Cambridge OL

Biology

CODE: (5090)

Chapter 19

Relationships of organisms with one another and with the environment

Energy flow

Dependence on sunlight

With the exception of atomic energy and tidal power, all the energy released on Earth comes from sunlight. The energy released by animals comes from plants that they or their prey eat. The plants depend on sunlight for making their food.

Food chains and food webs

Interdependence means the way in which living organisms depend on each other in order to remain alive, grow and reproduce.

Food chains

Organisms rely on each other for food: herbivores eat plants, carnivores consume other animals. Trophic level determines an organism's feeding position, with producers like plants supporting herbivores and carnivores preying on them. Plankton in surface waters are nourished by water, minerals, and dissolved carbon dioxide.

Pyramids of numbers

The width of the bands in Figure 19.2 is meant to represent the relative number of organisms at each trophic level. So, the diagrams are sometimes called pyramids of numbers. However, sometimes a pyramid of numbers would not show the same effect.

Key definitions

A **food chain** shows the transfer of energy from one organism to the next, beginning with a producer.

A **food web** is a network of interconnected food chains.

A **producer** is an organism that makes its own organic nutrients, usually using energy from sunlight, through photosynthesis.

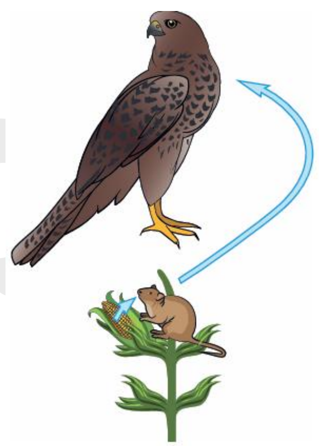
A **consumer** is an organism that gets its energy by feeding on other organisms.

A **herbivore** is an animal that gets its energy by eating plants.

A **carnivore** is an animal that gets its energy by eating other animals.

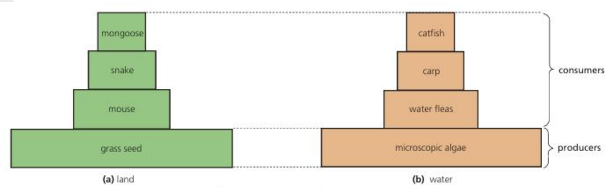
A **decomposer** is an organism that gets its energy from dead or waste organic material.

A **trophic level** is the position of an organism in a food chain, food web, **pyramid of numbers** or **ecological pyramid**.

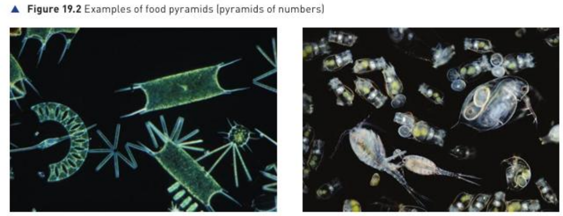


▲ **Figure 19.1** A food chain. The mouse eats the maize grains; the kestrel eats the mouse

▲ **Figure 19.4** The mongoose, a secondary or tertiary consumer



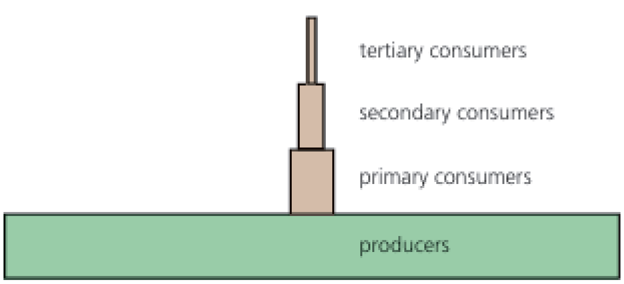
▲ **Figure 19.2** Examples of food pyramids (pyramids of numbers)



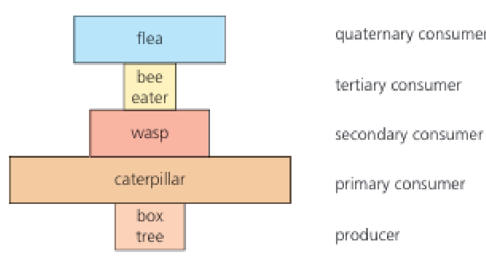
(a) phytoplankton (×100). These microscopic algae form the basis of a food pyramid in the water.

(b) zooplankton (×20). These crustacea will eat microscopic algae.

▲ **Figure 19.3** Plankton



▲ **Figure 19.6** Biomass (dry weight) of living organisms in a shallow pond (grams per square metre)



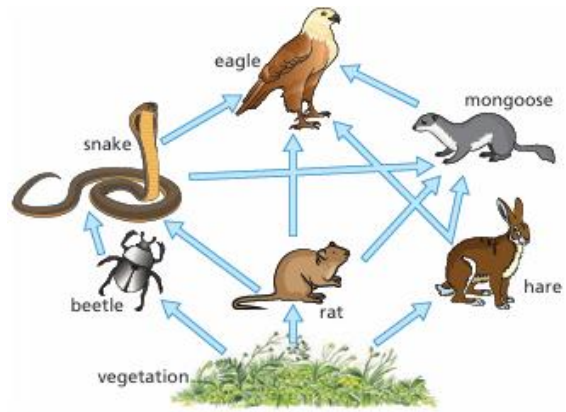
▲ **Figure 19.5** An inverted pyramid of numbers

Pyramids of biomass

Biomass is the term used when the mass of living organisms is being considered, and pyramids of biomass can be constructed as in Figure 19.6. A **pyramid of biomass** is nearly always the correct pyramid shape.

In Figure 19.6 the width of the horizontal bands is proportional to the masses

An alternative is to calculate the energy available in a year's supply of leaves and compare this with the energy needed to maintain the population of insects that feed on the leaves. This would produce a **pyramid of energy**, with the producers at the bottom having the greatest amount of energy.



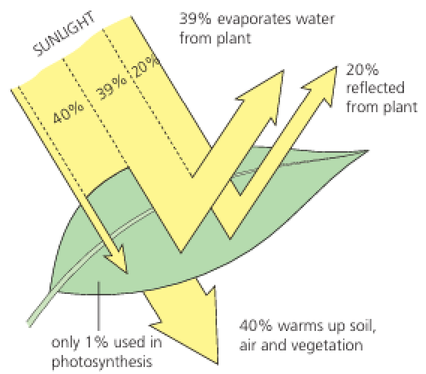
▲ **Figure 19.7** A food web

Food webs

Food chains are not as straightforward as described above. Most animals eat more than one type of food. A mongoose, for example, does not feed entirely on snakes but takes lizards, fish and birds' eggs in its diet too. To show these relationships more accurately, a food web can be drawn up (Figure 19.7).

Energy transfer

Study Figure 19.1. When herbivorous animals eat a plant (the mice feeding on maize grains), the chemical energy stored in that maize grain is transferred to the herbivores.



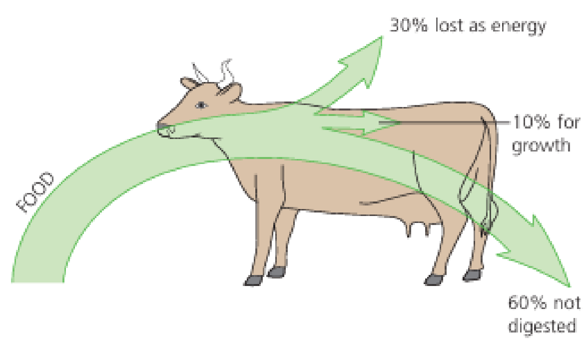
▲ **Figure 19.8** Absorption of Sun's energy by plants

Use of sunlight

To try and estimate just how much life the Earth can support, it is necessary to examine how efficiently the Sun's energy is used. When the Sun's energy falls onto grassland, about:

» 20% is reflected by the vegetation
» 39% is used in evaporating water from the leaves (transpiration)
» 40% warms up the plants, the soil and the air
» about 1% is used in photosynthesis for making new organic matter in the leaves of the plants (Figure 19.8).

Crop plants need enough water and mineral ions to be at their most efficient. Irrigation and the use of fertiliser help this.



▲ **Figure 19.9** Energy transfer from plants to animals

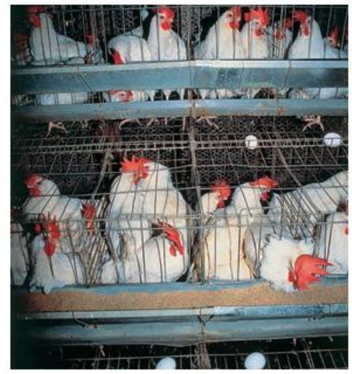
Energy transfer between organisms

Now, we will study the efficiency of energy transfer from plant products to primary consumers. On land, primary consumers only eat a small proportion of the vegetation that is available. In a deciduous forest only about 2% is eaten; in grazing land, 40% of the grass may be eaten by cows. The food chain below shows how the energy reduces through the chain. It is based on grass obtaining 100 units of energy

grass →	locust →	lizard →	snake →	mongoose
100 units	10 units	1 unit	0.1 unit	0.01 unit

Energy transfer in agriculture

In human communities, the use of plant products to feed animals that provide meat, eggs and dairy products is wasteful. This is because only 10% of the plant material is converted to animal products. It is more economical to eat bread made from the wheat than to feed the wheat to hens and then consume the eggs and chicken meat.

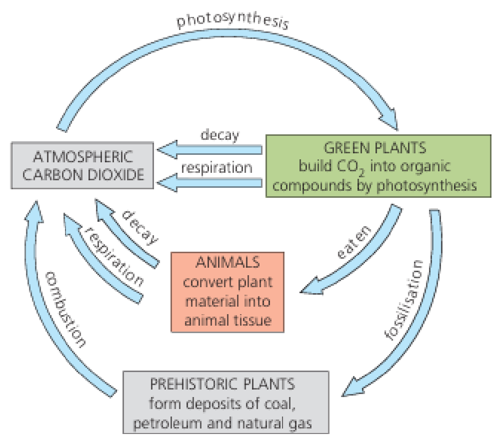


▲ **Figure 19.10** Battery chickens. The hens are well fed but kept in crowded and cramped conditions with no opportunity to move about or scratch in the soil as they would normally do

Nutrients cycle

The carbon cycle

Carbon is an element that occurs in all the compounds that make up living organisms. Plants get their carbon from carbon dioxide in the atmosphere and animals get their carbon from plants. So, the carbon cycle is mainly concerned with what happens to carbon dioxide (Figure 19.11).



▲ **Figure 19.11** The carbon cycle

Removal of carbon dioxide from the atmosphere

Photosynthesis

Green plants remove carbon dioxide from the atmosphere as a result of their photosynthesis. The carbon from the carbon dioxide is built first into a carbohydrate such as glucose. Some of this is changed into starch or the cellulose of cell walls, and the proteins, pigments and other compounds of a plant.

Fossilisation

Any conditions that stop fast **decomposition** may produce fossils. The carbon in the dead organisms becomes trapped and compressed and can remain there for millions of years. The carbon may form **fossil fuels** like coal, oil and natural gas.

▲ **Figure 19.12** Mould fungus growing on over-ripe oranges

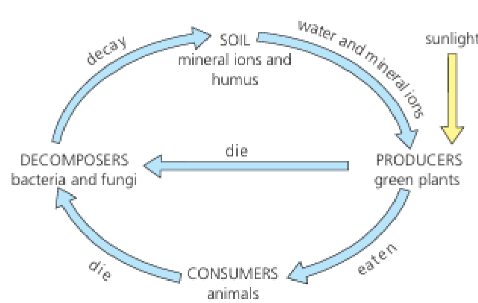
Addition of carbon dioxide to the atmosphere

Respiration

Plants and animals obtain energy by **respiration** using carbohydrates and oxygen in their cells. This process produces carbon dioxide and water (Chapter 10). The carbon dioxide and water are **excreted** so the carbon dioxide returns once again to the atmosphere.

Decomposition

Decomposition is a key process in carbon recycling, where dead organisms release essential materials through auto-digestion. Scavengers, blowfly larvae, earthworms, and microorganisms invade remaining tissues, releasing products like nitrates, sulfates, and phosphates into the soil or water, which are then taken up by ecosystem producers.



▲ **Figure 19.13** Recycling in an ecosystem

Combustion (burning)

When carbon-containing fuels like wood, coal, petroleum and natural gas are burned, the carbon is oxidised to carbon dioxide ($C + O_2 \rightarrow CO_2$).

So, an atom of carbon that is in a molecule of carbon dioxide in the air today may be in a molecule of cellulose in the cell wall of a blade of grass tomorrow. When the grass is eaten by a cow, the carbon atom may become part of a glucose molecule in the cow's bloodstream.

▲ **Figure 19.14** Root nodules of white clover – a leguminous plant

The nitrogen cycle

When a plant or animal dies its tissues decompose, partly as a result of the action of saprophytic bacteria. One of the important products of the decay of animal and plant protein is ammonia. The excretory products of animals contain nitrogenous waste products like ammonia and urea. Urea is formed in the liver of humans as a result of deamination.

Processes that add nitrates to soil

Nitrifying bacteria These are bacteria living in the soil, which use the ammonia from excretory products and decaying organisms as a source of energy (as we use glucose in respiration). In the process of getting energy from ammonia, called **nitrification**, the bacteria produce nitrates.

- The nitrite bacteria oxidise ammonium compounds to nitrites ($NH_4^+ \rightarrow NO_2^-$).
- Nitrate bacteria oxidise nitrites to nitrates ($NO_2^- \rightarrow NO_3^-$).

Nitrogen-fixing bacteria

This is a special group of nitrifying bacteria that can absorb nitrogen as a gas from the air spaces in the soil and build it into compounds of ammonia. Plants cannot use nitrogen gas. However, when it has been made into a compound of ammonia, it can easily be changed to nitrates by other nitrifying bacteria.

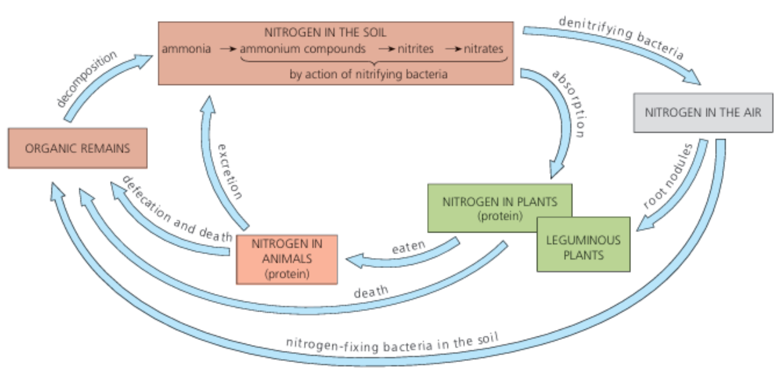
Lightning

The high temperature of lightning discharge causes some of the nitrogen and oxygen in the air to combine and form oxides of nitrogen. These dissolve in the rain and are washed into the soil as weak acids, where they form nitrates.

Processes that remove nitrates from the soil

Uptake by plants

Plant roots absorb nitrates from the soil and combine them with carbohydrates to make amino acids, which are built up into proteins (Chapter 6). These proteins are then available to animals, which feed on the plants and digest the proteins in them.



▲ **Figure 19.15** The nitrogen cycle

Denitrifying bacteria

Denitrifying bacteria obtain their energy by breaking down nitrates to nitrogen gas, which then escapes from the soil into the atmosphere. This process is called **denitrification**. All of these processes are summed up in Figure 19.15.

Key definitions

A **population** is a group of organisms of one species, living in the same area, at the same time.

A **community** is all the populations of different species in an ecosystem.

An **ecosystem** is a unit containing the community of organisms and their environment, interacting together.

Populations

In biology, the term population always refers to a single species. A biologist might refer to the population of sparrows in a farmyard or the population of catfish in a lake.

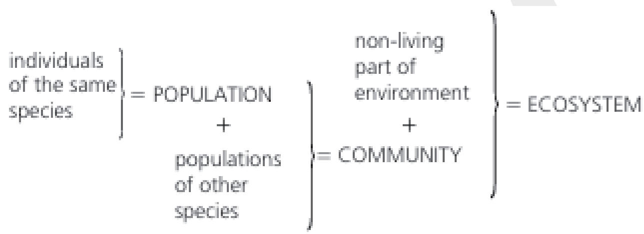
▲ **Figure 19.16** An ecosphere. The 5-inch globe contains seawater, bacteria, algae, snails and a few Pacific shrimps. Given a source of light it is a self-supporting system and survives for several years (at least). The shrimps live for up to 7 years, but few reproduce

Communities

A community is made up of all populations of plant and animal species living in an ecosystem. In the soil there is a community of organisms, which includes earthworms, springtails and other insects, mites, fungi and bacteria.

Ecosystems

An ecosystem consists of a community of organisms in a habitat, including plants and animals, and the non-living environment. In a lake ecosystem, plants absorb light for photosynthesis, animals feed on plants, and dead remains return nutrients to the soil.



Distribution in an ecosystem

All ecosystems contain producers, consumers and decomposers. The organisms are not spread evenly throughout the ecosystem but live in habitats that suit their way of life.
On a rocky coast, limpets and barnacles can resist exposure between the tides and colonise the rocks.

Factors affecting population growth

A population grows when the birth rate exceeds the death rate.

Food supply

If conditions are ideal, a population can increase in size. For this to happen there needs to be a good food supply. This will allow organisms to breed more successfully to produce more offspring; shortage of food can result in starvation, leading to death. It can also force emigration, reducing the population. The food shortage may be because the food source has all been eaten, has died out, or has completed its growing season.

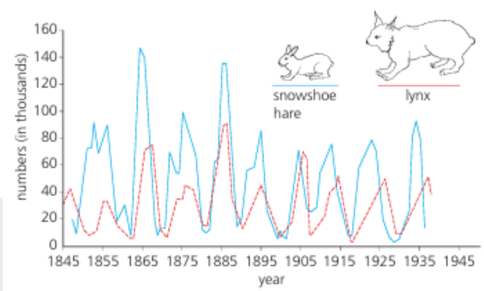
Competition

Within a habitat there will be competition for factors such as food and shelter. This competition may be between individuals of the same species, or between individuals of different species if they eat the same food. There will also be competition within a species for mates.

Predator–prey relationships

In a habitat there are likely to be predators. If heavy predation of a population happens, the rate of breeding may be unable to produce enough organisms to replace those eaten, so the population will drop in numbers.

Predators in habitats can lead to population decline. Lynx prey on snowshoe hares, causing hare population growth. Increased lynxes eventually reduced hare population, illustrating the importance of predators in habitats.



▲ **Figure 19.17** Predator–prey relationships: fluctuations in the numbers of pelts received by the Hudson's Bay Company for lynx (predator) and snowshoe hare (prey) over a 100-year period

Disease

Disease can be a special problem in large populations because it can spread easily from one individual to another. Epidemics can reduce population sizes very rapidly.

A pandemic refers to a global disease spread, such as COVID-19 in 2020 and 2021. Developing vaccines and hospital equipment is challenging. HIV remains a significant global issue, with 37.9 million infected and 770,000 deaths in 2018. 60% of infected people now receive effective medication.

Key definitions

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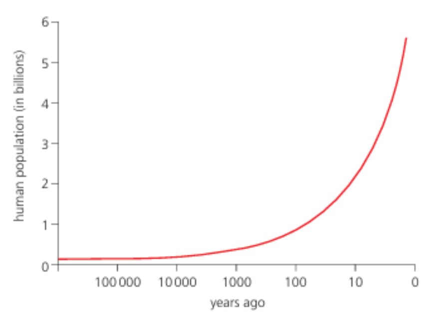
Human population

The world population reached 300 million in 1000ad, risen to 1 billion in the early 19th century, reaching 4.7 billion by 1984, 6 billion in 2000, and 7.7 billion in 2019, with the greatest population surge in 300 years.

Population growth

About 20 years ago, the human population was increasing at the rate of 2% a year.



▲ **Figure 19.18** World population growth. The time scale (horizontal axis) is logarithmic. The right-hand space (0–10) represents only 10 years, but the left-hand space (100 000 to 1 million) represents 900 000 years. The greatest population growth has taken place in the last 300 years

Diseases like malaria and sleeping sickness (spread by tsetse flies) have limited the spread of people into affected areas for many years. Diseases like bubonic plague and influenza have cut population growth from time to time, and the current AIDS epidemic in sub-Saharan Africa is having significant effects on population growth and life expectancy.

Factors affecting population growth

If a population is to grow, the birth rate must be higher than the death rate. Suppose a population of 1 000 people produces 100 babies each year but only 50 people die each year. This means that 50 new individuals are added to the population each year and the population will double in 20 years (or less if the new individuals start reproducing at 16).

Factors affecting the increase in size of the human population

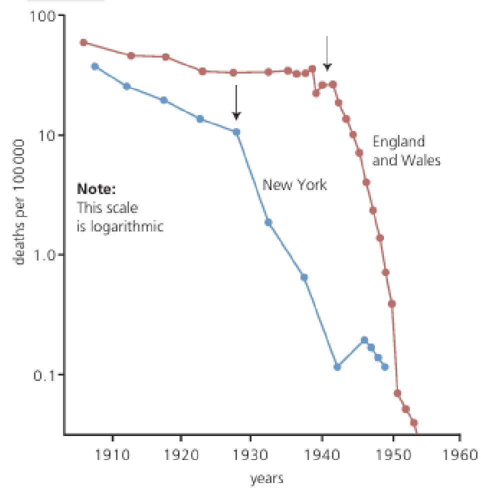
Increase in life expectancy

The life expectancy is the average age to which a newborn baby can be expected to live. In sub-Saharan Africa, life expectancy was rising to 58 years until the AIDS epidemic reduced it to about 45 years. It is now about 61 years, due to improvements in **nutrition** and access to water and HIV medication. Japan has the highest life expectancy, at 84 years.

Causes of the reduction in death rate

The causes are not always easy to identify and vary from one community to the next. In 19th century Europe, agricultural development and economic expansion led to improvements in nutrition, housing and sanitation, and to clean water supplies.

In the developing world, sanitation, clean water supplies and nutrition are improving slowly.



▲ **Figure 19.19** Fall in death rate from diphtheria as a result of immunisation. The arrows show when 50% or more of children were vaccinated. **Note:** The rate was already falling but was greatly increased by immunisation

Stability and growth

Up to 300 years ago, the world population was quite stable. Fertility (the birth rate) was high, but so was the mortality rate (death rate). Probably less than half the children born lived to have children of their own. Many died in their first year (infant mortality), and many mothers died during childbirth.

As a community grows wealthier, the birth rate goes down. There are believed to be four reasons:

» Longer and better education: marriage is postponed, and a better-educated couple will have learned about methods of family limitation.

» Better living conditions: once people realise that half their offspring are not going to die from disease or malnutrition, family sizes fall.

» Agriculture and cities: modern agriculture is no longer labour intensive. Farmers do not need large families to work on the land. City dwellers do not depend on their offspring to help raise crops or herd animals.

» Application of family planning methods: either natural methods of birth control or the use of contraceptives is much more common.

▲ **Figure 19.20** Family planning. A health worker in Bangladesh explains the use of a condom

Population pressures

More people, more agriculture and more industrialisation will put still more pressure on the environment unless we are very alert. If we damage the ozone layer, increase atmospheric carbon dioxide, release radioactive products or allow farmland to erode, we may face extra limits to population growth.

The demand for global resources

As the human population increases, so does the demand for global resources. This includes not only food, but fuel, materials for construction such as sand, gravel and limestone, and metals. Recycling is becoming more important to satisfy some of the increases in demand for materials.

Key definitions

Biodiversity is the number of different species that live in an area.

Effects of humans on ecosystems

Food chains and food webs

Any form of habitat destruction by humans, even where a single species is wiped out, can have an impact on food chains and food webs. This is because other organisms will use that species as a food source, and so then their numbers will decline.

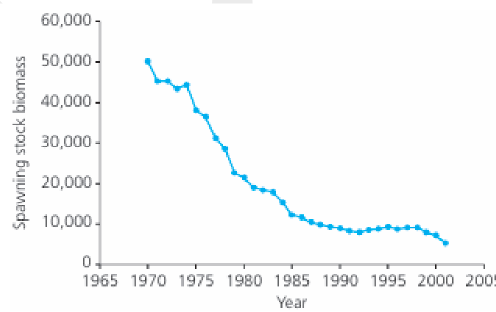
The effects of overharvesting

Overharvesting causes the reduction in numbers of a species to the point where it is endangered or made extinct. As a result, biodiversity is affected. The species may be harvested for food, or for body parts such as tusks (elephants), horns (rhinos – Figure 19.24), bones and fur(tigers), or for selling as pets (reptiles, birds and fish, etc.).

▲ **Figure 19.24** The rhinoceros is endangered. Some people believe that powdered rhino horn (*Cornu Rhinoceri Asiatici*) is a medicine. This is not true. Others like rhino horn handles for their daggers

Overfishing

Human activities have led to a decline in fish populations, with commercial fishing increasing and advanced methods becoming more prevalent. Whales, once the first marine organisms to face extinction, have been severely reduced. Lower-down fish, such as grouper fish, are also facing overgrazing on the Great Barrier Reef, posing a threat to their survival and becoming endangered.



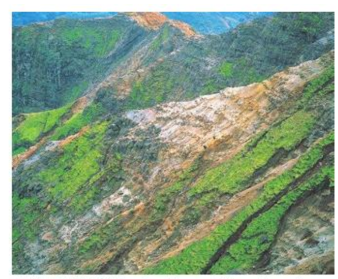
▲ **Figure 19.25** Effects of overfishing on bluefin tuna stocks from 1970–2002

Introducing non-native species to a habitat

An early example of this was an accident. Pirates or whalers in the 17th or 18th centuries introduced rats to the Galapagos Islands. The rats had no natural predators and there was a lot of food.

The use of pesticides and other poisons can also disrupt food chains and webs. Sometimes humans release them into the environment by accident.

▲ **Figure 19.26** Cutting a road through a tropical rainforest. The road not only destroys the natural vegetation, it also opens up the forest to further exploitation

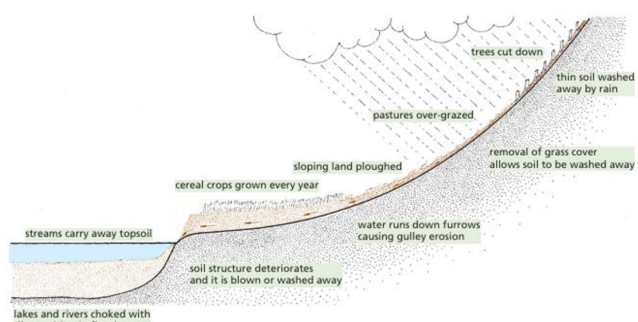


▲ **Figure 19.27** Soil erosion. Removal of forest trees from steeply sloping ground has allowed the rain to wash away the topsoil

The undesirable effects of deforestation on the environment

The removal of large numbers of trees result in habitat destruction on a massive scale.

» Animals living in the forest lose their homes and sources of food; species of plant become extinct as the land is used for other purposes.



▲ **Figure 19.28** The causes of soil erosion

» Soil erosion is more likely to happen as there are no roots to hold the soil in place. The soil can end up in rivers and lakes, destroying habitats there.

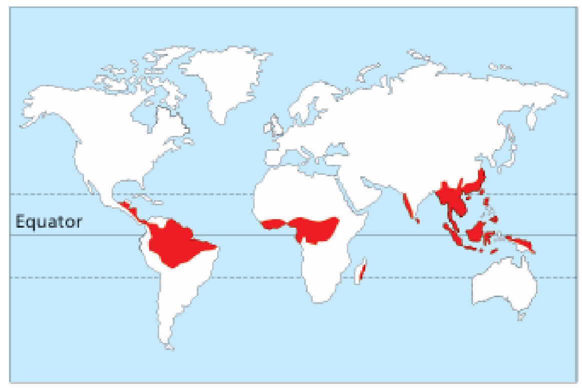
» Flooding becomes more frequent as there is no soil to absorb and hold rainwater. Plant roots rot and animals drown, destroying food chains and webs.

» Carbon dioxide builds up in the atmosphere as there are fewer trees to photosynthesise, increasing global warming. Climate change affects habitats.

The forests release the water steadily and slowly to the soil and to the streams and rivers that start in or flow through them. The tree roots hold the soil in place. At present, we are destroying forests, particularly tropical forests, at a rapid rate

1. for their timber
2. to make way for agriculture, roads (Figure 19.26) and settlements
3. for firewood.

The soil of tropical forests is usually very poor in nutrients. Most of the organic matter is in the leafy canopy of the tree tops.



▲ **Figure 19.29** The world's rainforests

Forests and climate

About half the rain that falls in tropical forests comes from the transpiration of the trees themselves. The clouds that form from this transpired water help to reflect sunlight. This keeps the region relatively cool and humid. When areas of forest are cleared, this source of rain is removed, cloud cover is reduced and the local climate changes quite dramatically.

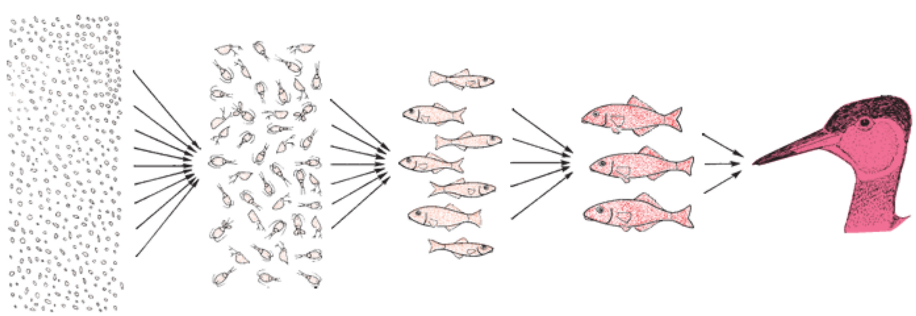
Forests and biodiversity

A pine wood or forest may consist of only one or two species of tree. So, destruction of tropical forest destroys a large number of different species. This is driving many of them to the edge of **extinction**. It also drives out the local populations of humans.

Pollution

Sewage

Diseases like typhoid and cholera are caused by certain bacteria when they get into the human intestine. The faeces passed by people suffering from these diseases will contain the harmful bacteria.



▲ **Figure 19.34** Pesticides may become more concentrated as they move along a food chain. The intensity of colour represents the concentration of DDT

When the water from the sewage treatment is discharged into rivers it contains large quantities of phosphate and nitrate, which allow the microscopic plant life to grow very rapidly (Figure 19.35).

▲ **Figure 19.35** Growth of algae in a lake. Large concentrations of nitrate and phosphate from treated sewage and from farmland make this growth possible

Fertilisers

When nitrates and phosphates from farmland and sewage escape into water they cause excessive growth of microscopic green plants. This may result in a serious oxygen shortage in the water, resulting in the death of aquatic animals.

Effects of sewage and fertilisers on aquatic ecosystems

Nitrates and phosphates are present in several sources, including untreated sewage, detergents from manufacturing and washing processes, arable farming and factory farming.

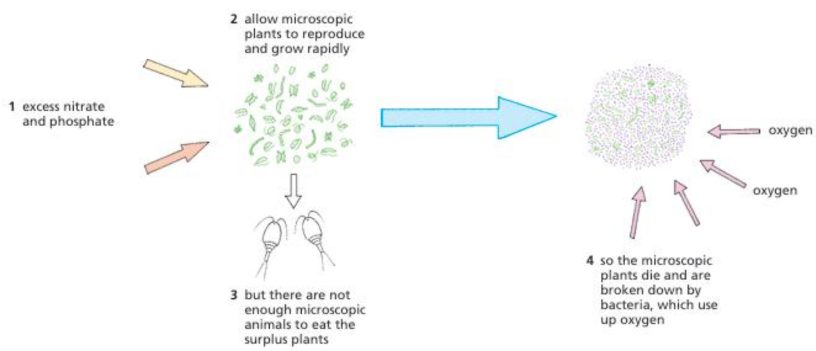
Eutrophication

Plants require nitrates for proteins and other ions for chemical reactions and growth. Availability of nitrates and ions affects plant growth. In rivers and lakes, nitrate and ion levels have risen.
This leads to a faster process of **eutrophication.**

▲ **Figure 19.36** Fish killed by pollution. The water may look clear but it is so short of oxygen that the fish have died from suffocation

It is possible to reduce eutrophication by using
» detergents with less phosphates
» agricultural fertilisers that do not dissolve so easily
» animal wastes on the land instead of letting them reach rivers

Discarded plastics



▲ **Figure 19.38** Processes leading to eutrophication

▲ **Figure 19.39** Plastics washed up on a shoreline

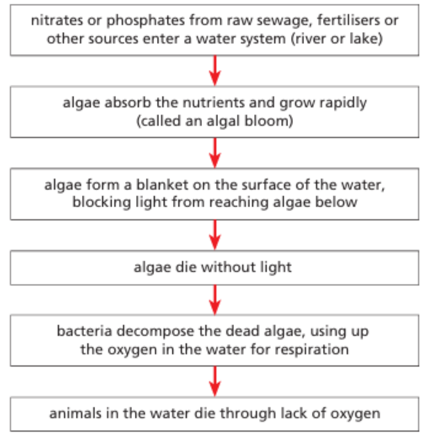
▲ **Figure 19.40** Seal trapped in a discarded fishing net

As towns and cities expand, their increasing populations pose waste disposal challenges. Inadequate disposal can lead to diseases and pollution. Landfill sites become overloaded, contaminating the environment and attracting pests.

Plastics and the environment

Plastics are non-biodegradable, persisting in the environment, taking up space, causing pollution, and harming wildlife. Plastic fragments in water are consumed by animals, leading to illness. Some countries ban plastic bags and tax them, using revenue for environmental projects.

Figure 19.37 shows this sequence of events as a flow chart.



▲ **Figure 19.37** The events leading to death of an aquatic ecosystem

The greenhouse effect and climate change

Levels of carbon dioxide in the atmosphere are influenced by natural processes and by human activities. Processes that change the balance include

» cutting down forests (deforestation) – less photosynthesis » combustion of fossil fuels (coal, oil and gas)

» increasing numbers of animals (including humans) – they all respire.

The build-up of greenhouse gases causes a gradual increase in the atmospheric temperature, known as the enhanced greenhouse effect. This can

» melt polar ice caps, causing flooding of low-lying land

» change weather conditions in some countries, increasing flooding or reducing rainfall – changing arable (farm) land to desert; extreme weather conditions become more common

» cause the extinction of some species that cannot survive in raised temperatures.

CO_2 levels reached 407.4 ppm in 2018, the highest in at least 800,000 years per NOAA. Deforestation in Brazil involves burning rainforests for cattle grazing, increasing carbon dioxide levels. Uncertain outcomes include climate and rainfall changes disrupting agriculture, ocean expansion, polar icecaps melting, sea level rise, extreme weather causing droughts and food shortages. The impact of these scenarios remains unknown

▲ **Figure 19.41** Recycling polythene. Polythene waste is recycled for industrial use

▲ **Figure 19.42** *Plasphalt* is made up of grains of plastic produced from unsorted plastic waste. This replaces the sand and gravel usually used in asphalt production for road surfaces. It can also contain recycled glass pellets

▲ **Figure 19.44** Burning rainforest to clear land for cattle to graze on

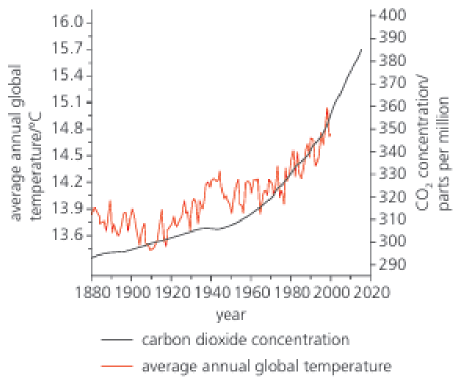


Figure 19.45 Annual average global temperatures and carbon dioxide levels since 1880

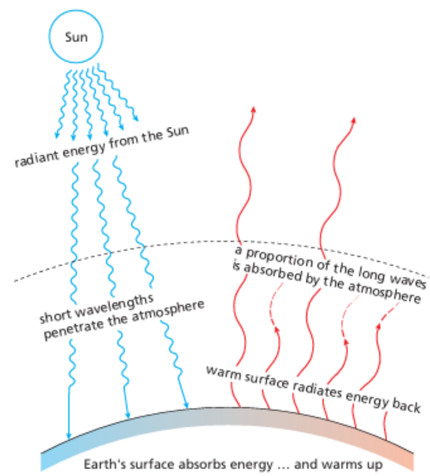


Figure 19.43 The greenhouse effect

Revision questions

1.

Fig. 2.1 shows crop productivity for a range of plants but the bar graph is incomplete.

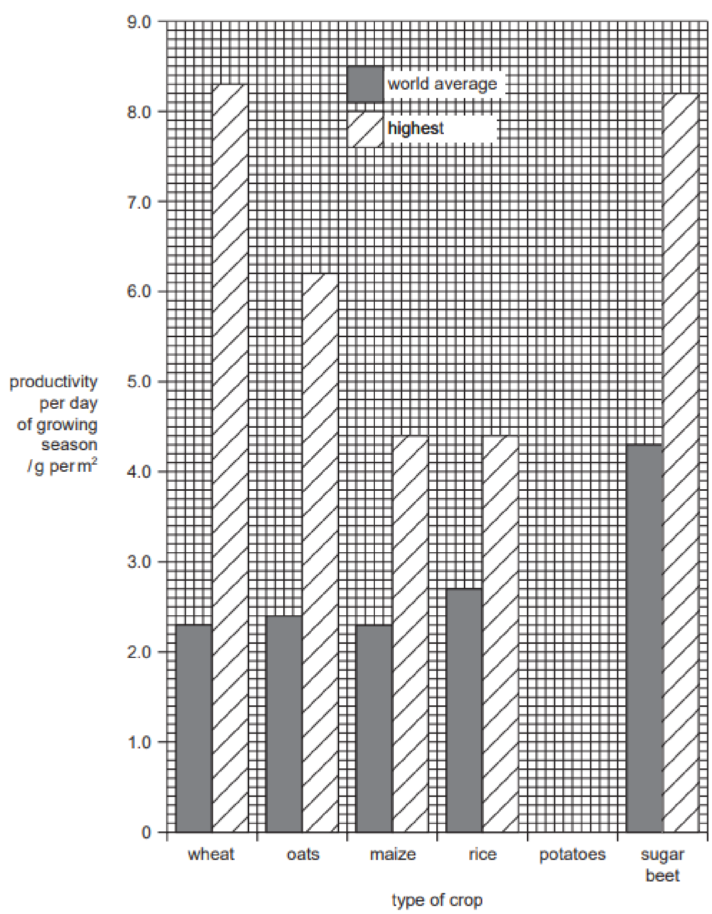


Fig. 2.1

(a) Complete Fig. 2.1 using the following data.

crop	productivity per day of growing season / g per m ^{2}	
	world average	highest yield
potatoes		5.6

[2]

(b) State which crop has

(i) the highest average productivity,

(ii) the greatest difference between the average yield and the highest yield. [2]

(c) Outline how modern technology could be used to increase the productivity of a crop from the average yield to a high yield. [3]

(d) When the yield is measured, dry mass is always used rather than fresh mass. Suggest why dry mass is a more reliable measurement than fresh mass

(e) Maize is often used to feed cows, which are grown to provide meat for humans. Explain why it is more efficient for humans to eat maize rather than meat from cows that have been fed on maize.

2.

The Ruddy duck, *Oxyura jamaicensis*, is a native of America.
A flock of 20 birds was introduced into Britain from America before 1950.
The original flock settled quickly in their new habitat and started breeding. Numbers now exceed 6000.
The White-headed duck, *Oxyura leucocephala*, (a native of Spain) is a closely related species to the Ruddy duck.
Female White-headed ducks are more attracted to male Ruddy ducks than to males of their own species.
Cross-breeding between the two species produces a new variety of fertile duck.
The White-headed duck is now threatened with extinction.
Some conservationists are considering a plan to kill the British population of Ruddy ducks to prevent the White-headed duck becoming extinct.

Fig. 6.1 shows a male Ruddy duck.

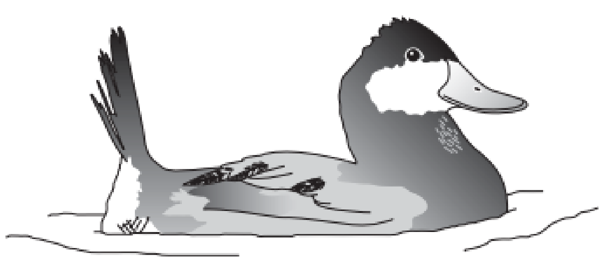


Fig. 6.1

(a) State two features, visible in Fig. 6.1, that distinguish birds, such as the Ruddy duck, from other vertebrate groups.

(a) State two features, visible in Fig. 6.1, that distinguish birds, such as the Ruddy duck, from other vertebrate groups. [2]

(b) (i) With reference to an example from the passage, describe what is meant by the term binomial system.

(ii) State two reasons, based on information in the passage, why the Ruddy duck and White-headed duck are considered to be closely related.

(c) (i) Explain why Ruddy ducks would not become ex ecbome ex conservationists carried out their plan.

(ii) Suggest one factor, other than the breeding habits of the Ruddy duck, that could result in the extinction of a bird such as the White-headed duck.

(d) The Ruddy duck feeds on seeds and insect larvae. The ducks are eaten by foxes and humans. Explain why these feeding relationships can be displayed in a food web, but not in a food chain.

3.

Some pollutants are not broken down easily and remain in the environment for a long time. These are described as persistent pollutants. PCBs are a waste material from the manufacturing of electrical insulation. PCBs are one of the most persistent pollutants in the environment.

Between 1947 and 1976, factories dumped large quantities of PCBs into the Hudson River in the USA. Studies measured the concentrations of PCBs in the tissues of organisms in a food chain in the sea near the Hudson River, as shown in Fig. 6.1.

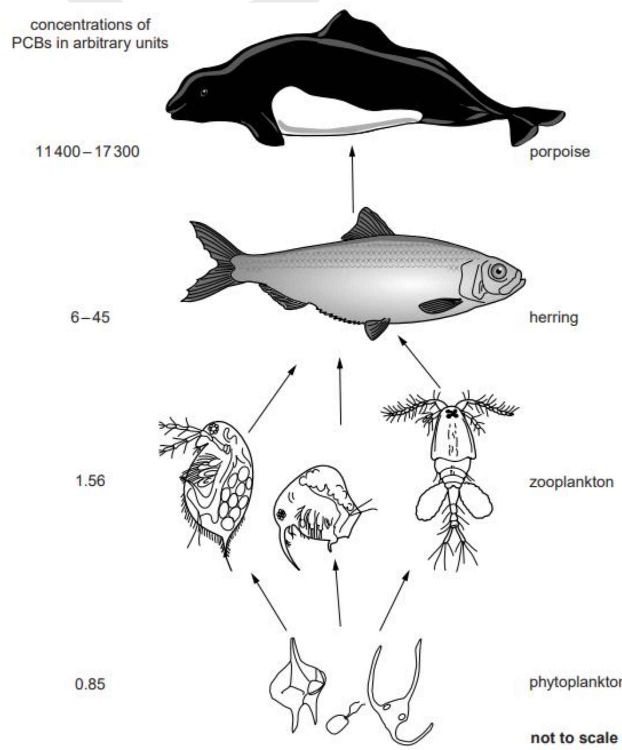


Fig. 6.1

(a) (i) Describe the results shown in Fig. 6.

(ii) Suggest an explanation for the different concentrations of PCBs in the organisms of the food chain.

(b) PCBs are toxic to many organisms because they bind to a protein molecule known as AHR. The Atlantic tomcod, Microgadus tomcod, is a fish that lives in the Hudson River and other rivers nearby. 90% of the tomcod population in the Hudson River is resistant to the effects of PCBs. This is because these fish have a different type of AHR compared with other tomcod populations.

(i) Suggest how this resistance came about.

(ii) Scientists predict that the proportion of fish resistant to PCBs will decrease if the concentration of PCBs in the river decreases. Suggest reasons why the proportion of fish with the altered AHR protein might decrease.

4.

Fig. 6.1 shows Soay sheep on St. Kilda, a group of small remote islands off the coast of Scotland. These islands experience extreme conditions of cold, wind and rain. Sheep were introduced to the islands thousands of years ago and the Soay sheep are descended from them. The islands of St. Kilda have been uninhabited by people since 1930. The sheep are now left unfarmed and in their natural state.

Fig. 6.1

(a) The populations of Soay sheep on St. Kilda show much more variation in their phenotype than modern breeds of sheep. Explain, by using an example from Fig. 6.1, what is meant by variation in their phenotype.

(b) Scientists have recorded the numbers of Soay sheep and lambs on St. Kilda for many years. Each year between 1985 and 1996, the lambs (young sheep) were caught, marked and weighed. In some years, the total number of sheep on St. Kilda was lower than in other years. Fig. 6.2 shows the frequency of lambs of different body mass in years when the total number of sheep was low and years when the total number was high.

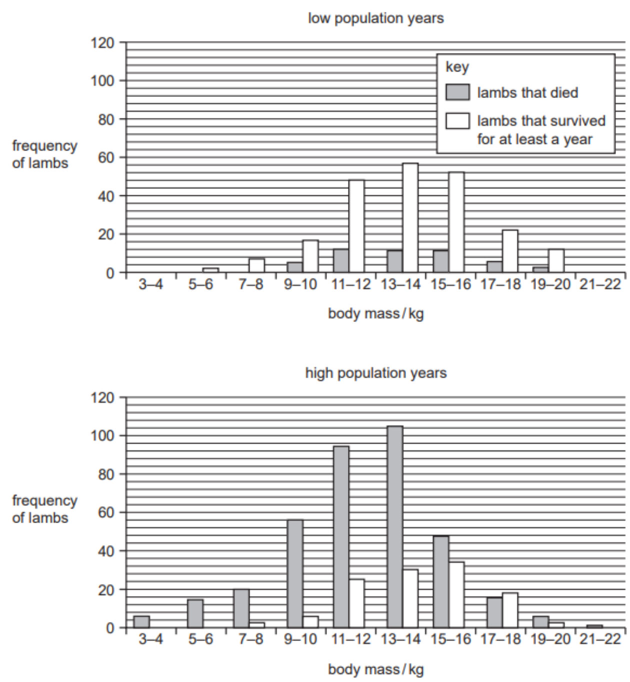


Fig. 6.2

(i) Population size has a great effect on the survival of lambs on St. Kilda. Describe the evidence from Fig. 6.2 that supports this statement.

(ii) Suggest an explanation for the effect that you have described.

(c) Soay sheep are adapted to the extreme conditions experienced on St. Kilda. Explain how natural selection could account for the adaptive features of Soay sheep.

5.
Scientists are considering the use of a genetically engineered virus to kill a population of the cane toad, Bufo marinus, which is growing out of control in Australia. This virus will introduce a modified form of genetic material, responsible for hormone production. The normal hormone causes the toads to mature in a similar way to hormones causing puberty in mammals.

The modified genetic material will prevent toads maturing, leading to their death. The toad was introduced into Australia because it eats scarab beetles, a pest of sugar cane plants. Sugar cane is an important crop plant. Animals such as crocodiles and dingos are predators of the toad, but the toad can kill them by squirting a powerful toxin.

(a) Define the term genetic engineering.

(b) State which part of the virus would carry the modified genetic material.

(c) (i) Name the hormone that causes puberty in male mammals.

(ii) State two characteristics that develop in a boy when this hormone is produced.

6.
Toads are amphibians. Only two species are native to Britain, the Common toad (Bufo bufo) and the Natterjack toad (Bufo calamita). Natterjack toads like warm sandy soil in open and sunny habitats, with shallow pools for breeding. Examples of these habitats are heathland and sand dunes. Common toads like cooler, more shady habitats, such as woodland.

Many areas of sand dunes are being developed for camp sites. Heathland can easily change to woodland as trees grow on it. In the summer, woodland is colder than heathland due to the shade the trees create. These conditions suit the Common toad, but not the Natterjack. As a result of the changing habitats the Natterjack toad is becoming an endangered species.

(a) (i) Name one external feature that identifies an animal as an amphibian.

(ii) Amphibians are a class of vertebrate. Name two other vertebrate classes. 1. 2.

(b) State one piece of information from the passage to show that the Common toad and Natterjack toad are closely related species.

(c) From the information provided, state two reasons why Natterjack toads are becoming endangered.

7.

Fig. 1.1 shows a food web for British toads.

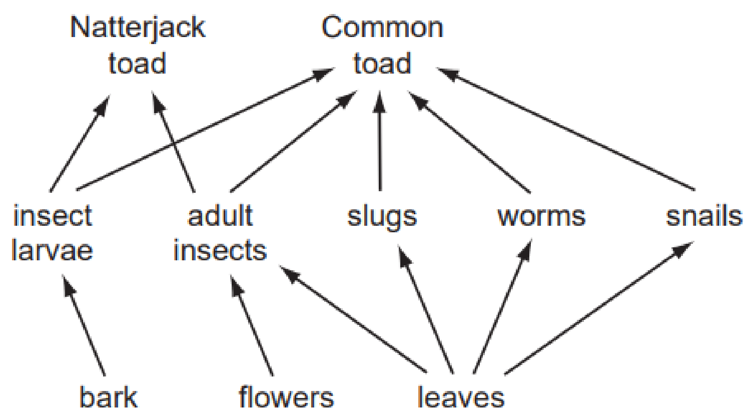


Fig. 1.1

(a) (i) State the trophic level of toads. [1]

(ii) State which foods the two species of toad both eat.

(iii) With reference only to food, suggest why the Common toad is more likely to survive when the two species are in competition.