west coast of the USA) in the summer of 1980.

Table 2.5 The ways in which biotic factors can affect population growth

Biotic factor	How it affects population size
Predation	The presence of a predator (or herbivore in the case of plants) will effectively increase mortality and reduce the numbers in a population.
Disease-causing organisms	If disease is widespread, then mortality will be increased and population growth will be slowed.
Intra-specific competition	Competition between members of the same species can operate in two main ways: • reducing the resources to all of the population can reduce their fertility and so reduce population growth, and • reducing the resources to just some of the population (as others compete more effectively) means that they die whilst the others reproduce, but population growth is still reduced.
Inter-specific competition	Although the competitive exclusion principle states that two species cannot occupy the same niche, this is not absolute. The following can happen in appropriate circumstances: • one of the two species outcompetes the other, which may die out • both species suffer a reduction as they are nearly equal in their ability to 'harvest' the resource and the effects of intra-specific competition for a reduced resource also come into play, or • the species are able to coexist.

However, the density of this initial infestation was quite low, allowing most of the caterpillars to metamorphose into adults. The adults mated and laid masses of eggs (each mass containing several hundred eggs) on nearly every tree in the region. In the following spring, all the eggs hatched and the caterpillars began feeding. As they fed and grew, they stripped all the trees of their leaves.

The millions of caterpillars were soon competing for a very limited resource – any remaining leaves! As a result, their population crashed and very few caterpillars were able to metamorphose into adults.

Intra-specific competition is a major factor in controlling the populations of predators. In a typical predator–prey relationship when the population of prey begins to fall, there is intra-specific competition between the predators for the remaining prey, leading to a population decline. This allows the numbers of the prey to recover.

There can also be intra-specific competition between plants. In one experiment, different numbers of sunflower seeds were planted in the same sized pots. The number of live plants per pot and the mean plant height are shown in Tables 2.6A and 2.6B on the next page.

With increased numbers planted, there is increased intra-specific competition between the germinating seedlings, resulting in fewer, smaller plants surviving. This has applications in agriculture with packets of seeds of crop plants being supplied with recommended sowing densities to give maximum yields.

Figure 2.35 *Gypsy moth caterpillar feeding on a leaf*

Table 2.6A Number of live plants

Time/days	Number of seeds per pot				
	2	4	8	16	32
7	2	3	6	11	24
14	2	3	6	11	24
21	2	3	4	10	22
28	2	3	3	8	20
35	2	3	3	7	17

Table 2.6B Mean height of plants per pot/cm

Time/days	Number of seeds per pot				
	2	4	8	16	32
7	8.5	7.5	6.1	5.2	4.8
14	9.3	8.3	7.2	5.9	5.3
21	18.9	16.2	11.4	9.6	7.3
28	20.2	18.6	14.6	13.4	11.3
35	27.4	22.5	17.4	16.3	15.2

Activity 2.12: Verifying the results

You can easily conduct this experiment yourself. All you need is:

- Five plant pots or similar containers (yoghurt cartons make a good substitute) with a top diameter of about 10 cm
- Soil or compost
- Small cereal seeds, such as barley or wheat

Carry out the following:

- Fill each container with the same amount of soil/compost.
- Plant different numbers of seeds the same depth (max. 1 cm) in each container, as below:
  - pot 1 – 2 seeds per pot
  - pot 2 – 4 seeds per pot
  - pot 3 – 8 seeds per pot
  - pot 4 – 16 seeds per pot
  - pot 5 – 32 seeds per pot

  Space the seeds as evenly as you can in the pots.
- Add the same amount of water (about 100 cm^3) to each.

Record:

- The number of live plants per pot, and
- The average height of the live plants in each pot every seven days for 35 days.

Inter-specific competition

This occurs when two different species compete for the same resource in the same habitat. Although most organisms have their own ecological niche, there is very often some overlap between the niches of two species. Barnacles are a kind of crustacean that live on rocky shores. *Chthalamus* and *Balanus* are different species of barnacle. *Chthalamus* can live anywhere in the intertidal zone (between high tide and low tide). *Balanus* cannot live in the upper

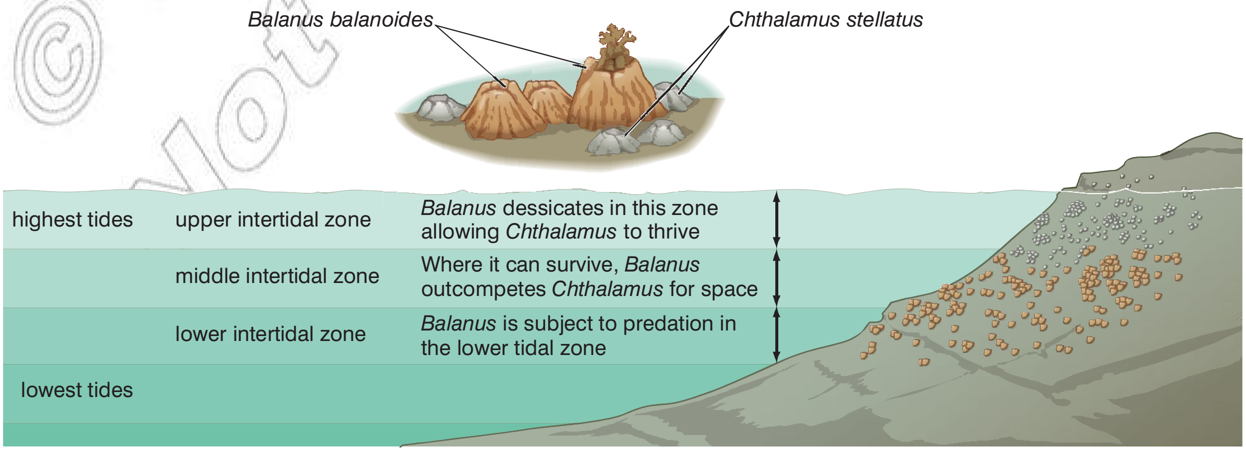


Figure 2.36 Inter-specific competition between two species of barnacles – Balanus *and* Chthalamus

intertidal zone (nearest the high tide region) as in this region it desiccates because it is out of water for too long. However, in the other regions, it outcompetes *Balanus* for the available resources, particularly space. This is summarised in figure 2.36.

On beaches where *Balanus* is absent, *Chthalamus* occupies all three zones.

Inter-specific competition also occurs in some areas of Ethiopia between the Ethiopian wolf and domestic dogs. In these areas both animals hunt rats and so compete with each other.

DID YOU KNOW?

About a famous investigation into inter-specific competition in *Paramecium*

In 1934 G F Gause grew two different species of *Paramecium* (a unicellular organism) in a culture medium of oatmeal and yeast. Initially, he grew each species in isolation and monitored the population densities. Then, he grew the species together and, again, monitored the population densities. His results are shown in the graphs in Figure 2.37.

Gause concluded that if the two species utilise the same resource in the same way, then one will totally outcompete the other, which will become locally extinct.

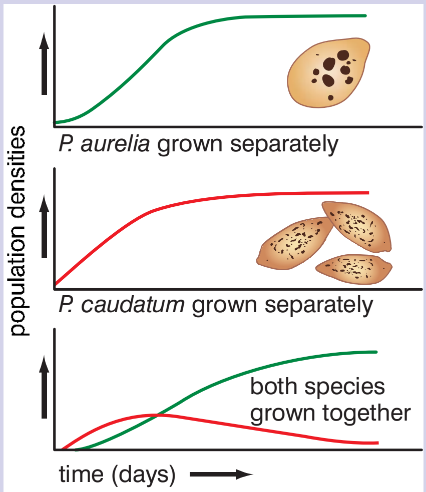


Figure 2.37 *Results from Gause's experiments*

How do populations grow?

All populations show the same pattern of growth. After an initial 'establishing' phase, they show what is called exponential growth, until they are limited by the environment. The difference between exponential and arithmetic growth is illustrated in table 2.7. In arithmetic growth, the numbers increase by the same fixed amount in each time period. This produces a uniform rate of growth over the time period. In exponential growth, the population doubles in each time period, producing an ever-increasing growth rate that is clearly not sustainable in nature.

Table 2.7 *Arithmetic and exponential growth*

Time period	Numbers in population	
	Arithmetic growth	Exponential growth
0	10	10
1	15	20
2	20	40
3	25	80
4	30	160
5	35	320
6	40	640
7	45	1280
8	50	2560

Figure 2.38 shows populations increasing with:

- a slow rate of exponential growth (orange line)
- a fast rate of exponential growth (green line)
- arithmetic growth (red line)

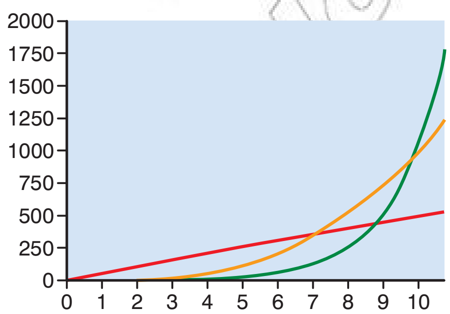


Figure 2.38 *Different rates of exponential growth and arithmetic growth compared*

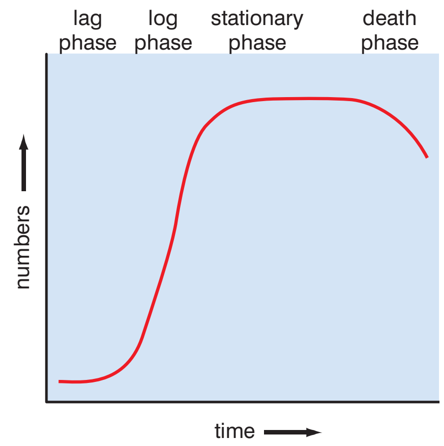


Figure 2.39 The main phases in a population growth curve

As a result of the combined influence of some or all of the biotic and abiotic factors described above, most populations develop through four main stages, illustrated in figure 2.39. The four phases are also described in table 2.8.

***Table 2.8** The main phases of the growth curve*

Phase	What is happening	Effect on population size
Lag	Population establishing itself; some organisms are not adapted to the environment and die, others reproduce.	Numbers remain low and static or increase slowly.
Log	All are adapted and reproduce rapidly due to plentiful resources.	Numbers increase rapidly.
Stationary	The carrying capacity is reached; the same numbers are dying as are produced in reproduction.	Numbers remain fairly constant; they fluctuate about a 'mean' level.
Decline	Nutrients exhausted, a new disease strikes or toxic excretory products accumulate.	Numbers decline rapidly.

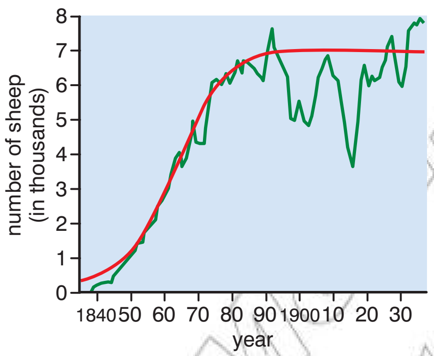


Figure 2.40 The growth curve of a sheep population in Australia

The curve shown in figure 2.40 is an idealised curve and not many populations actually grow exactly in that manner. Figure 2.40 shows an actual population growth curve for a population of sheep over a period of 30 years. The first two phases match the 'idealised' curve fairly closely, but the stationary phase is anything but stationary. It fluctuates quite widely from the idealised curve. Why is this?

To understand, we need to consider an idea mentioned in table 2.8 – that of 'carrying capacity'. The carrying capacity of a population is the number that the environment is capable of supporting (or 'carrying') at that time. This can change from year to year. In this case, if there is a year with lots of sunshine and rain to encourage growth of grass, the sheep may well be able to obtain more food and produce more lambs than they normally would. But then the increased population would need to be supported in subsequent years. And if environmental conditions deteriorated for a few years, the population could not be sustained and would fall.

What about human populations?

Figure 2.41 shows the change in the human population over the past 500 000 years.

We have come from a population of less than 5 million 10 000 years ago to a population of 6 800 000 000 (6.8 billion) at the end of 2009. The population has been increasing particularly quickly over the

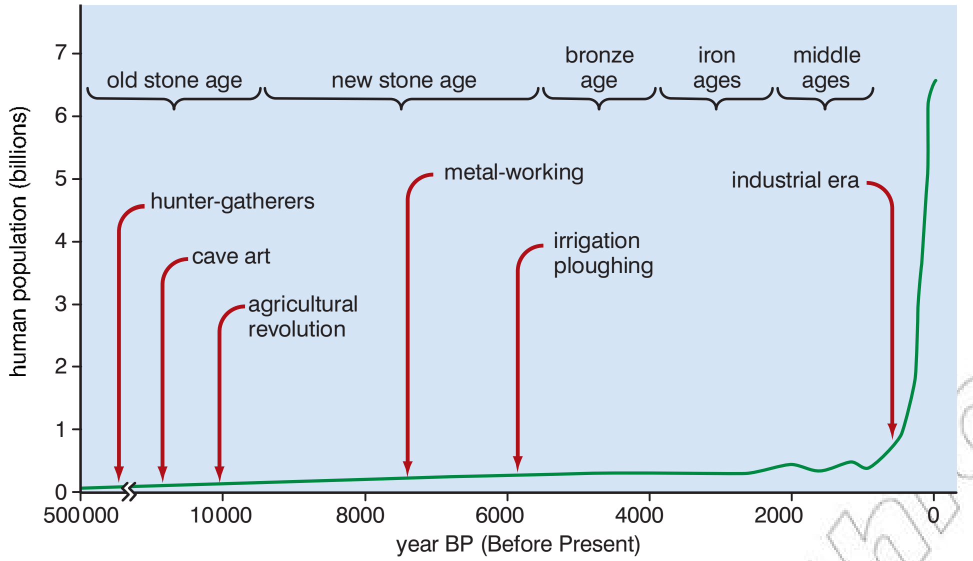


Figure 2.41 *The human population from 500 000 years ago to the present time*

past two hundred years, because we have (generally) increased the quality and quantity of food available and we have decreased the impact of disease-causing organisms with improved sanitation and medical care. However, there can be no doubt that the human population has increased far too much and far too quickly. In countries with the highest population growth rates, the high growth rate is one factor in preventing or slowing development. The sheer weight of numbers makes it much more difficult to implement education programmes, health programmes, proper sanitation and all similar measures.

However, looking carefully at figure 2.42 shows that the rate of population growth is slowing. This should result in the numbers levelling at around 12 billion by the year 2200. This may sound like good news, but set this alongside the fact that estimates of the carrying capacity of the Earth for humans average at around 10 billion. There will still be too many of us.

The human population is subject to the same checks as other populations; the various biotic and abiotic factors still influence population size. However, the human population is subject to other factors affecting its development. These include the point at which the particular country or region develops agriculture and industrialisation. This affects growth rates, death rates and life expectancy.

These changes are called the **demographic transition** and the stages of the demographic transition are shown in figure 2.43 overleaf.

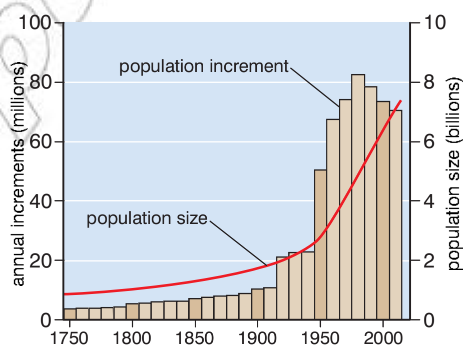
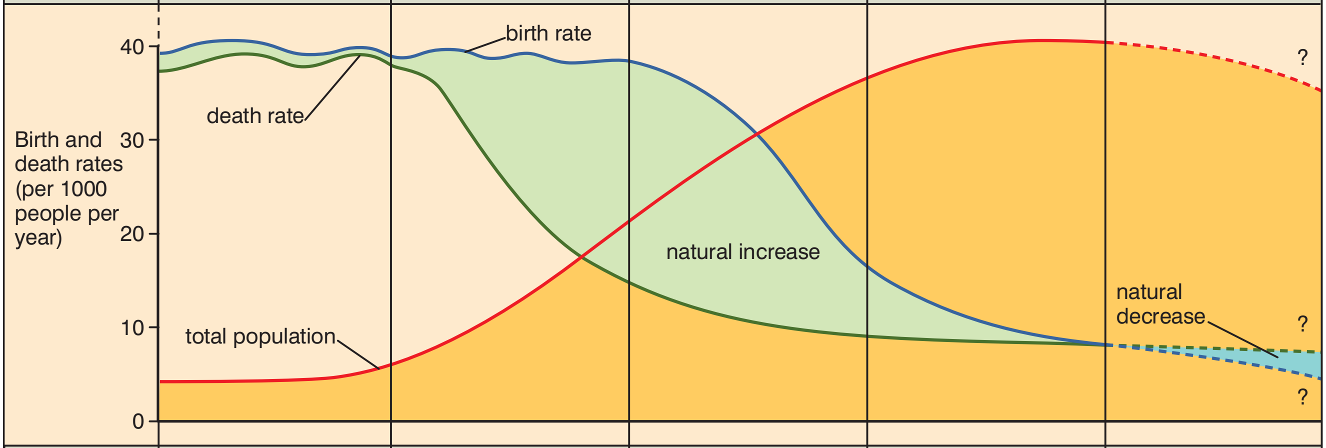


Figure 2.42 *The annual increase in the human population*

KEY WORD

demographic transition
a model that seeks to explain the transformation of countries from having high birth and death rates to low birth and death rates

Stage	1 pre-industrial	2 mechanisation of agriculture/urbanisation	3 mature industrial age	4 post-industrial age	5 post-industrial age



Examples	a few remote groups	Egypt, Kenya, India	Brazil	USA, Japan, France, UK	Germany
Birth rate	high	high	falling	low	very low
Death rate	high	falls rapidly	falls more slowly	low	low
Natural increase	stable or slow increase	very rapid increase	increase slows down	stable or slow increase	slow increase
Reasons for changes in birth rate	Many children needed for farming. Many children die at an early age. Religious/social encouragement. No family planning.		Improved medical care and diet. Fewer children needed.	Family planning. Good health improving status of women. Later marriages.	
Reasons for changes in death rate	Disease, famine, poor medical knowledge so many children die.	Improvements in medical care, water supply and sanitation. Fewer children die.		Good health care Reliable food supply.	

***Figure 2.43** The stages of the demographic transition*

Notice that in the second and third stages of the demographic transition, death rates fall before birth rates. This creates a period when the population is increasing. In the final stages, birth rates and death rates are low and the population is stable, with either a slow increase or a slow decrease.

Most developed countries are in one of these two final stages of the demographic transition, whereas developing countries are still in one of the two middle stages. As a result most of the population growth is occurring in developing countries. Rapid growth slows the transition to the later stages.

In the demographic transition, the relative numbers of young and old people changes. These are best shown in age pyramids. Figure 2.44 shows age pyramids for Afghanistan (a country still developing) and the USA and Italy (developed countries).

The broad base to the population in Afghanistan shows that large numbers of children are still being born and that the population is increasing. The structure in the USA is different. There are similar numbers in all the age groups until about age 60. This suggests that the numbers being born are slightly greater than those dying and the population numbers are increasing slowly. Can you explain the lack of growth in Italy? Notice also that life expectancy is greater in Italy and the USA. This is true of most developed countries. Figures 2.45A and B show the population pyramids for Ethiopia in 2000 and the projected population pyramid for 2025.

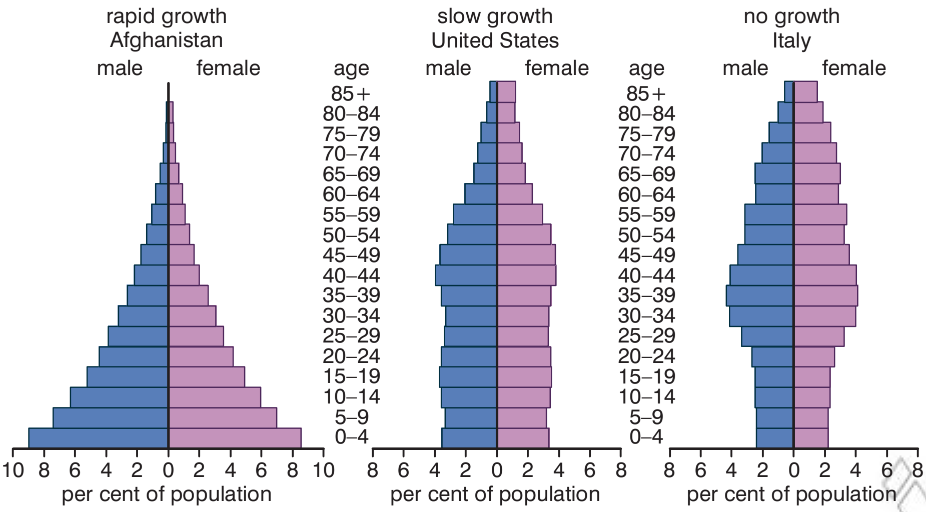


Figure 2.44 Age pyramids for Afghanistan, the USA and Italy

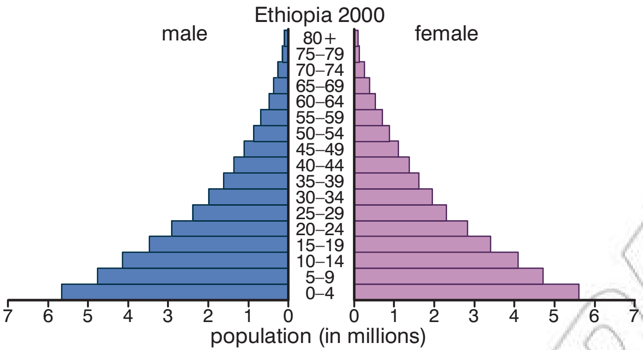


Figure 2.45A *Ethiopia in 2000*

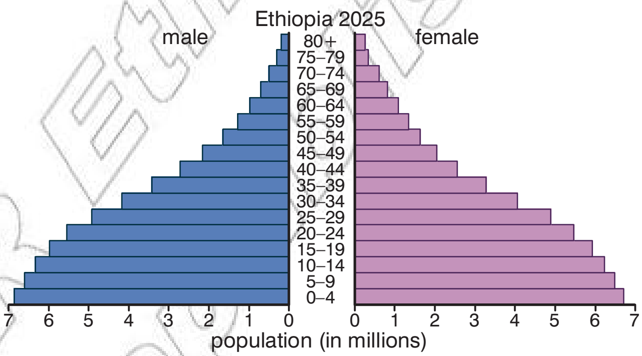


Figure 2.45B *Ethiopia in 2025*

Note that, although the population has increased (predicted by the structure of the population in 2000), the rate of increase is slowing. The base of the new pyramid shows several age bands of more or less the same size – typical of populations showing no growth.

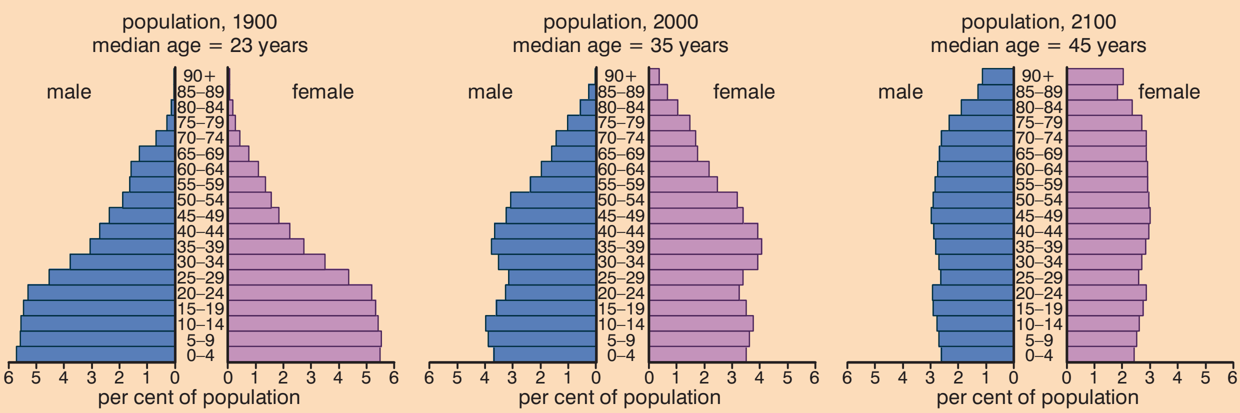
Activity 2.13: Analysing population pyramids

The three population pyramids in Figure 2.46 are of the same country in 1900, 2000, and the predicted structure for 2100. Describe precisely how each of the following changes with time:

- median age of the population
- the percentage of the population over 70 years of age
- the overall shape of the population

Use your knowledge of the demographic transition to explain these changes.

Figure 2.46



KEY WORDS

natality *the rate at which people or members of an animal species are born*

mortality *the rate at which people or members of an animal species die*

What can we do about it?

Whether the global human population increases or decreases depends on the balance between global **natality** and global **mortality**. There are no migration issues. We aren't going anywhere. So the mathematics is fairly simple; to reduce global population, either:

- mortality will increase; this is the 'do-nothing option' and we can wait until the population crashes or war is rife from competition for resources because we are so far over our carrying capacity, or
- natality must decrease – this is the only option we really have and one we can control; we must control the numbers of children being born if we are to stop the runaway growth of the human population.

Many countries now encourage some kind of population control. A few of these are described in table 2.9.

***Table 2.9** The effects of population control policies*

Country	Way of reducing numbers born	Effect on population
China	In 1979 a policy was introduced which discouraged more than one child per family; an unwanted pregnancy is punished with a fine.	Population is still increasing but there has been a huge slowing of the rate of increase.
India	Only people with two or fewer children may serve in local government. Contraception has been introduced.	Population is still increasing, but rate of increase has been slowed.
Iran	Compulsory contraception courses for males and females before a marriage licence can be granted.	Rate of population increase has decreased from 4% in 1980 to 1.3% in 2008.
USA	Free contraception available as well as free sex education; priority is given to those who are poorest.	Population is stable and increasing only slightly.

Activity 2.14: What should Ethiopia do?

Read and discuss the measures taken by other countries to reduce birth rates, as shown in table 2.9. List the measures that you think should be taken in Ethiopia. Explain why you have chosen each measure.

At the moment Ethiopia has one of the highest birth rates in Africa, but there are some hopeful signs that this is changing. It is progressing through the demographic transition, and, as it does so, death rates and birth rates will fall as more resources become generally available.

In the meantime, it is essential that education regarding contraception is available to the people throughout Ethiopia. There are several methods of contraception available, but widespread use of condoms will have the most impact as they are the most easily available. They also give some limited protection against the transmission of HIV.

Fewer children will be needed, particularly in rural communities, if more of them live longer. Good health alongside education will help to reduce the rapid increase in population growth that characterises Ethiopia at the moment.

It is vital that the government makes available as many resources as possible to help local communities, particularly rural communities, with:

- sex education
- access to contraception
- general education to enable students to consider other options in their futures

All of these will help in reducing the rapid population growth rate. In addition, help with the following will improve general health, which is usually associated with lower reproduction rates:

- education about diet
- resources to improve the quantity and quality of crops grown and stock reared in rural communities

Review questions

Choose the correct answer from A to D.

1. A population is:
   A a group of one species in the same place at the same time
   B a group of different species in the same place at the same time
   C all the organisms of one species in the same place at the same time
   D all the organisms of different species in the same place at the same time
2. Which of the following definitions best describes a habitat?
   A the role of an organism within its surroundings
   B the physical surroundings in which an organism lives
   C the area where an organism lives and finds everything it needs – its home
   D the number of organisms of a particular species living in an area
3. The sequence of phases in a population growth curve is:
   A log – lag – stationary – decline
   B lag – log – stationary – decline
   C lag – log – decline – stationary
   D log – lag – decline – stationary
4. The age pyramid in Figure 2.47 represents:
   A an expanding population
   B a static population
   C a population in decline
   D an unbalanced population

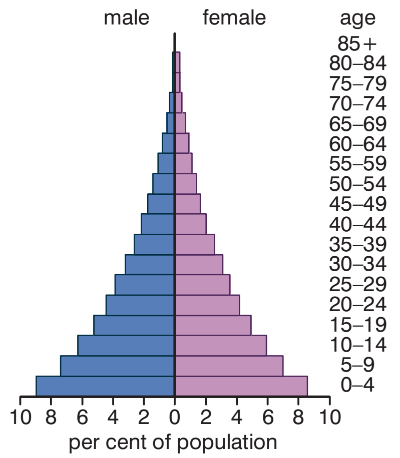


Figure 2.47

5. Inter-specific competition is:
   - A competition between members of different species in the same ecosystem
   - B competition between members of the same species in the same ecosystem
   - C competition between members of the same species in the same habitat
   - D competition between members of different species in the same habitat
6. The best description of the abiotic factors of a pond ecosystem is:
   - A the pond water and dissolved oxygen
   - B the pond water and all the dissolved substances
   - C the pond water, the dissolved substances and the mud at the bottom and sides of the pond
   - D the pond water, the dissolved substances, the mud at the bottom and sides of the pond and the air above the pond
7. In exponential growth, numbers increase:
   - A by the same amount in each successive time period
   - B by a decreasing amount in each successive time period
   - C by an increasing amount in each successive time period
   - D none of the above
8. The human population is currently:
   - A increasing at an increasing rate
   - B increasing at a steady rate
   - C increasing at a slowing rate
   - D decreasing
9. The carrying capacity of a population is:
   - A the maximum number the population can attain
   - B the maximum number that can be sustained by the environment
   - C the minimum level at which the population is still viable
   - D none of the above
10. Action that can be taken to reduce rapid population growth includes:
   - A reproductive (sex) education
   - B access to condoms
   - C improved resources for agriculture
   - D all of the above

Summary

In this unit you have learnt that:

- Decomposers, including bacteria and fungi, feed saprobiotically to break down the dead remains of organisms, which releases mineral ions contained in organic molecules in the dead matter.
- In the carbon cycle:
  - carbon dioxide is removed from the air and fixed into organic molecules in photosynthesis
  - carbon dioxide is replaced in the air when any organism respires or when fossil fuels are burned
  - organic molecules are passed from animals to plants by feeding and assimilation
  - organic molecules are passed from animals and plants to decomposers by saprobiotic feeding on the dead remains of organisms
  - sometimes dead remains form fossil fuels; carbon dioxide is released when these are burned
- In the nitrogen cycle:
  - nitrates are absorbed from the soil by plants and used to make proteins
  - animals eat the plants and use the plant proteins to make animal protein
  - when the animals and plants die the proteins pass into the detritus; in addition, excretory products such as urea pass into detritus
  - decomposers release ammonium ions from nitrogen-containing organic molecules
  - nitrifying bacteria oxidise the ammonium ions to nitrates
  - denitrifying bacteria reduce nitrates to nitrogen gas
  - nitrogen-fixing bacteria reduce nitrogen gas to ammonium ions, either free in the soil or in root nodules of legumes
- In the phosphorus cycle:
  - phosphates are absorbed from the soil by plants and used to make organic molecules
  - animals eat the plants and make their own phosphorus-containing organic molecules
  - when the animals and plants die the organic molecules pass into the detritus
  - decomposers release phosphate ions from phosphorus-containing organic molecules
  - some phosphate ions become incorporated into rocks
  - the rocks may be mined and used to make fertilisers that are added to the soil

- In the sulphur cycle:
  - sulphates are absorbed from the soil by plants and used to make proteins
  - animals eat the plants and use the plant proteins to make animal protein
  - when the animals and plants die the proteins pass into the detritus
  - decomposers release hydrogen sulphide from sulphur-containing organic molecules; this is then oxidised to sulphates
- In the water cycle:
  - water evaporates from the oceans and falls as rain or snow over the land and sea
  - some water enters waterways and returns to the sea either directly or after having been used by humans
  - some water runs off the land
  - some water enters large underground aquifers
- Complex ecosystems develop from simpler ones in the process of succession.
- In a primary succession:
  - a hostile area is colonised by pioneer species
  - the pioneer species change the abiotic conditions and allow other species to colonise the area
  - the new species also change the abiotic conditions allowing another stage of colonisation
  - the different stages are called seres
- As more plant species colonise, they create more niches for other organisms.
- The most complex ecosystem to develop is the climax community.
- A secondary succession can occur when an existing ecosystem is destroyed.
- A biome is a geographically and climatically defined region with organisms which have similar ecological adaptations.
- Biomes may be terrestrial, marine or freshwater.
- The main factors in determining terrestrial biomes are temperature and precipitation.
- Biodiversity is the variability of living things; it includes their species diversity, genetic diversity and ecological diversity.
- Humans have reduced biodiversity in a number of ways including non-sustainable felling of forests and the introduction of large-scale agricultural practices.

- Ethiopia has a high biodiversity at the moment, but the biodiversity is threatened by:
  - deforestation or the burning of vegetation
  - commercial logging
  - subsistence farming
- A loss of biodiversity can lead to:
  - worsening health
  - increasing insecurity of food supply
  - increasing vulnerability
  - less freedom for choice and action
- Planting a tree can help to increase biodiversity.
- Two key activities in maintaining biodiversity are:
  - maintaining habitats
  - using resources in a sustainable way
- A population is all the individuals of a particular species in a particular habitat at a particular time.
- A habitat is an area where a population lives and finds the nutrients, water, living space and other essentials it needs to survive.
- An ecological niche describes the role of an organism within a habitat.
- The size of a population is affected by:
  - biotic factors – predation, disease-causing organisms, intra-specific and inter-specific competition for a resource (often food)
  - abiotic factors – factors of the physical environment, such as temperature, light intensity, concentration of oxygen or carbon dioxide, availability of water
- In intra-specific population, members of the same species compete for a resource; overuse of the resource can lead to a population crash.
- In inter-specific competition, members of different species compete for a resource; this usually leads to local extinction of the weakest competitor, although coexistence is possible if the two species do not use the resource in the same way.
- In arithmetic increase, numbers increase by a set amount in each time period.
- In exponential increase, numbers increase by an increasing amount in each time period.
- The four stages of a population growth curve are:
  - lag phase – population is low and stable as the population adapts to the new surroundings

- log phase – the adapted population increases rapidly due to abundant resources
- stationary phase – numbers are high and stable as deaths are matched by births; this is the carrying capacity for the population in that area
- decline phase – overuse of resources or accumulation of toxic waste products causes a decline in the population; if the resources recover, the population may also recover, otherwise it may decline to zero

- The stages of development of the human population of a country can be represented in the demographic transition as it changes from a pre-agricultural society to an industrial society and finally post-industrial society.
- Age pyramids show the percentage of males and females in each age group in a population.
- Expanding, stationary and contracting populations have different age pyramids.
- Rapid population growth can be controlled by:
  - contraception programmes
  - education about sex
  - better provision of resources to agriculture

End of unit questions

1. a) Name four compounds that contain carbon.
   b) Draw a labelled diagram to describe the main stages of the carbon cycle.
2. a) Explain the importance of nitrogen-fixing bacteria.
   b) Explain the difference between nitrification and denitrification.
   c) Describe how ammonification takes place.
3. Figure 2.48 shows how a pond ecosystem can change over time through succession.
   a) What name precisely describes this type of succession?
   b) What would you expect to see happen if the process were allowed to continue?
   c) Give three features that are common to all successions.

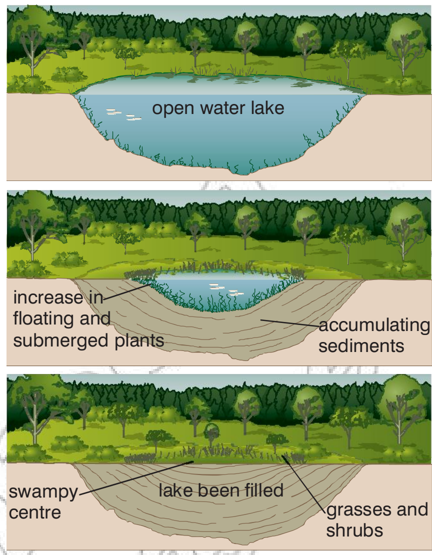


Figure 2.48

4. Figure 2.49 shows a typical population growth curve.
   a) Explain why the population does not increase:
      (i) during phase A
      (ii) during phase C
   b) Give two reasons for the decline during phase D.
   c) Which phase corresponds most closely to the current rate of change of the human population? Explain why this is the case.

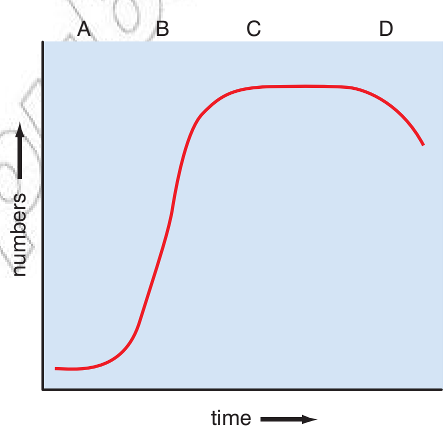


Figure 2.49

5. Figure 2.50 shows potential changes in the biomes in South Africa as a result of climate change. Nama karoo is a kind of scrub biome, in between savannah and thorn forest.

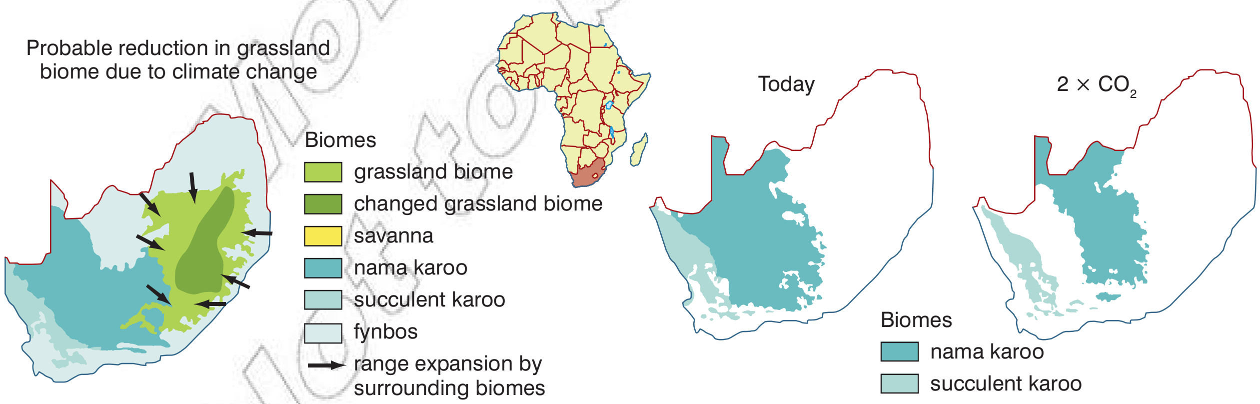


Figure 2.50

   a) What is a biome?
   b) Compare the biome richness of Ethiopia with that of South Africa.
   c) Describe, as fully as you can, the changes that are predicted to occur in the South African biomes.

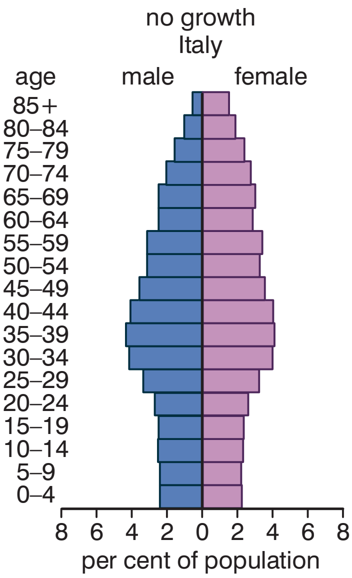


Figure 2.51

6. Figure 2.51 shows the age pyramid of a developed country.
   a) Describe the evidence in the pyramid that suggests that women have a longer life expectancy than men.
   b) Is this an expanding, static or shrinking population? Use evidence from the diagram to support your answer.
   c) State three ways in which the population structure of a developing country would be different from this country.
7. Figure 2.52 shows the phosphorus cycle.

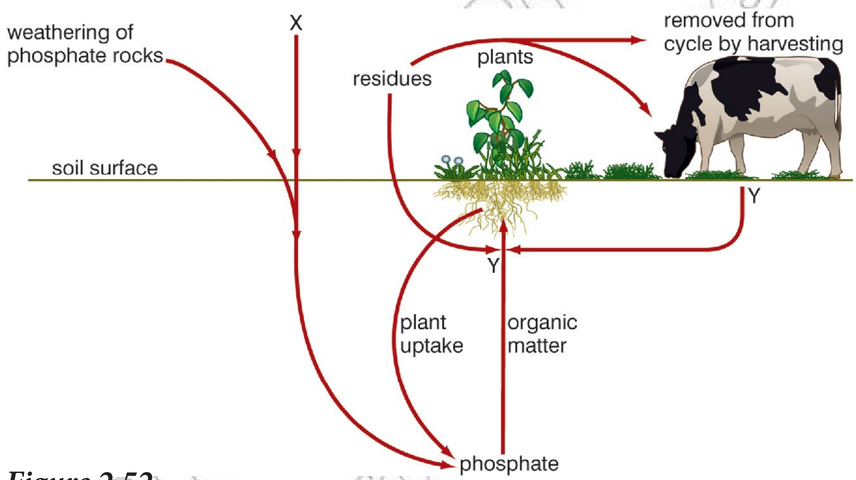
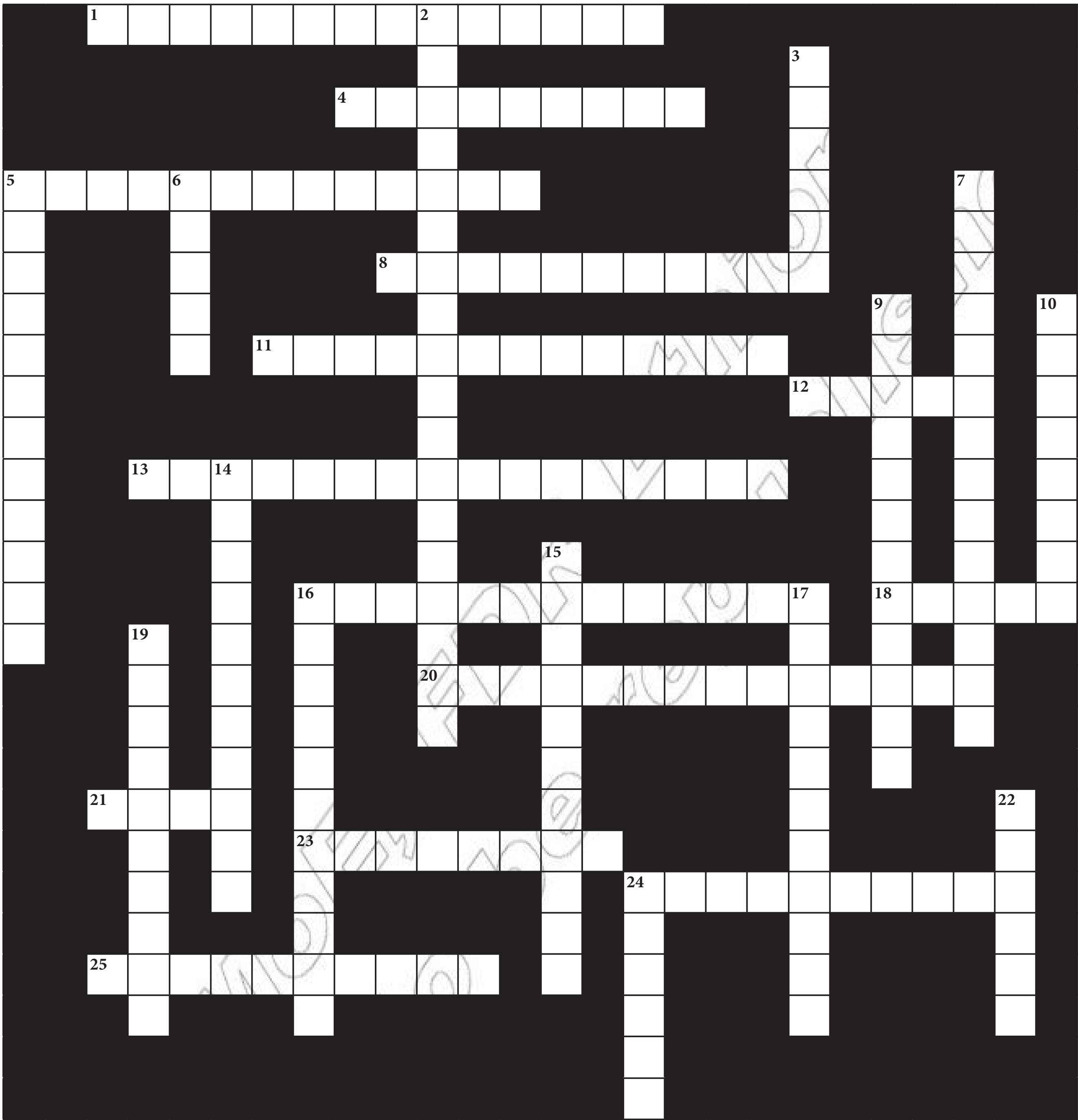


Figure 2.52

   a) Describe three ways in which living things use phosphorus.
   b) (i) Describe what happens in process Y.
      (ii) Harvesting and process X are linked. Explain how.
   c) When compared to the carbon cycle, describe two ways in which the phosphorus cycle is:
      (i) similar
      (ii) different
8. Write a short essay on biodiversity. You should include the following in your essay:
   - What we mean by biodiversity.
   - How we are damaging our biodiversity.
   - The effects of loss of biodiversity.
   - What we can do about it.

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

1. The process in the carbon cycle that removes CO_2 from the air (14)
4. The layer at the surface of the Earth where life is found (9)
5. The practice of felling trees for human benefit (13)
8. The type of nutrition shown by decomposers (11)
11. This type of competition occurs between members of different species (13)

12. A geographical area with a specific climate and soil type and with specifically adapted animals and plants (5)
13. The sulphur-containing gas that smells of bad eggs and is released when organisms are decayed (8, 8)
16. The type of digestion that occurs outside cells (13)
18. Phosphates can enter the soil when … are weathered (5)
20. The sulphur-containing gas that contributes to acid rain (7, 7)
21. One of the stages of a succession (4)
23. If this exceeds mortality, the size of a population will increase (8)
24. A process in the carbon cycle carried out by humans only, that adds CO_2 (10)
25. All the organisms of a particular species in a specific area (10)

Down

2. A biome that is warm, with thin soil and has many different animals and plants (8, 10)
3. Predation and disease are examples of this sort of factor that affects populations (6)
5. These bacteria reduce the amount of available nitrogen in a soil (12)
6. A reaction that involves reduction and oxidation (5)
7. Organisms that are the first stage in a primary succession (7, 7)
9. The species richness and abundance of an area is its … (12)
10. We must preserve these in order to conserve endangered species (8)
14. These organisms decay dead matter (11)
15. A process in the carbon cycle carried out by all living things that adds CO_2 to the air (11)
16. The type of population growth in which the numbers in a population double in a set period of time (11)
17. Some nitrogen-fixing bacteria live in these (4, 7)
19. The process by which bare ground becomes a complex ecosystem (10)
22. A biome that is cold, dry with lichens and mosses that are fed on by migrating animals (6)
24. This type of community is the final and most complex stage of a succession (6)