SCHOLAR Study Guide

Higher Biology

Unit 3: Sustainability and Interdependence

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Contents

Topic 1

Food supply

Contents

Prerequisites

You should already know that:

- fertilisers and pesticides can be used to increase crop yield;
- at each level in a food chain 90% of energy is lost as heat, movement or undigested materials.

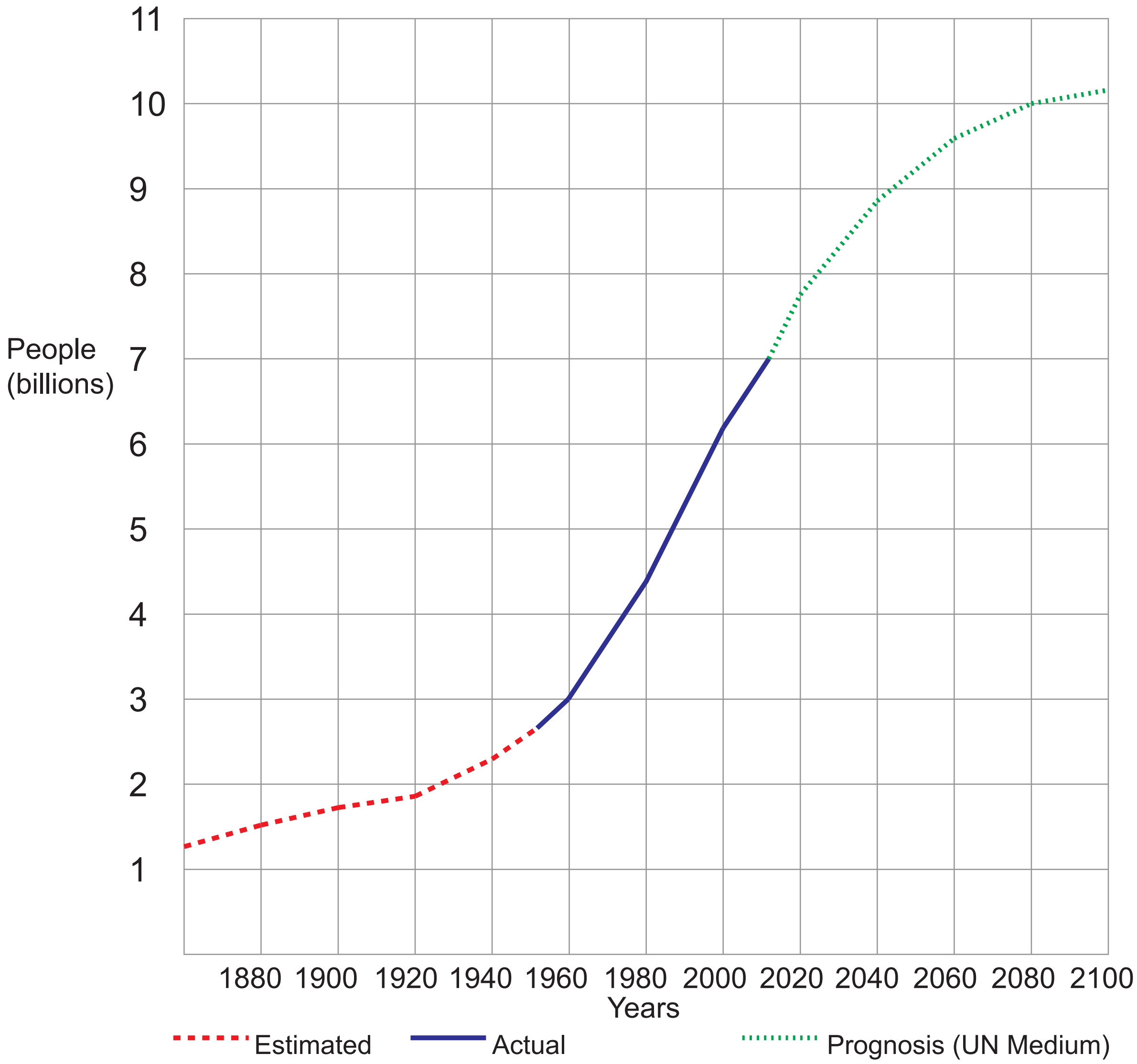
Learning objective

By the end of this topic, you should be able to:

- explain the need to increase global food production;
- describe the role of food security on a global market;
- describe the result of increase in human population on demand for increased food production;
- outline the need for sustainable food production;
- describe the need to ensure that food production does not degrade the natural resources on which agriculture depends;
- describe how all food production is ultimately dependent on photosynthesis;
- apply the knowledge that a small number of plant crops produce most human foods;
- describe the fact that if the area to grow crops is limited, increased food production will depend on other factors that control plant growth;
- describe how control of plant growth can be influenced by the breeding of high yielding cultivars;
- describe how protecting crops from pests, disease and competition can lead to increase in growth;
- outline why livestock produce less food per unit area than plant crops;
- outline the loss of energy between trophic levels;
- describe how livestock production may be possible in managed and wild habitats unsuitable for cultivation of crops.

1.1 Food security

Food security is the ability of human populations to produce food of sufficient quality and quantity. Such conditions for food security can be assessed on any scale, from a single household to a global scale.



The growing human population

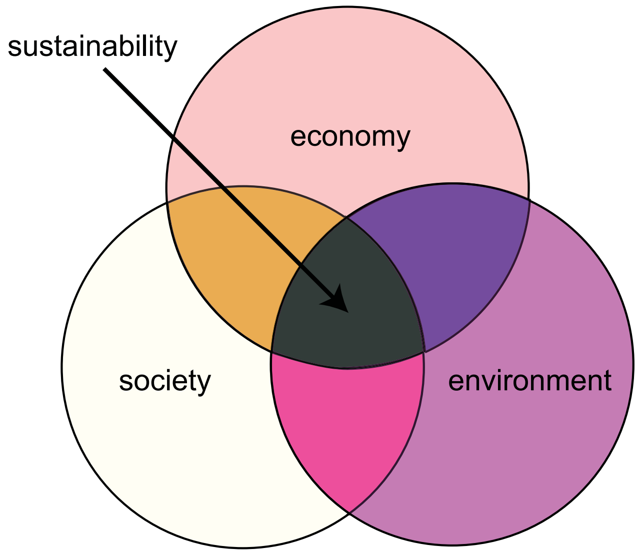
In 2011, the human population reached 7 billion. It is estimated that by 2050 this figure will increase to 9.4 billion. Sustaining this increasing population will not be possible without a change in agricultural practices.

There is also a demand that food production is sustainable and does not degrade the natural resources upon which agriculture depends. The Food and Agricultural Organization of the United Nations conclusion is that global food production must rise by 70% by 2050 to cater for growth in the world population of more than 30%.

Food production should be **sustainable**. Sustainability in food production can be defined as the ability of food systems to keep production and distribution going continuously without environmental degradation. It implies the ability to sustain the growth of food production to meet the demand for food in the future.

Sustainable food should be produced, processed and traded in ways that:

- contribute to thriving local economies and sustainable livelihoods - both in the UK and, in the case of imported products, in producer countries;
- protect the diversity of the environment for both plants and animals (and the welfare of farmed and wild species), and avoid damaging natural resources and contributing to climate change;
- provide benefits for society, such as good quality food, safe and healthy products, and educational opportunities.



Sustainable food production

1.2 Agricultural production - Food production and photosynthesis

All food production is dependent ultimately upon photosynthesis.

Photosynthesis is a chemical process that occurs in green plants which traps light energy and converts carbon dioxide and water into organic compounds, especially sugars, using the energy from sunlight and photosynthetic pigments in the green plant.

The summary equation for photosynthesis can be written as follows:

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

$6CO_2$	+	$6H_2O$	$\xrightarrow{\text{light}}$	$C_6H_{12}O_6$	+	$6O_2$
carbon dioxide		water		sugar		oxygen

Starch is produced after photosynthesis when large numbers of sugar units join together. Starch is produced by all green plants as an energy store. It is the most common carbohydrate in the human diet and is contained in large amounts in such staple foods as potatoes, wheat, maize (corn) and rice. Most human food comes from a small number of plant crops (cereals, potato, roots, and **legumes**) which contain starch and other food groups.

If the area to grow crops is limited, increased food production will depend on factors that control plant growth. For example the breeding of higher yielding **cultivars**. This means producing plants with an increased yield, disease/pest resistance, higher nutritional values, physical characteristics suited to rearing and harvesting or the ability to thrive in particular environmental conditions.

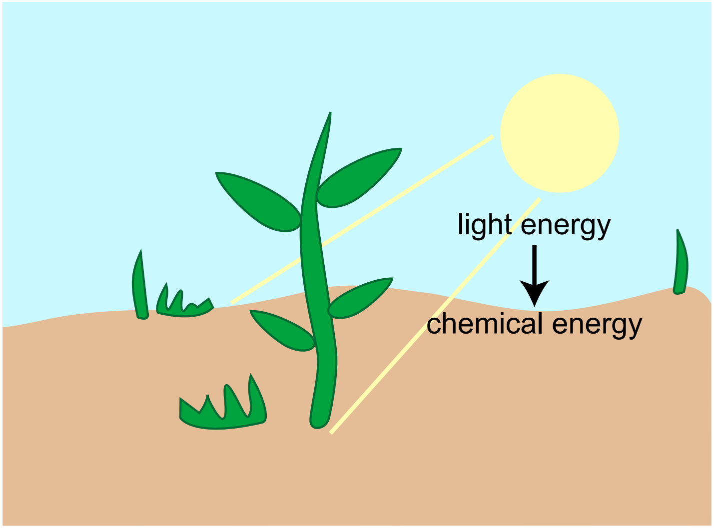
Methods of protecting crops from pests and diseases (for example through the use of pesticides) and reducing **competition** (for example through the use of herbicides) may also help to increase food production.

Agricultural production - Plant growth: How it works Go online

When light from the sun shines on a plant leaf, some of it is absorbed by special pigments (chemicals) in the leaf. These pigments use the energy from the sun to produce food in the process of photosynthesis. Photosynthesis takes place primarily in plant leaves and little to none occurs in plant stems. The process of photosynthesis takes place in chloroplasts in the leaf where photosynthetic pigments are located.

The most important photosynthetic pigment is chlorophyll. The chlorophyll molecules trap the energy from light to drive a series of chemical reactions. In photosynthesis, carbon dioxide from the atmosphere and water are converted into organic compounds (especially sugars) along with the release of oxygen gas as a waste product.

The sugars and other compounds produced from photosynthesis are used for plant growth and other essential metabolic processes in plants. In addition to maintaining normal levels of oxygen, photosynthesis is the source of energy for nearly all life on earth. The production of food for plants to allow them to grow is referred to as primary **productivity**. This source of energy can be passed onto animals when they consume plant material in their food. Therefore, photosynthesis is ultimately the source of almost all the food on earth.

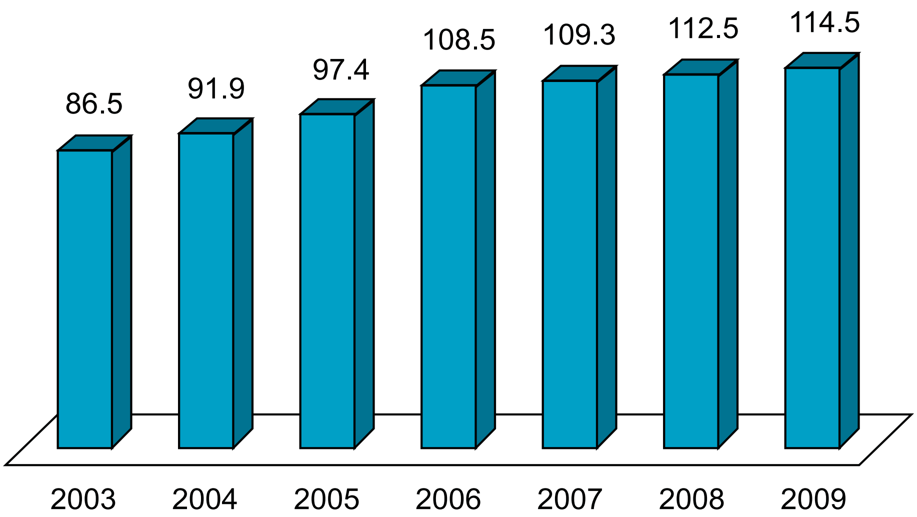


Agricultural production - Food production and photosynthesis: Questions Go online

Q1: Complete the table using the words listed.

Raw materials for photosynthesis	Essential requirements	Products of photosynthesis

Words: carbon dioxide, chlorophyll, light, oxygen, sugar, water.



Chinese wheat production

Note: a bushel is technically a unit of capacity and so the weight of grain in a bushel depends on the type of grain. For wheat, one bushel is about 27 kilograms.

The increase in wheat yield in China is due to spread of technologies including modern irrigation projects, pesticides which protect crops from pests, synthetic (man-made) nitrogen fertilisers and improved crop varieties or cultivars with higher yields of wheat.

Q2: Calculate the percentage increase in wheat production in China from 2003 to 2009 to one decimal point.

. . . .

Q3: Predict the level of wheat production in 2015 in million bushels.

. . . .

Q4: Give two reasons why this might not be reached.

1.3 Agricultural production - Food production and trophic levels

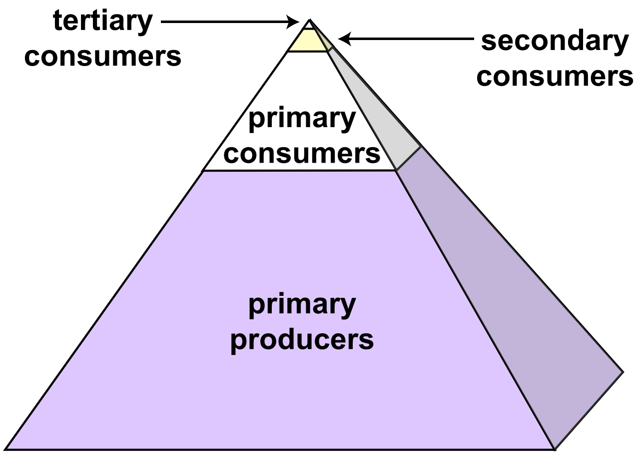
Livestock produce less food per unit area than plant crops due to loss of energy between **trophic levels**.

	Trophic levels
Trophic level 4	Second level carnivores: eat first level carnivore
	↑
Trophic level 3	First level carnivores: eat herbivores
	↑
Trophic level 2	Herbivores: eat plants
	↑
Trophic level 1	Plants: produce energy from the sun and nutrients

Trophic levels

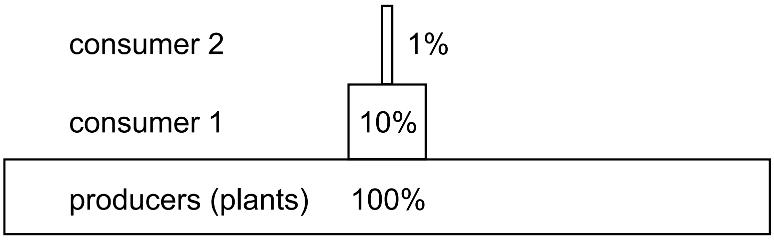
A food chain represents a succession of organisms that eat another organism and are, in turn, eaten themselves. The trophic level of an organism is the position it occupies in a food chain. The number of steps an organism is from the start of the chain is a measure of its trophic level.

Food chains start at trophic level 1 with primary **producers** such as plants, move to primary consumers (**herbivores**) at level 2, secondary consumers at level 3 and typically finish with tertiary consumers or apex **predators** at level 4. Secondary and tertiary consumers which feed on meat can be described as **carnivores**.



Pyramid of energy

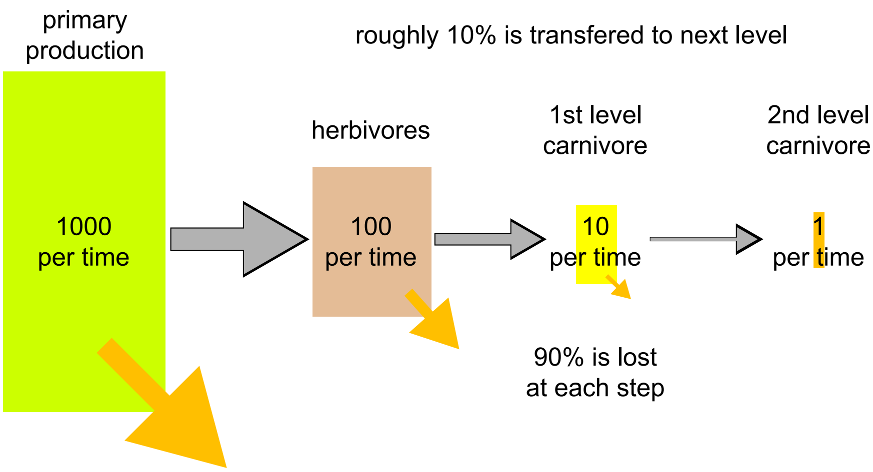
The efficiency with which energy or **biomass** is transferred from one trophic level to the next is called the ecological efficiency. Consumers at each level convert on average only about 10 percent of the chemical energy in their food to their own organic tissue. For this reason, food chains rarely extend for more than 5 or 6 levels.



Pyramid of energy

The amount of available energy available in a food chain decreases from one stage to the next. Some of the available energy goes into growth and the production of offspring. This energy becomes available to the next stage, but most of the available energy is used up in other ways:

- energy released by respiration is used for movement and other life processes, and is eventually lost as heat to the surroundings;
- energy is lost in waste materials, such as faeces.



Energy loss along a food chain

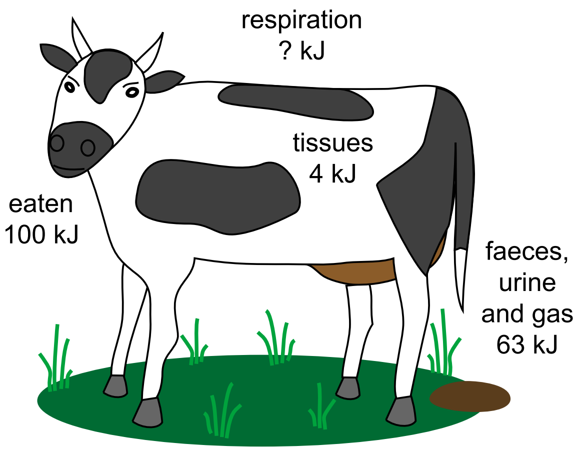
The efficiency of food production can be improved by reducing the amount of energy lost to the surroundings. This can be done by:

- preventing animals moving around too much;
- keeping their surroundings warm.

Mammals and birds maintain a constant body temperature using energy released by respiration. As a result, their energy losses are high. Keeping pigs and chickens in warm sheds with little space to move around allows more efficient food production. But this raises moral concerns about the lives of such animals. In reality, a balance must be reached between the needs of farmers and consumers and the welfare of the animals.

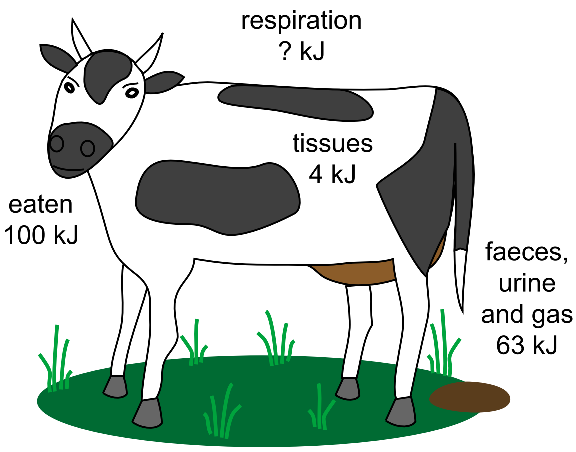
Agricultural production - Trophic levels: Questions Go online

Q5: From the information given in the diagram, how much energy in kJ is used in respiration?



. . . .

Q6: If only 4 kJ of the original energy available to the bullock is available to the next stage, which might be humans, what is the percentage efficiency of this energy transfer?



. . . .

Q7: Why is energy transfer between trophic levels inefficient?

. . . .

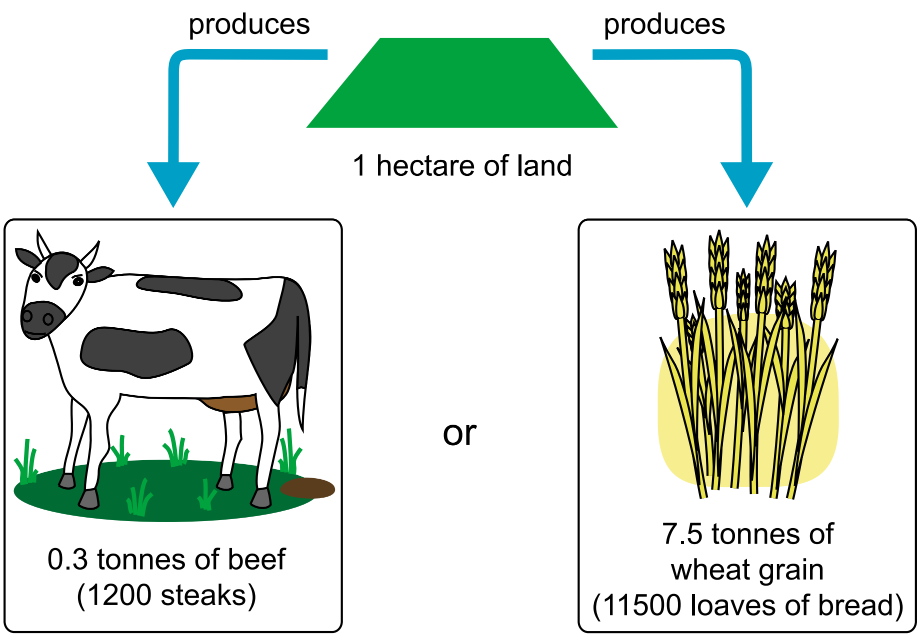
Q8: What happens to the energy that is not passed on at each stage of the food chain?

. . . .

Q9: How would changing to a plant-based diet help reduce world hunger?

1.4 Agricultural production - Efficient food production

Food production is more efficient if the food chain is short. There are fewer **trophic levels** at which energy can be lost and therefore a higher percentage of energy is available to humans.



Efficient food production

On average about 10 percent of net energy production at one trophic level is passed on to the next level. The nutritional quality of material that is consumed also influences how efficiently energy is transferred, because consumers can convert high-quality food sources into new living tissue more efficiently than low-quality food sources.

One of the consequences of loss of energy at each trophic level is that shorter food chains are more efficient than longer ones, as more energy is available to the final consumer.

Therefore the food chain:

wheat grain → ***human***

has two trophic levels and is more efficient than the food chain below which has three trophic levels:

grass → ***cow*** → ***human***

and therefore passes on less energy to humans.

From the earliest times, humans, who were unable to consume grass, learnt how to put it to good use by becoming herdsmen, long before they became farmers. Keeping **livestock** in fact enabled them to make the best use of spontaneous plant growth of this kind, and still remains the best way of turning primary production to good account in areas where, because of latitude or altitude, low temperatures or the limited amount of daylight do not permit farming.

Livestock production may be possible in managed and wild habitats unsuitable for cultivation of crops.

1.5 Learning points

Summary

- Food security is the ability of human populations to access food of sufficient quality and quantity.
- As a result of increase in human population and concern for food security, there is a continuing demand for increased food production.
- Food production should be sustainable.
- Food production should not degrade the natural resources on which agriculture depends.
- All food production is dependent ultimately upon photosynthesis.
- Most human food comes from a small number of plant crops.
- Due to limited area to grow crops, increased food production will depend on factors that control plant growth, for example the use of fertilisers to increase crop yield.
- Factors that increase food production are the breeding of higher yielding cultivars and protecting crops from pests, disease and competition.
- Livestock produce less food per area than plant crops due to loss of energy between trophic levels.
- Livestock production may be possible in managed and wild habitats unsuitable for the cultivation of crops.

1.6 Extension materials

The material in this section is not examinable. It includes information which will widen your appreciation of this section of work.

Extension materials: Measures against falling fish stocks

The number of cod in the North Sea has decreased dramatically in the past 20 years. In 1980 roughly 300,000 tons of cod were caught by fishermen in the North Sea, by 2001 this had fallen to 50,000 tons, and it is continuing to fall. There are huge problems for ensuring the survival of the stock.

The seas have been overfished and the number of cod has fallen dramatically. The quota of fish that can be removed has been drastically reduced and areas of the North Sea have been closed to fishermen to give the cod time to reproduce and replenish themselves.

The European Union (EU) has stated that a 40,000 square mile area of the North Sea, almost a fifth of its entire area, will be off limits for a couple of months for a few years to cod, haddock and whiting fishermen during the crucial spawning period for the fish, as part of a desperate attempt to ensure that the cod stock is not wiped out. This will put many trawlermen out of work, but it has been argued that it is essential if there are to be any cod left in the North Sea.

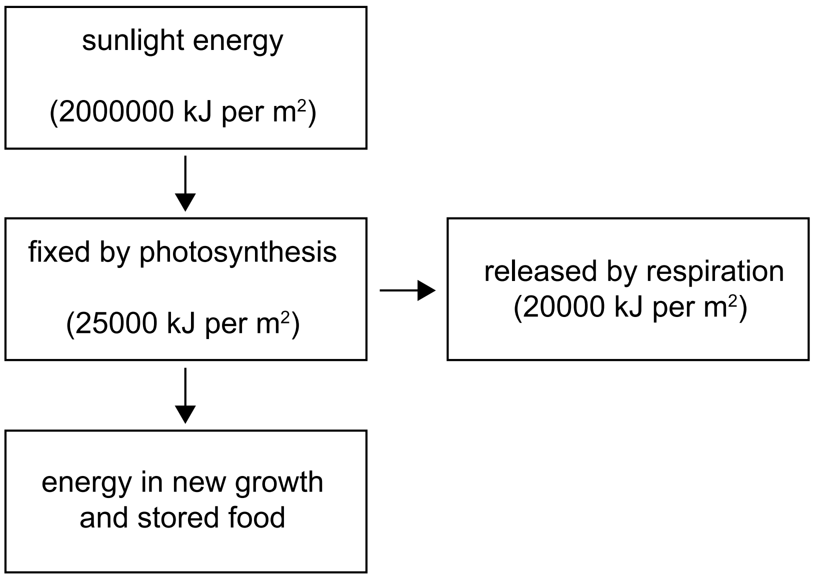
Cod stocks have fallen to their lowest levels in the last hundred years and quotas for the white fish were cut by 40% by EU ministers. An area from the north of Scotland to the east of England will be closed to trawlermen who take cod, haddock and whiting in the same nets. The North Sea ban will last from mid-February until the end of April. This is the crucial spawning period for cod. Some fishermen will be allowed into the so-called 'controlled zone' but these will be on the lookout for species which swim at higher level such as mackerel and the policy will be rigorously policed with on-board observers making sure that they do not catch any cod.

Norway, which manages North Sea fishing along with the EU, has already agreed to include other emergency measures such as forcing fishermen to apply for special permits and reporting what they catch in greater detail.

1.7 End of topic test

End of Topic 1 test Go online

Q10: The following flow chart shows the energy flow in a field of potatoes during one year.



What percentage of the available sunlight energy would be present in new growth and stored food in the potato crop?

a) 2.25
b) 1.25
c) 1.00
d) 0.25

. . . .

Q11: Organisms that obtain their energy directly from photosynthesis are known as:

a) herbivores.
b) producers.
c) first level carnivores.
d) second level carnivores.

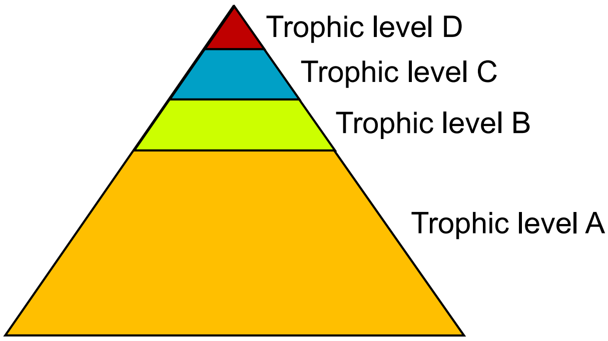
. . . .

Q12: Which of the following characteristics would a cultivar not be selected for and continually cultivated?

a) Increased yield of grain
b) Increased fruit production
c) Increased susceptibility to disease
d) Increased rate of growth

. . . .

Q13: The following diagram represents a food chain consisting of four trophic levels A, B, C and D.



Based on the diagram above, the greatest amount of energy (and biomass) in a healthy food chain will be found in:

a) trophic level A: producers.
b) trophic level B: primary consumers.
c) trophic level C: secondary consumers.
d) trophic level D: 3rd (tertiary) consumers.

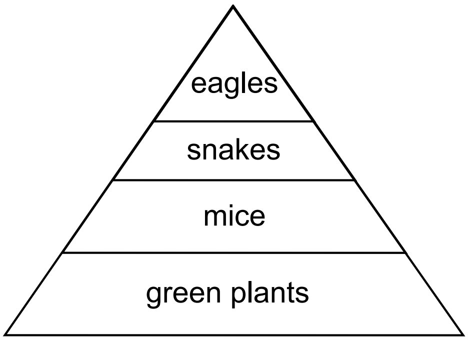
. . . .

Q14: A woodland ecosystem receives about 1,000,000 kJ m^{-2} $year^{-1}$ of solar energy. Of this, energy 96% is not used in photosynthesis. Which of the following shows the amount of energy captured by the producers in this ecosystem?

a) 400 kJ $m^{-2} year^{-1}$
b) 4,000 kJ $m^{-2} year^{-1}$
c) 40,000 kJ $m^{-2} year^{-1}$
d) 400,000 kJ $m^{-2} year^{-1}$

. . . .

Q15: The following diagram shows a food chain consisting of four trophic levels.



If 1,000 kJ of energy enters at the green plant trophic level, how much energy is available for use by the eagle?

a) 100 kJ
b) 10 kJ
c) 1 kJ
d) 0.1 kJ

. . . .

Q16: Upon which process does all food production ultimately depend?

. . . .

Q17: Why does the human population need to increase its rate of food production?

Topic 2

Plant growth and productivity

Contents

Prerequisites

You should already know that:

- photosynthesis is a series of enzyme-controlled reactions, in a two-stage process;
- during the light reactions, light energy from the sun is trapped by chlorophyll in the chloroplasts and is converted into chemical energy in the form of ATP;
- water is split to produce hydrogen and oxygen (excess oxygen diffuses from the cell);
- during carbon fixation, hydrogen and ATP produced by the light reaction is used with carbon dioxide to produce sugar;
- the chemical energy in sugar is available for respiration or can be converted into plant products such as starch and cellulose.

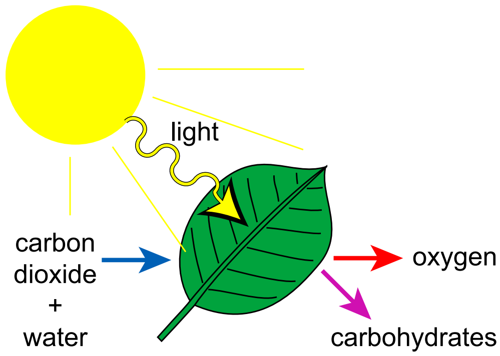
Learning objective

By the end of this topic, you should be able to:

- describe the fates of light as it strikes a leaf;
- give two reasons plants absorb light energy;
- give the meaning of the term absorption spectrum;
- state that each pigment absorbs a different range of wavelengths of light;
- describe the role of carotenoids;
- give the meaning of the term action spectrum;
- compare the absorption spectrum of chlorophyll a and b and carotenoids to action spectra for photosynthesis;
- describe how light energy is used to generate ATP;
- describe photolysis;
- describe the carbon fixation stage;
- describe the fates of glucose produced by photosynthesis.

2.1 Photosynthesis and energy capture

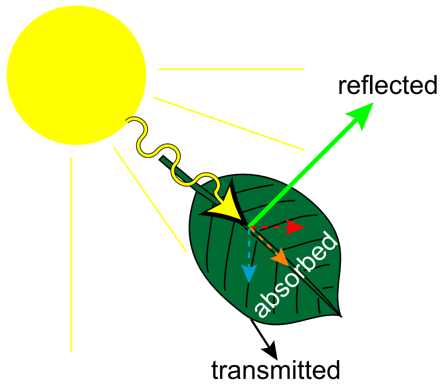
Photosynthesis converts light energy into chemical energy stored in carbohydrates (sugars) and other organic compounds. This process consists of a series of chemical reactions that require carbon dioxide (CO_2) and water (H_2O). Light energy from the sun drives the reaction. The light energy is trapped by photosynthetic pigments such as **chlorophyll** and stored as chemical energy in the carbohydrates produced. Oxygen (O_2) is a by-product of photosynthesis and is released into the atmosphere. The following equation summarises photosynthesis:



$6CO_2$	+	$6H_2O$	$\rightarrow$	$6(CH_2O)$	+	$6O_2$
carbon dioxide		water		sugar		oxygen

Photosynthesis

Only particular wavelengths of light that strike a leaf are **absorbed** by photosynthetic pigments but very little of the energy is actually converted into useful chemical energy. The rest of the light striking the leaf is either **reflected** off the leaf surface or is **transmitted** through the leaf. These processes are sometimes called the fates of light striking a leaf.



The fate of light striking a leaf

- Absorbed: Light is taken into the leaf (5%).
- Reflected: Light is bounced back from the leaf surface (85%).
- Transmitted: Light passes through the leaf (10%).

Of the light which is absorbed only a very small part is used for photosynthesis. The rest is lost, or radiated as heat from the leaf. Light is absorbed into organelles called **chloroplasts** that are found in the palisade layer of the leaf. Chloroplasts contain **chlorophyll**, a pigment that is essential for photosynthesis.

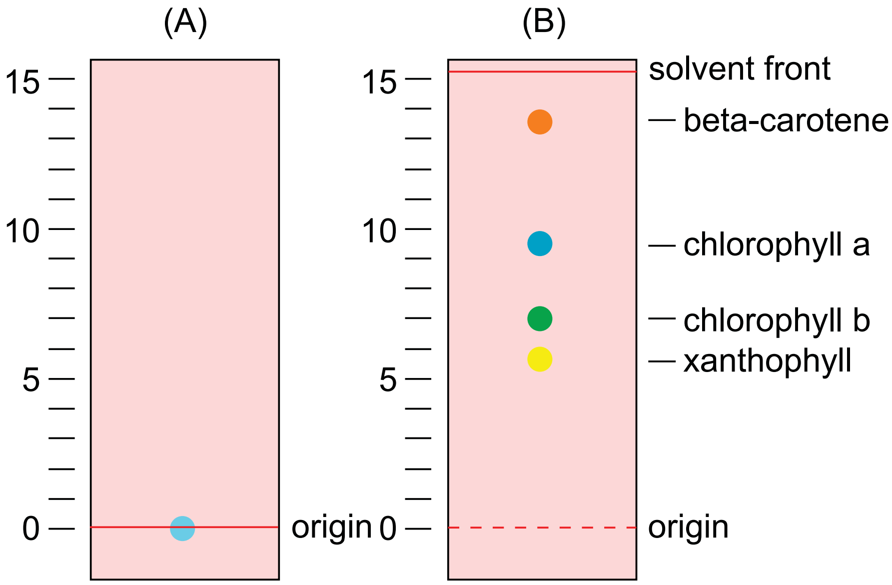
2.2 Photosynthetic pigments

The photosynthetic pigments absorb light energy and convert it into chemical energy. Chlorophyll a and b are the main photosynthetic pigments, they absorb mainly blue and red light wavelengths. The carotenoids are accessory pigments that absorb other wavelengths of light. The carotenoids extend the range of wavelengths absorbed and pass this energy onto **chlorophyll**.

Photosynthetic pigments: Thin layer chromatography Go online

This activity illustrates the separation of photosynthetic pigments by thin layer chromatography.

In (A), the sample has been spotted onto the plate. In (B), the solvent has moved to the top of the plate and the photosynthetic pigments have been separated.



Each of the four photosynthetic pigments has a characteristic Rf value. The Rf value is calculated by dividing the distance moved by the pigment (at the front or leading edge) by the distance moved by the solvent.

In this experiment, the solvent has moved a distance of 15.3 units. The pigment beta-carotene (a carotenoid) has moved a distance of 14 units, so the Rf value for beta-carotene is $\frac{14}{15.3}$ or 0.92.

Q1: What is the R_f value for xanthophyll (a carotenoid)?

a) 0.39
b) 0.49
c) 0.59
d) 0.69

. . . .

Q2: What is the R_f value for chlorophyll b?

a) 0.28
b) 0.38
c) 0.48
d) 0.58

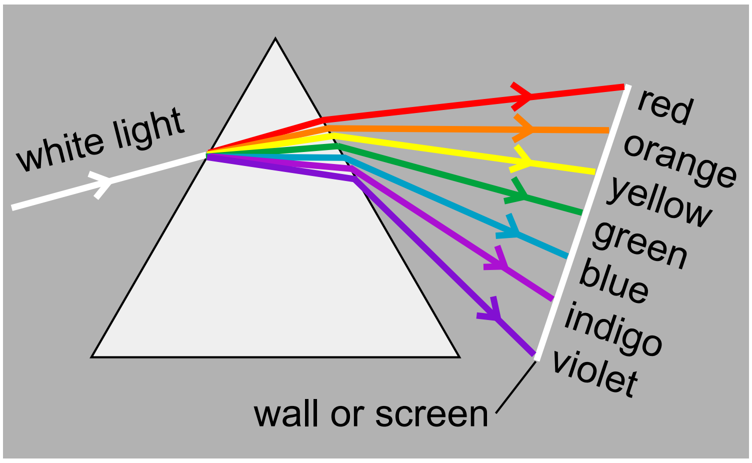
. . . .

Q3: What is the R_f value for chlorophyll a?

a) 0.34
b) 0.44
c) 0.54
d) 0.64

2.3 The spectrum of light

The spectrum of light can be seen if a beam of light is shone through a glass prism onto a screen. The spectrum is a rainbow of colours of different wavelengths.

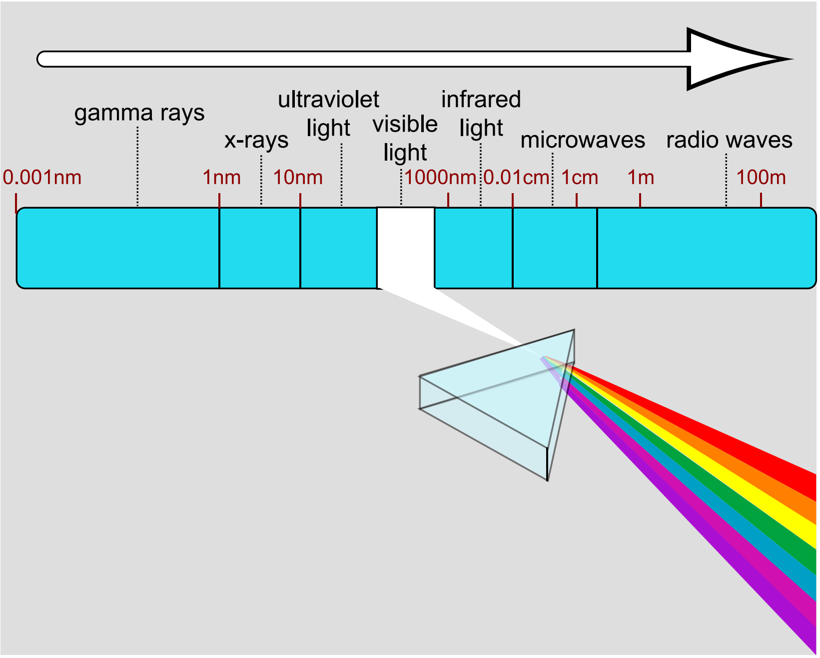


Light split into its spectrum by a prism

Colours of the spectrum of light: red, orange, yellow, green, blue, indigo and violet.

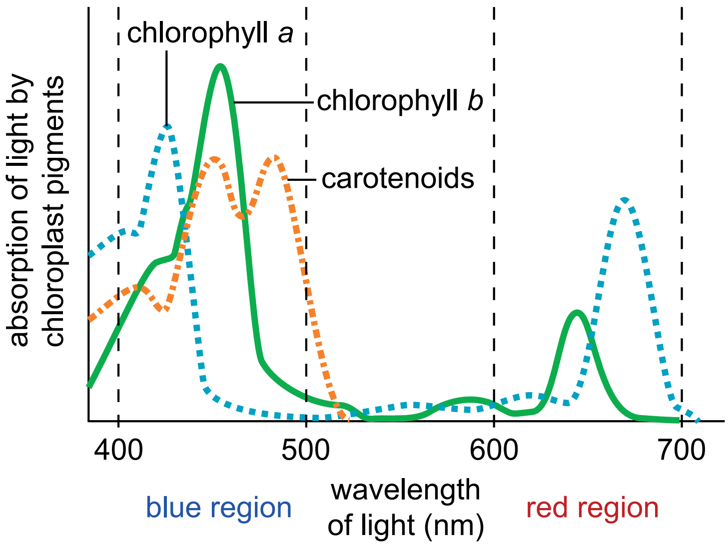
The spectrum of light: The colour spectrum of visible light Go online

This activity shows what happens when visible light passes through a prism. It is the blue and red parts of visible light that are directly absorbed by chlorophyll.



2.4 Absorption spectrum

The absorption spectrum shows the extent to which different colours of light are absorbed by a pigment. This can be shown as a graph.



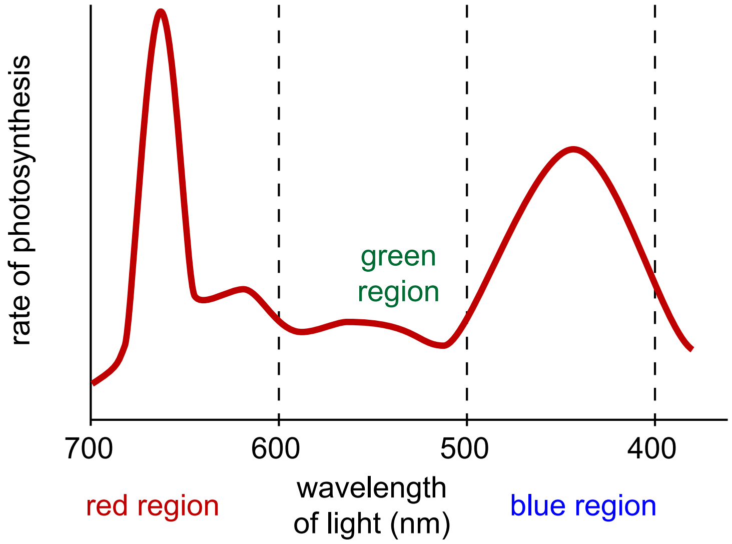
The absorption spectra of chlorophyll a, b and carotenoids

The graph shows that there is limited absorption between wavelengths 500-650 nm which is the green region of the spectrum with most light reflected or transmitted. This is why most plants are green in colour.

Chlorophyll a and b absorb mainly in the blue and red regions of the spectrum. The carotenoids extend the range of wavelengths available for photosynthesis and pass this energy onto **chlorophyll**.

2.5 Action spectrum

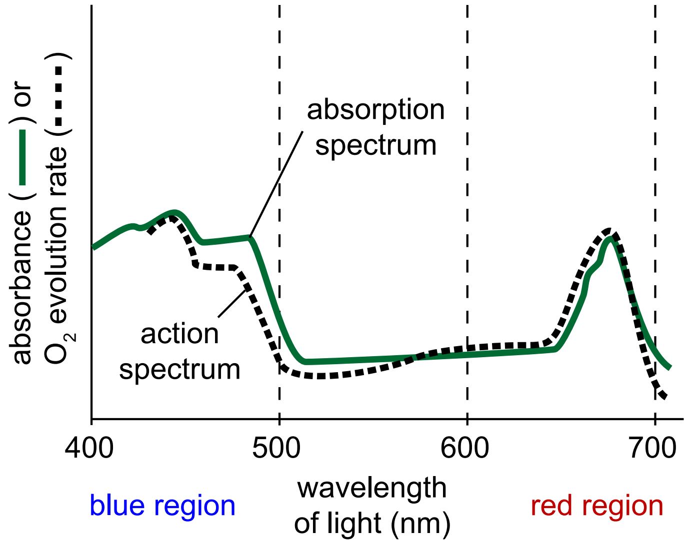
The action spectrum shows the rate of photosynthesis carried out in different wavelengths of light. Again, this can be shown as a graph.



Action spectrum

The graph shows the rate of photosynthesis is highest in the red and blue regions of the spectrum.

If the action spectrum for photosynthesis is placed on top of the absorption spectrum for photosynthetic pigments, you can see that the two are very closely related. This shows that the pigments are involved in absorption of light for photosynthesis.



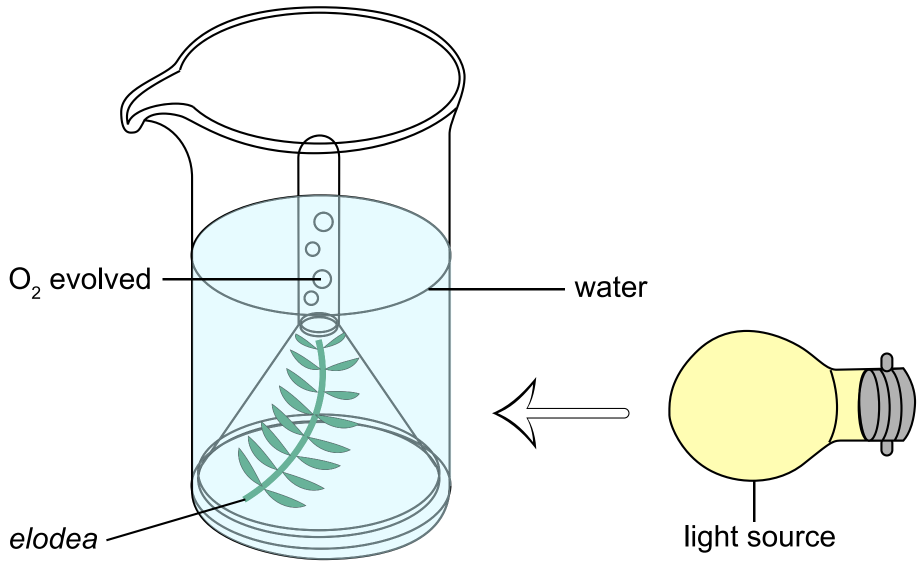
Absorption spectrum and action spectrum combined

Action spectrum: An experiment to determine an action spectrum for photosynthesis

Go online

The following experiment was carried out to investigate which parts of the visible light spectrum are used in photosynthesis.

- A sample of the aquatic plant Elodea, with the cut edge of the stem uppermost, was added to a beaker of water. Water was added to ensure the plant was fully covered.
- A lamp was placed 20 cm from the beaker to provide a light source.
- The plant was allowed to photosynthesise without treatment for 10 minutes.
- Coloured filters (blue, green, yellow and red) were placed at separate times between the lamp and the plant. The number of oxygen bubbles produced in a 2 minute period was counted.



The following table shows the results of the experiment.

Colour of filter	Number of oxygen bubbles produced
Blue	20
Green	5
Yellow	9
Red	16

Q4: Which wavelengths of light are used for photosynthesis? Plot the results of the experiment on a graph with the number of oxygen bubbles produced on the y-axis and the colour of filter (the wavelength of light) on the x-axis.

. . . .

Q5: What conclusion can you draw from these results?

. . . .

Q6: Why is it necessary to allow the plant to photosynthesise without treatment before carrying out the experiment?

2.6 First stage of photosynthesis: The light-dependent stage

Photosynthesis is a series of enzyme-controlled reactions that occurs in the chloroplasts of plants.

- In photosynthesis, organic molecules such as carbohydrates and amino acids are **synthesised** by the reduction of carbon dioxide.
- The energy to drive the reactions comes from light.
- Light energy is **absorbed** into the pigments contained in plant cell **chloroplasts**.

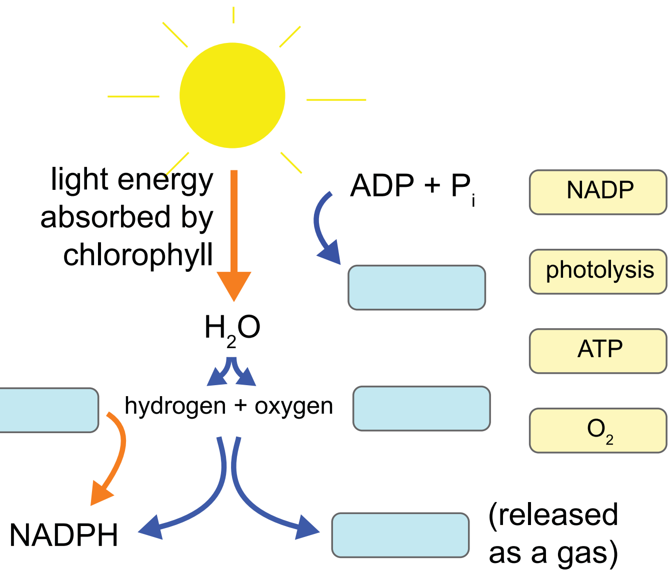
The first stage of photosynthesis is dependent on light and is often referred to as the **light reaction**. If a pigment molecule absorbs light energy, an electron in the molecule becomes excited i.e. the electron's energy level is raised to become a high-energy electron. These high-energy electrons can then be transferred through the electron transport chain to bring about production of **ATP** by the enzyme ATP synthase.

The energy is also used for the photolysis of water. Water is split into oxygen which is evolved as a by-product of the reaction, and hydrogen which is transferred to the coenzyme **NADP** and combined to produce NADPH. The ATP and NADPH produced in the light reaction of photosynthesis are used in the next stage of photosynthesis referred to as the carbon fixation stage (**Calvin Cycle**).

The following activity summarises the light-dependent stage of photosynthesis.

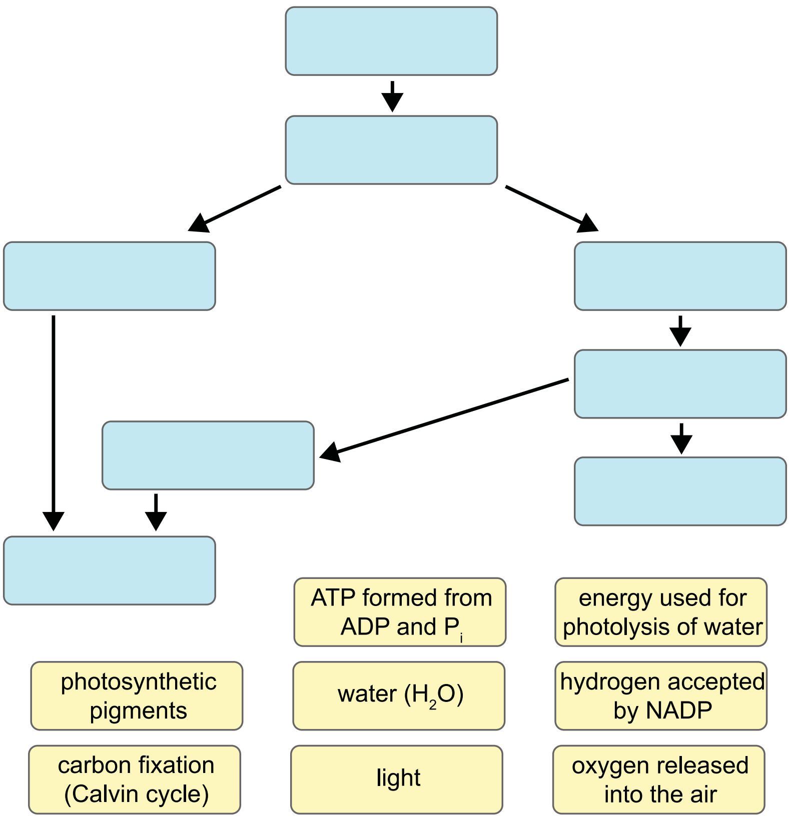
The light-dependent stage Go online

Q7: Complete the labelling of the diagram using the terms listed to the right.



. . . .

Q8: Complete the labelling of the diagram using the words and phrases listed underneath.



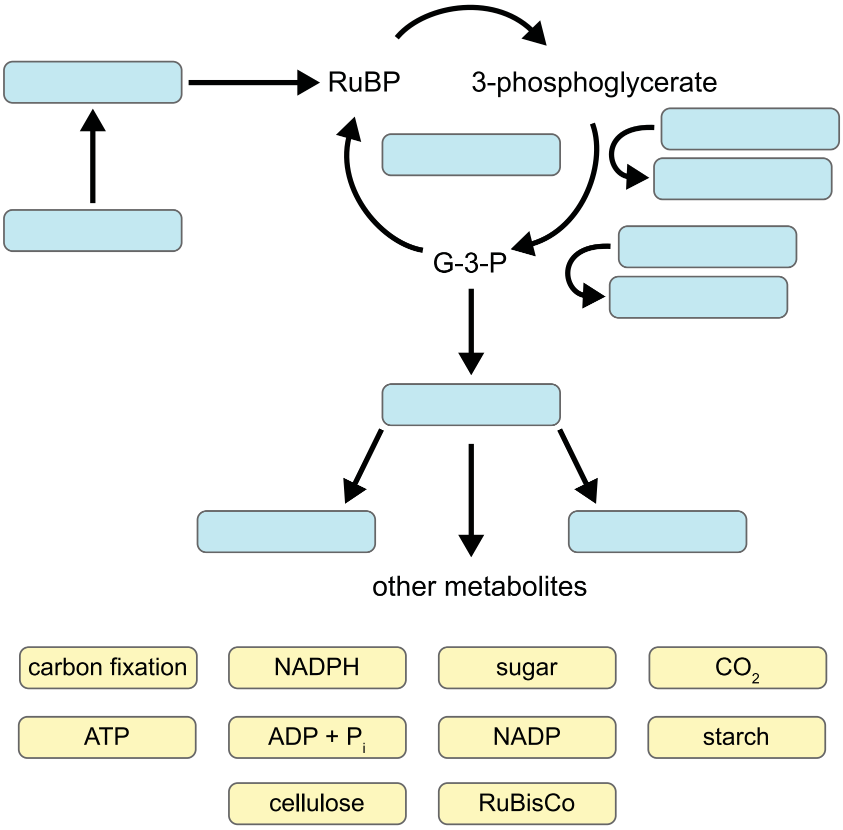
2.7 The second stage of photosynthesis: The carbon fixation stage

The second stage of photosynthesis is known as the carbon fixation stage or the **Calvin Cycle**. This stage does not require light. In this reaction carbon dioxide is converted into sugars using **ATP** and **NADPH** from the **light reaction**.

In the carbon fixation stage, the enzyme Ribulose-1,5-bisphosphate carboxylase oxygenase, commonly known by the shorter name **RuBisCO**, fixes carbon dioxide (CO_2) from the atmosphere. RuBisCO fixes carbon dioxide by attaching it to RibuloseBisPhosphate (**RuBP**) to form 3-phosphoglycerate. The 3-phosphoglycerate produced is phosphorylated by ATP and combined with hydrogen from **NADPH** to form the stable compound glyceraldehyde-3-phosphate (**G-3-P**). G-3-P is used to regenerate RuBP and for the synthesis of glucose. Glucose may be used as a respiratory substrate, synthesised into starch or cellulose or passed to other biosynthetic pathways. These biosynthetic pathways can lead to the formation of a variety of **metabolites** such as DNA, protein and fat.

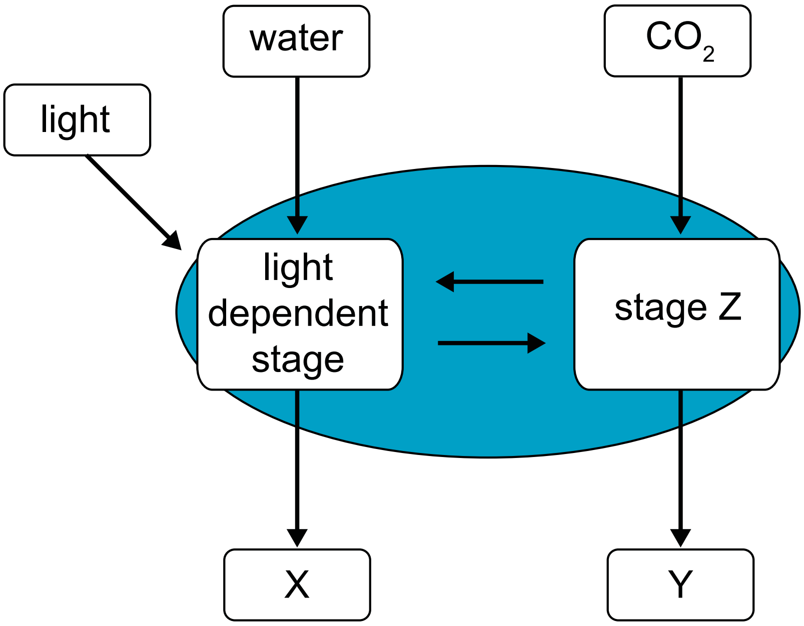
The second stage of photosynthesis: The carbon fixation stage Go online

Q9: Complete the carbon fixation diagram using the terms listed underneath.



The second stage of photosynthesis: Questions Go online

The following diagram summarises the process of photosynthesis in a chloroplast of a leaf.



Use the diagram to answer the following questions.

Q10: Name the molecules X and Y.

. . . .

Q11: In the light-dependent stage water is split up into its constituent components using light energy. What term is used to describe this splitting of water?

. . . .

Q12: Name stage Z.

. . . .

Q13: Molecule Y can be converted into a cell wall component. Name the cell wall component.

. . . .

Q14: Name two molecules formed in the light-dependent stage which are required for stage Z.

2.8 Learning points

Summary

- Light striking a leaf is transmitted, reflected or absorbed.
- Chlorophylls a and b are the major pigments involved in absorption of light.
- The wavelengths of light that are absorbed by a photosynthetic pigment are called its absorption spectrum.
- The absorption spectrum of chlorophyll is closely related to the rate of photosynthesis.
- Absorption of light by chlorophyll occurs mainly in the blue and red regions of the spectrum.
- Carotenoids extend the range of wavelengths absorbed and pass the energy to chlorophyll for photosynthesis.
- The wavelengths of light actually used by a pigment in photosynthesis are called its action spectrum.
- Photosynthesis is a series of enzyme-controlled reactions that synthesise carbohydrates from carbon dioxide and water.
- Photosynthesis occurs in two stages: the light dependent stage and the carbon fixation stage.
- In the light dependent stage, light energy is used to regenerate ATP, absorbed light energy excites electrons in the pigment molecule, these high-energy electrons are transported through electron transport chain and generate ATP by ATP synthase.
- Light energy is also used to split a water molecule into hydrogen and oxygen, a process called the photolysis of water.
- Oxygen is evolved from the leaf as a by-product.
- The hydrogen is transferred to the carbon fixation stage by the hydrogen acceptor NADP that becomes reduced to form NADPH.
- The ATP from the light dependent stage is transferred to the carbon fixation stage.
- The enzyme RuBisCO fixes carbon dioxide from the atmosphere by attaching it to RuBP.
- The 3-phosphoglycerate produced is phosphorylated by ATP and combined with the hydrogen from NADPH to form G-3-P.
- G-3-P is used to produce sugars such as glucose which may be synthesised into starch, cellulose or other metabolites.
- G-3-P is also used to regenerate RuBP to continue the cycle.
- Major biological molecules in plants such as proteins, fats, carbohydrates and nucleic acids are derived from the photosynthetic process.

2.9 Extended response question

The activity which follows presents an extended response question similar to the style that you will encounter in the examination.

You should have a good understanding of photosynthesis before attempting the question.

You should give your completed answer to your teacher or tutor for marking, or try to mark it yourself using the suggested marking scheme.

Extended response question: Plant growth and productivity

A) Discuss the role of light and photosynthetic pigments in photosynthesis. *(8 marks)*

B) Give an account of the light-dependent stage of photosynthesis and the carbon fixation stage. *(8 marks)*

2.10 End of topic test

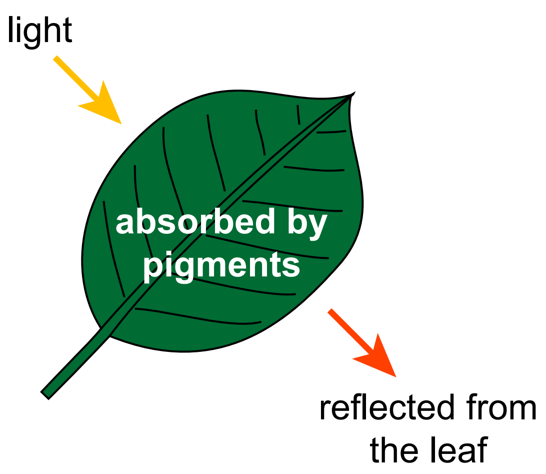
End of Topic 2 test Go online

Q15: The action spectrum of photosynthesis is a measure of the ability of plants to:

a) absorb all wavelengths of light.
b) absorb light of different intensities.
c) use light to build up foods.
d) use light of different wavelengths for photosynthesis.

. . . .

Q16: The following diagram contains information about light striking a leaf.

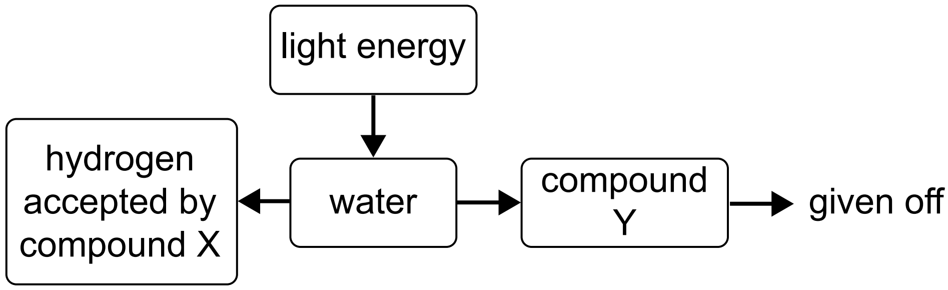


1. Apart from being absorbed or reflected, what can happen to light which strikes a leaf?

2. Pigments that absorb light are found within leaf cells. State the location of these pigments within leaf cells.

....

Q17: The following diagram shows part of the light dependent stage of photosynthesis.



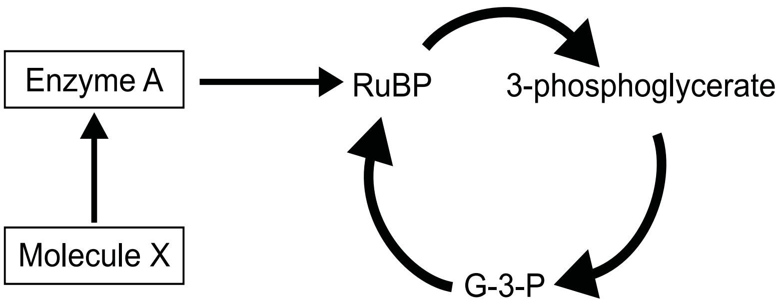
1. Name this part of the light dependent stage.
2. Name compound X.
3. Name compound Y.

....

Q18: As well as chlorophyll, plants have other photosynthetic pigments. State the benefit to the plant of having these other pigments.

....

Q19: The following diagram is a simplified version of the carbon fixation stage.



1. Enzyme A fixes molecule X by attaching it to RuBP. Name molecule X.
2. Name Enzyme A.

....

Q20: Hydrogen is formed in the light stage of photosynthesis and is required for the carbon fixation stage. Name ONE other substance which is produced in the light stage and is also required for the carbon fixation stage.

....

Q21: Which of the following changes in concentration of the chemicals RuBP and G-3-P would occur if an illuminated green plant cell's source of carbon dioxide were removed?

	RuBP	**G-3-P**
A	Increase	Increase
B	Decrease	Decrease
C	Increase	Decrease
D	Decrease	Increase

. . . .

Q22: Complete the table about the first stage in the chemistry of photosynthesis by matching the terms to the descriptions.

Term	**Description**
	Product of the photolysis of water which is required for aerobic respiration.
	Compound which accepts hydrogen during the photolysis of water.
	Raw material which becomes split into oxygen and hydrogen during photolysis of water.
	Components of a high-energy compound.
	Breakdown of water during the light- dependent stage of photosynthesis.
	Product of photolysis of water which becomes attached to NADP.
	Green pigment which traps light energy.
	First stage in photosynthesis in which light energy is converted to chemical energy.

Terms: ADP + P_i, Chlorophyll, Hydrogen, Light dependent reaction, NADP, Oxygen, Photolysis, Water.

. . . .

Q23: Complete the table about the carbon fixation stage in the chemistry of photosynthesis by matching the terms to the descriptions.

Term	Description
	Structure found in a leaf where photosynthesis takes place.
	Hydrogen acceptor needed for the fixation of carbon in carbohydrates.
	Carbon compound which acts as a carbon dioxide acceptor.
	First stable compound formed in the carbon fixation stage (Calvin Cycle) after carbon dioxide combines with its acceptor molecule.
	Raw material which supplies carbon atoms to be fixed into carbohydrates.
	High-energy compound used to phosphorylate the intermediate compound in carbon fixation (Calvin Cycle).
	Second stage in photosynthesis which is also known as the carbon fixation stage (Calvin Cycle).
	The enzyme which fixes carbon dioxide by attaching it to RuBP.

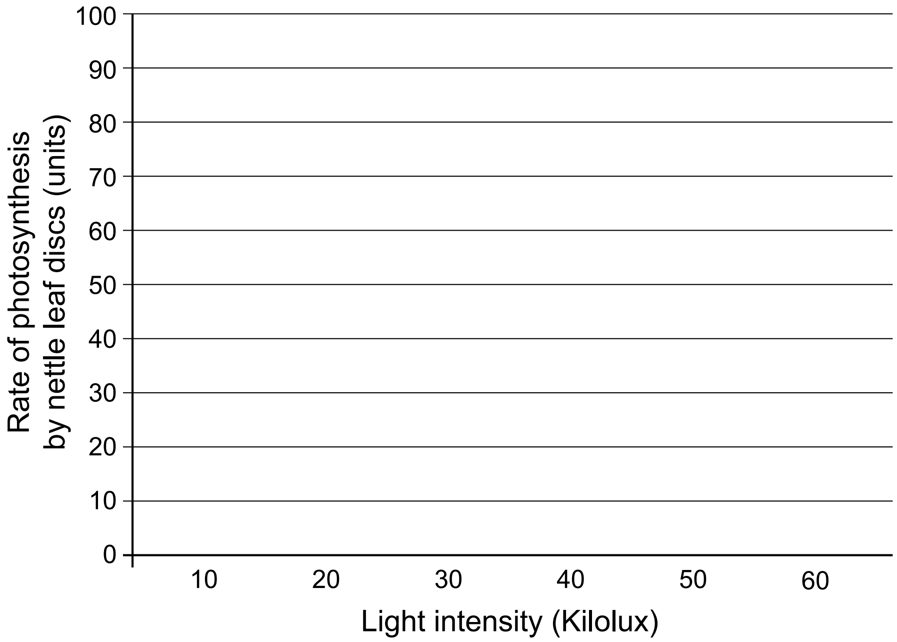
Terms: ATP, Carbon dioxide, Carbon fixation, Chloroplast, G-3-P, NADPH, RuBisCO, RuBP.

. . . .

Q24: In an investigation, the rate of photosynthesis by nettle leaf discs was measured at different light intensities. The results are shown in the following table.

Light intensity (Kilolux)	Rate of photosynthesis by nettle leaf discs (Units)
10	4
20	28
30	60
40	90
50	92
60	92

1. Plot a line graph to show the rate of photosynthesis by nettle leaf discs at different light intensities. Use appropriate scales to fill most of the graph paper. (*2 marks*)
2. From the table, predict how the rate of photosynthesis at light intensities of 50 kilolux could be affected by an increase in carbon dioxide concentrations. Justify your answer.

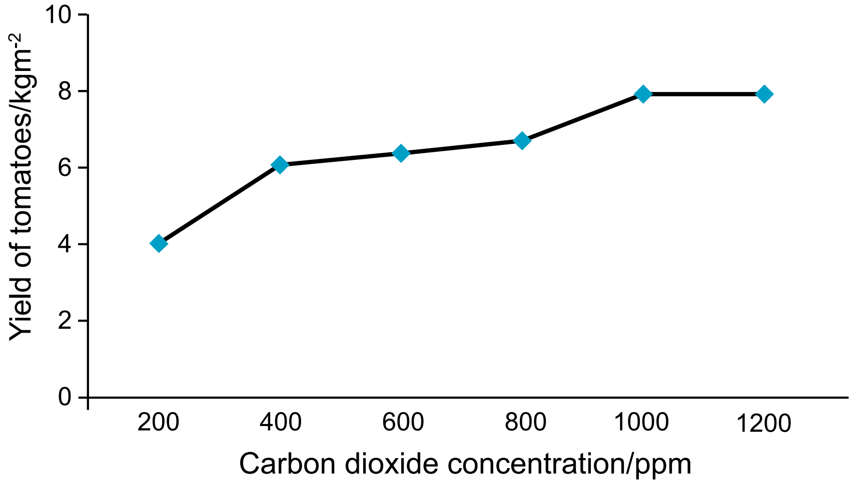


. . . .

Q25: An investigation was carried out into the effect of carbon dioxide concentration on yield. Tomato plants were cultivated in glasshouses, where it was possible to control the concentration of carbon dioxide in the atmosphere.

The carbon dioxide concentrations ranged from 50 to 1200 parts per million (ppm) per volume. The yield of tomatoes was measured in kg per m^2. The temperature and light intensity conditions were constant for all concentrations of carbon dioxide.

The results are shown in the following graph.



1. Describe the effect of increasing the carbon dioxide concentration on the yield of tomatoes. (*2 marks*)
2. The normal concentration of carbon dioxide in the atmosphere is 300 ppm. From the graph, determine the yield of tomatoes when the concentration in the glasshouse was 300 ppm.

3. Calculate the percentage change in yield that would be expected if the tomatoes were grown in an atmosphere where the carbon dioxide concentration was increased to 1000 ppm compared with the yield at 200 ppm.

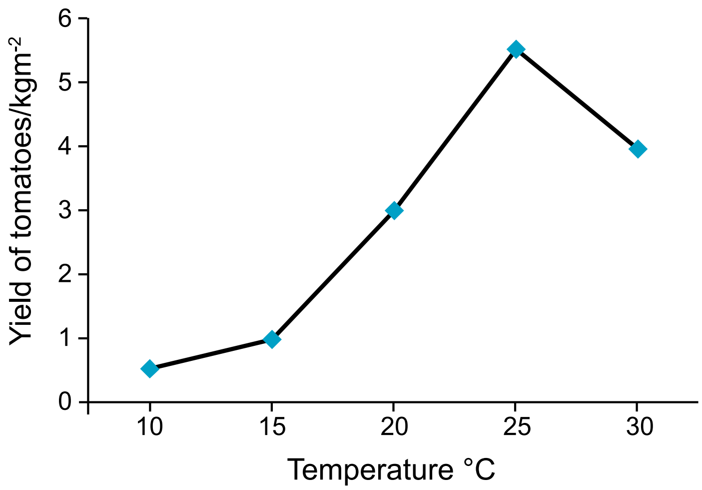
. . . .

Q26: Explain why carbon dioxide concentration affects the yield of tomatoes.

. . . .

Q27: A further experiment was carried out to investigate the effect of temperature on yield. In this experiment the carbon dioxide concentration was 300 ppm and the light intensity remained constant.

The results are shown in the following graph.



1. Compare the yield of tomatoes at 15°C with that at 25°C and suggest an explanation for the difference in yield. (*2 marks*)
2. Calculate the percentage increase in yield of tomatoes from 15°C to 25°C.
3. Name one factor, other than light, temperature and carbon dioxide concentration, which could affect the yield of tomatoes grown in a glasshouse. (*1 mark*)
4. Suggest an explanation for the shape of the graph between 25°C and 30°C.

Topic 3

Plant and animal breeding

Contents

Prerequisites

You should already know that:

- an increasing human population requires an increased food yield;
- GM crops may be an alternative to mitigate the effects of intensive farming on the environment;
- alleles are the different forms of a gene;
- homozygous means having the same alleles for a particular gene;
- heterozygous means having different alleles for a particular gene.

Learning objective

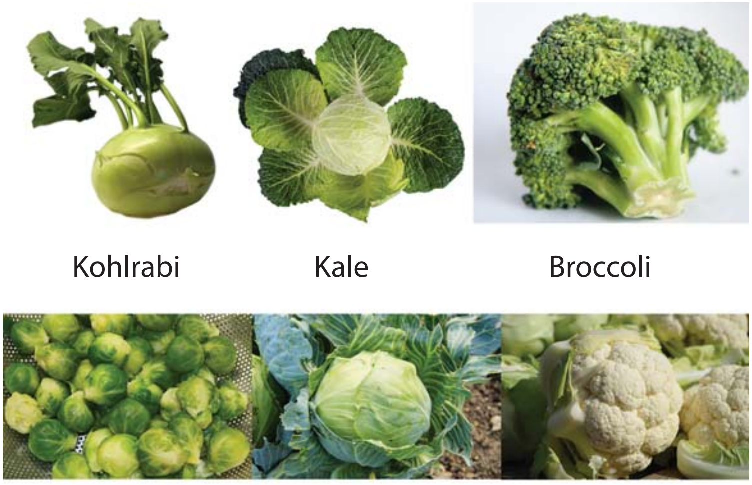
By the end of this topic you should be able to:

- state that plant and animal breeding involves the manipulation of heredity;
- state that this manipulation will allow the development of new and improved organisms to provide sustainable food sources;
- describe the characteristics that breeders seek to develop in crops and stock;
- describe the process of artificial selection;
- explain the need for plant field trials;
- explain that trials are carried out in a range of environments to compare the performance of different cultivars or treatments;
- explain the factors which have to be taken into account when designing field trials including:
  - the selection of treatments to ensure fair comparison;
  - the number of replicates to take account of the variability within the sample;
  - the randomisation of treatments to eliminate bias when measuring treatment effects;
- describe the process of inbreeding;
- understand that inbreeding depression is the accumulation of recessive, deleterious homozygous alleles;
- explain how new alleles can be introduced to plant and animal lines;
- describe how, in animals, individuals from different breeds may produce a new crossbreed population with improved characteristics;
- state that the F2 generation will have a wide variety of genotypes;
- state that, in plants, F1 hybrids, produced by the crossing of two different inbred lines, creates a relatively uniform heterozygous crop;
- state that F1 hybrids often have increased vigour and yield;
- describe how as a result of genome sequencing, organisms with desirable genes can be identified and then used in breeding programmes;
- explain that genetic transformation techniques allow a single gene to be inserted into a genome;
- describe how this reprogrammed genome can be used in breeding experiments.

3.1 Introduction

Rice, wheat, maize, barley, sorghum, millet and sugar cane are grasses that have been adapted for human use. Humans have bred these grasses for plumper seeds, taller stems, earlier ripening and resistance to drought, rain, insects or disease. The area of land given over to crops such as these continues to increase. Together grasses supply around 15 percent of carbohydrates and more than 50 percent of protein to the human population.

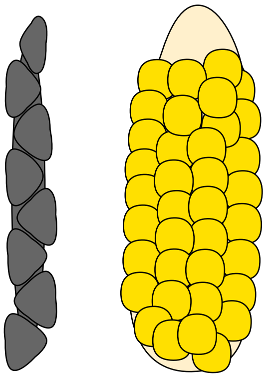
All the plants in the figure below are derived from one wild species, the wild cabbage, *Brassica oleracea*. Humans have taken this wild plant and, over the centuries, shaped it into these different kinds of foods. This form of selection in which humans have improved characteristics in organisms is known as **artificial selection**.



Kohlrabi Kale Broccoli

Brussels sprouts Cabbage Cauliflower

Artificial selection has generated diversity in both plants and animals. In **agriculture**, superior strains of corn, wheat, and soybeans have resulted from careful breeding.



Teosinte (left) and its modern descendent, corn (right), a product of artificial selection.

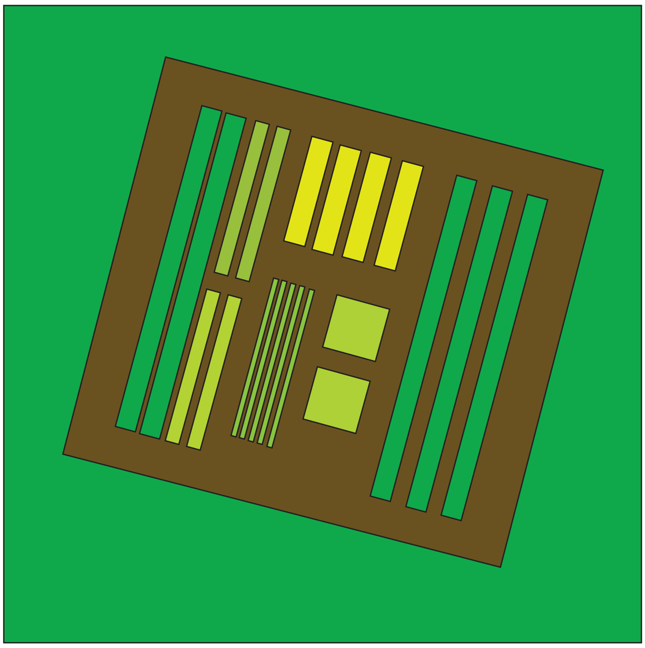
Plant and animal breeding involves the manipulation of heredity to develop new and improved organisms to provide sustainable food sources. Breeders seek to develop crops and stock with higher yield, higher nutritional values and resistance to pests and diseases. Other physical characteristics suited to rearing and harvesting have also been developed, as well as those characteristics which enable crops and stock to thrive in particular environmental conditions.

Wheat is one example of a crop which has undergone artificial selection for centuries. By the mid 1900s farmers had managed to produce high yielding wheat plants but they were so tall that the heavy seed heads caused them to fall over in the wind, making the seeds fall to the ground and rot. By crossing a tall high yielding variety of wheat with a dwarf variety, farmers were able to produce a short plant with a high yield which could withstand windy conditions.

3.2 Field trials

The aim of plant breeding is to produce **cultivars** that will have good yield in the growth conditions typical for that crop. Final crop growth is a result of both genetic and environmental factors; a new plant variety may grow well in a laboratory environment however its performance will have to be evaluated in field trials. Plant field trials are carried out in a range of environments to compare the performance of different cultivars or treatments. Field trials can also be used to evaluate genetically modified (GM) crops.

Field trials have to be carefully and scientifically monitored to ensure accurate results are obtained and there are no adverse effects on the environment. Field trials are carried out in an area of land which is divided into plots. Each plot is given a different treatment for example varying herbicide concentration or used to grow a different variety of crop.



Plant field trials

In designing plant field trials account has to be taken of the selection of treatments, the number of replicates and the randomisation of treatments.

The selection of treatments must be considered to ensure fair comparisons. For example several plots may be given different quantities of herbicide to ensure a variety of treatments can be compared. There must be an adequate number of replicates to take account of the variability within the sample; in other words several replicates of each plot must be performed. The treatments must also be randomised to eliminate bias when measuring treatment effects. Randomisation means ensuring that replicate plots are not always in the same orderly sequence.

Field trials may show that a new variety of plant is not only superior to existing ones but is capable of growing in conditions where existing varieties would fail. For example maize for animal fodder can now be grown in northern parts of Scotland and most of the wheat for bread making in the UK is now grown in the UK rather than being imported from North America as a result of the development of new varieties.

Field trials: Question Go online

Q1: Complete the following table by matching the design features of field trials to the reasons for carrying out procedures.

Design feature	Reason for carrying out this procedure
	To eliminate bias when measuring treatment effects.
	To take account of the variability within a sample.
	To ensure fair comparison.

Design features: Selection of treatments; Number of replicates; Randomisation of treatment.

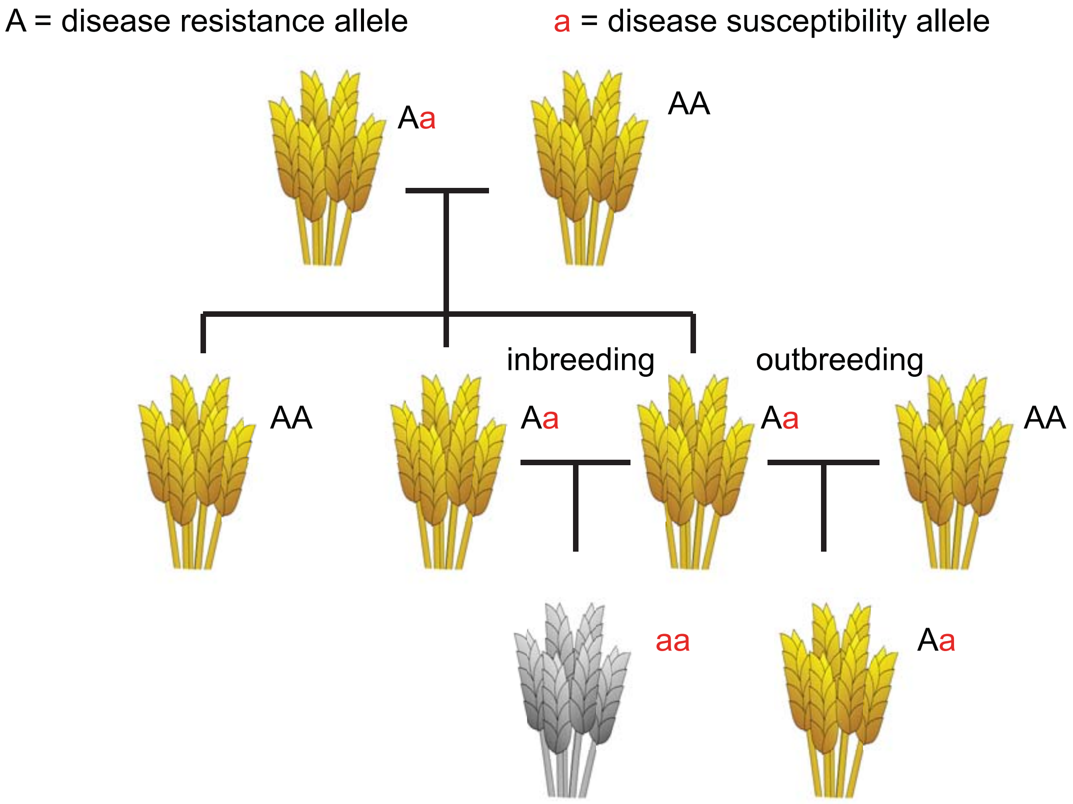
3.3 Inbreeding

Outbreeding is the mating or breeding of unrelated individuals. Outbreeding often prevents the expression of deleterious (harmful) traits because the recessive **allele** controlling the trait is masked by a dominant allele.

Inbreeding is the mating or breeding of closely related individuals. When inbreeding is performed for long periods of time, there is a loss of **heterozygosity**. This means plants or animals become **homozygous** for the trait being selected. In inbreeding selected plants or animals are bred for several generations until the population breeds true to the desired type due to the elimination of heterozygotes. This means all the offspring are homozygous for the desired trait i.e. disease resistance.

Although inbreeding can select for desirable characteristics the accumulation of other homozygous alleles can cause the expression of deleterious (harmful) recessive alleles. This is referred to as **inbreeding depression** and may result in reduced yield. This generally leads to a decreased fitness of a population.

The cross below shows what can happen to a variety of wheat when inbreeding occurs. There is a chance that a combination of two recessive deleterious (harmful) alleles (aa) will be produced.



Some of the consequences of inbreeding depression include; reproductive failures, poor health, small litters, reduced immune system, high susceptibility to infections and shorter lives.

3.4 Cross breeding and F1 hybrids

Inbreeding cannot be carried out indefinitely; eventually deleterious **alleles** will accumulate and cause **inbreeding depression**. New alleles can be introduced to plant and animal lines by crossing a **cultivar** or breed with an individual with a different, desired **genotype**.

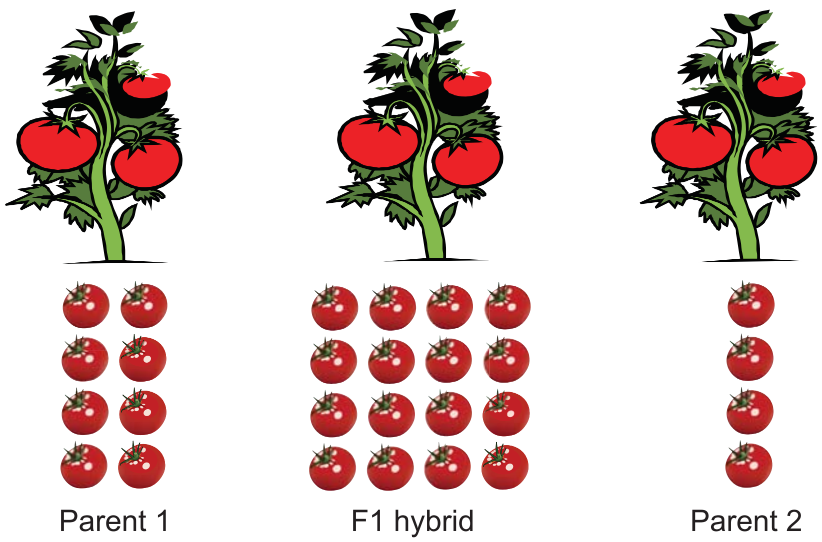
For example, different breeds of sheep show variation in their fertility, rate of meat production, disease resistance and wool quality. A breeder may choose to **crossbreed** a variety of sheep which has a good rate of meat production with a different breed which has a high lambing rate. The offspring of this mating are known as the F1 generation and they receive half their genetic information from one parent and half from the other. A series of back crosses are then performed to eliminate any unwanted genetic material from the new breed, whilst maintaining the desired characteristic.

A backcrossing is a crossing of a heterozygous organism showing a desirable characteristic with one of its homozygous parents showing the same desirable characteristic. The offspring showing the desired characteristics are selected to parent the next generation and another backcross is performed. This process is repeated until much of the unwanted genetic material is lost and only the desirable characteristics remain.

In plants, F1 hybrids, produced by the crossing of two different inbred lines, create a relatively uniform heterozygous crop. F1 hybrids often have increased vigour and yield. As an F2 population will have a wide variety of genotypes, a process of selection and backcrossing is required to maintain the new breed. Alternatively the two parent breeds can be maintained to produce more heterozygous F1 hybrids.

3.5 F1 Hybrids

Two parent plants from different inbred lines can be crossed to produce hybrid offspring. These offspring are heterozygous, usually show a uniform phenotype and are known as F1 hybrids. F1 hybrids often have increased vigour. This means they have a bigger yield and/or increased fertility or have other improvements compared to their parents. In the following example, the hybrid plant has a greater yield than either parent.

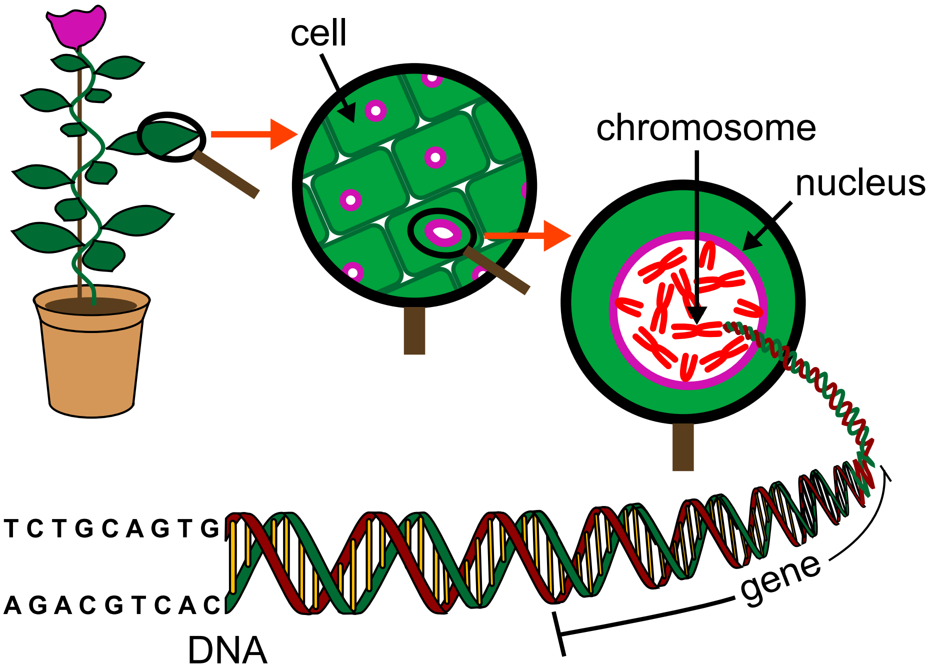


Hybrid vigour

F1 hybrids have a high degree of heterozygosity. This means when the F1 generation is self-crossed, the F2 generation will show a variety of genotypes. The F2 generation is described as genetically variable and is of little use for further production although it can provide a source of new varieties.

3.6 Genetic technology

As humans have made advances in technology, genetic sequencing and genetic transformation now play an important role in plant and animal breeding.



Gene sequences

Genome sequencing involves discovering the sequence of bases within an organism's genome. The information generated by this process can be used to identify organisms with specific desirable gene sequences. This organism can then be used in breeding programmes to produce offspring also showing the desirable characteristic.

Artificial selection can only draw on the natural variation within a species. Breeders sometimes want to combine a desirable characteristic from one species with another species. If genetic information from one species is to be transferred to another, techniques of genetic engineering are used.

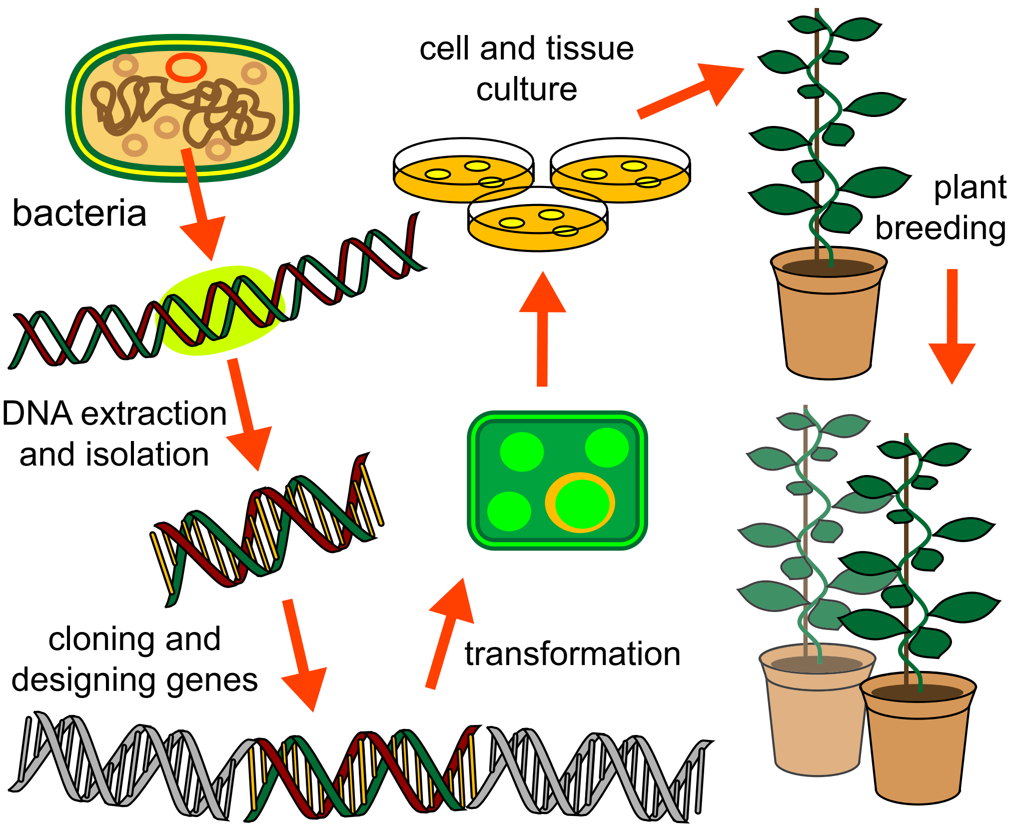
Genetic transformation techniques allow a single gene to be inserted into a genome and this genome can then be used in breeding programmes. For example, insect resistant cotton uses a gene from a naturally occurring soil bacterium to provide it with built-in insect protection. The use of insect resistant cotton has reduced pesticide use over 80 percent in Australia.

Glyphosate

Glyphosate is a widely available herbicide which is extensively used by farmers and gardeners to control weeds. Genetically modified soybeans containing the glyphosate resistance gene for herbicide tolerance are now commercially available. Along with other agricultural crops such as soy, maize, alfalfa, canola and sorghum, these genetically modified plants have had the glyphosate gene inserted into their own genome. These cultivars greatly improve conventional farmers' ability to control weeds, since glyphosate could be sprayed on fields without damaging the crop. As of 2013, 90% of U.S. soybean fields were planted with glyphosate-resistant varieties.

Bt toxin

Bt toxin is produced by the bacterium *Bacillus thuringiensis* (Bt) in an inactive form (protoxin), which is transformed to its active form (delta-endotoxin) in the guts of certain insects. The active toxin binds to receptors in the gut, killing the insect. By means of genetic engineering, the genes for the active agent (Bt toxin) can be transferred from Bt bacteria to plants. There they produce the toxic agent inside the plant cells. In this way, biotechnology has been used to confer insect resistance to a number of economically important crops. Bt maize and Bt cotton are widely grown in several countries.



Transfer of Bt toxin gene to plants

3.7 Learning points

Summary

- Plant and animal breeding allows breeders to improve characteristics to help support sustainable food production.
- Breeders develop crops and animals with higher food yields, higher nutritional values, pest and disease resistance and ability to thrive in particular environmental conditions.
- Plant field trials are carried out in a range of environments to compare the performance of different cultivars or treatments and to evaluate GM crops.
- In designing field trials account has to be taken of the selection of treatments, the number of replicates and the randomisation of treatments.
- The selection of treatments to ensure valid comparisons, the number of replicates to take account of the variability within the sample, and the randomisation of treatments to eliminate bias when measuring treatment effects.
- In inbreeding, selected related plants or animals are bred for several generations until the population breeds true to the desired type due to the elimination of heterozygotes.
- A result of inbreeding can be an increase in the frequency of individuals who are homozygous for recessive deleterious alleles. These individuals will do less well at surviving to reproduce. This results in inbreeding depression.
- In animals, individuals from different breeds may produce a new crossbreed population with improved characteristics. The two parent breeds can be maintained to produce more crossbred animals showing the improved characteristic.
- In plants, F1 hybrids, produced by the crossing of two different inbred lines, create a relatively uniform heterozygous crop. F1 hybrids often have increased vigour and yield.
- In inbreeding animals and plants, F1 hybrids are not usually bred together as the F2 produced shows too much variation.
- New alleles can be introduced to plant and animal lines by crossing a cultivar or breed with an individual with a different, desired genotype.
- Plants with increased vigour may have increased disease resistance or increased growth rate.
- As a result of genome sequencing, organisms with desirable genes can be identified and then used in breeding programmes.
- Single genes for desirable characteristics can be inserted into the genomes of crop plants, creating genetically modified plants with improved characteristics.
- Breeding programmes can involve crop plants that have been genetically modified using recombinant DNA technology.
- Recombinant DNA technology in plant breeding includes insertion of Bt toxin gene into plants for pest resistance and glyphosate resistance gene inserted for herbicide tolerance.

3.8 Extension materials

The material in this section is not examinable. It includes information which will widen your appreciation of this section of work.

Extension materials: The cheetah

The cheetah originated about 4,000,000 years ago, long before the other big cats. The oldest fossils place it in North America in what is now Texas, Nevada and Wyoming. Cheetahs were common throughout Asia, Africa, Europe and North America until the end of the last Ice Age, about 10,000 years ago, when massive climatic changes caused large numbers of mammals to disappear. About that time all cheetah in North America and Europe and most of those in Asia and Africa vanished.

Some experts think our present populations were derived from inbreeding by those very few surviving and closely related animals. This inbreeding 'bottleneck', as theorised, led to the present state of cheetah genetics. All cheetahs are very genetically similar to each other and as a result, the 12,500 cheetahs that are alive now do not have enough genetic diversity to protect them from a micro-biological crisis such as a bad feline virus. If one cheetah dies from a virulent pathogen that comes along, there is a strong chance that a very high proportion of cheetahs could die from it also. This unusually low genetic variability in cheetahs is accompanied by a very low sperm count, reduced sperm motility, and deformed flagella on the sperm. These are the consequences of inbreeding depression in cheetahs.

3.9 End of topic test

End of Topic 3 test Go online

Q2: Give one example of a characteristic which breeders may attempt to improve in a plant or animal species.

. . . .

Q3: In inbreeding, selected plants or animals are bred for several generations until the population breeds true to the desired type due to the elimination of _________.

Choose from:

- homozygotes;
- heterozygotes.

. . . .

Q4: Pedigree dogs are produced by mating members of the same breed with one another. This often results in the production of offspring suffering conditions which affect their fitness. For example, bulldogs have problems with their breathing and Labradors are prone to arthritis.

This phenomenon is know as:

a) hybrid depression.
b) natural selection.
c) inbreeding depression.
d) selective breeding.

. . . .

Q5: The bacterium *Bacillus thuringiensis* produces a substance called T-toxin that is poisonous to leaf-eating insects. The following information shows some of the procedures used by genetic engineers to insert the gene for the production of T-toxin into crop plants.

Procedure 1	chromosome extracted from the bacterial cells
	↓
Procedure 2	position of T-toxin gene located
	↓
Procedure 3	T-toxin gene cut out from bacterial chromosome
	↓
Procedure 4	T-toxin gene transferred into nucleus of host plant
	↓
Procedure 5	plant cells containing T-toxin gene grown into small plants

Explain why such genetically engineered crop plants would grow better than unmodified crop plants.

. . . .

Q6: These crops were commercially successful for several years. However, they have since become susceptible to attack by some members of a particular insect species.

Suggest a reason that would account for this observation.

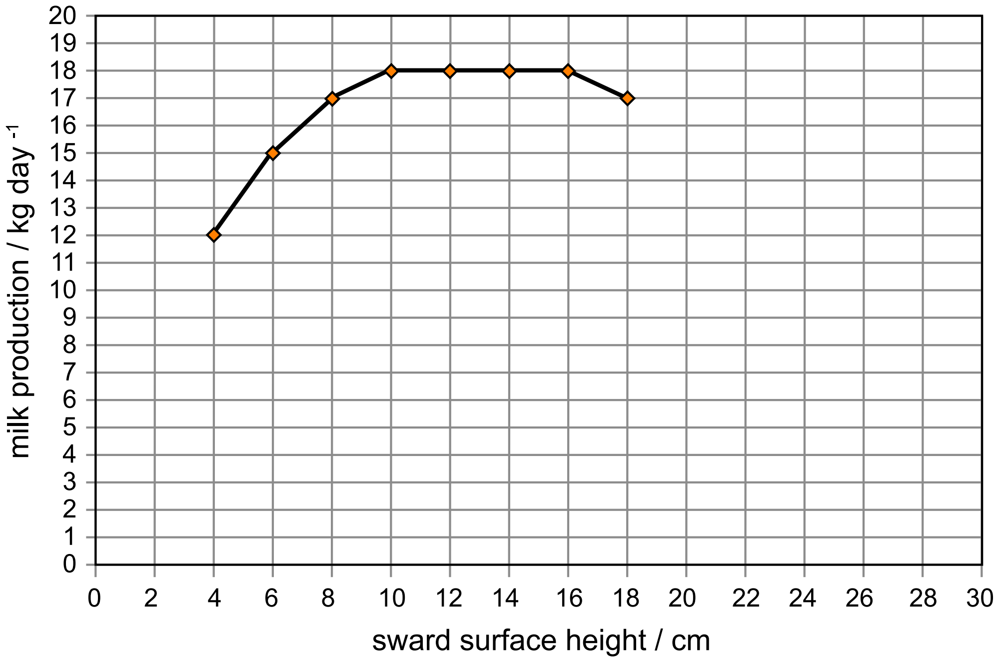
. . . .

Q7: In order to produce a supply of hybrids showing genetic uniformity, horticulturists often maintain two different true-breeding parental lines of a species of bedding plant. The hybrids cannot be used as the parents of the next generation because:

a) hybrids of annual plants always form sterile seeds.
b) the hybrids are heterozygous and therefore not true breeding.
c) a high mutation rate occurs amongst hybrid gametes.
d) hybrid vigour cannot be passed onto the next generation.

. . . .

Q8: *Sward height* (the height of the vegetation) is a useful practical indicator of the availability of herbage (grass and other plants) to grazing animals. Sward surface height can be measured by placing a ruler vertical so that the lower edge just touches the ground. The height of the tallest leaf at that point is recorded. The following graph shows the influence of sward surface height on milk production in kg day^{-1} from spring-calving cows.



Describe the relationship between milk production and the sward surface height.

. . . .

Q9: Using the information on the graph, suggest a suitable minimum sward height needed for grazing lactating dairy cows.

Topic 4

Crop protection

Contents

Prerequisites

You should already know that:

- pesticides are used to kill unwanted pests on crops;
- pesticides which are sprayed onto crops can accumulate in the bodies of organisms over time;
- as pesticides are passed along food chains, toxicity increases and can reach fatal levels;
- biological control involves using natural predators to kill the pests;
- biological control may be an alternative to mitigate the effects of intensive farming on the environment.

Learning objective

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

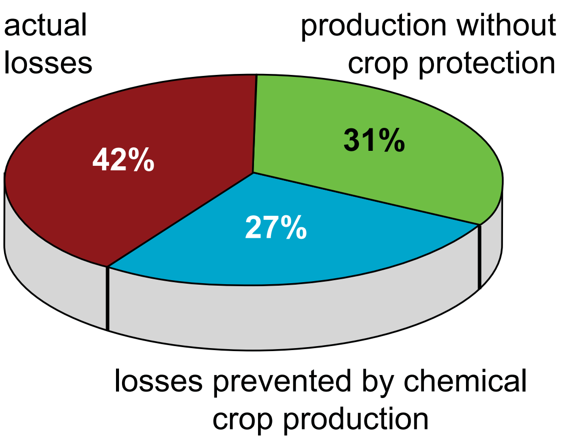
- explain why crop protection is important;
- state that pests and weeds compete with crop organisms for resources, so yield is reduced;
- describe the properties of annual weeds;
- describe the properties of perennial weeds;
- state that most of the pests of crop plants are invertebrate animals such as insects, nematode worms and molluscs;
- state that plant diseases can be caused by fungi, bacteria or viruses, which are often carried by invertebrates;
- state that pests and weeds can make infection by pathogens more likely;
- state that chemical control of pests involves using herbicides, fungicides or insecticides;
- understand that chemical control relies on use of chemical pesticides to kill pests;
- describe the roles of herbicides, fungicides, pesticides and insecticides;
- describe the differences between selective and systemic pesticides;
- explain that protective applications of fungicide based on disease forecasts are often more effective than treating a diseased crop;
- describe the potential problems associated with pesticides including:
    - toxicity to animal species;
    - persistence in the environment;
    - accumulation in food chains;
    - magnification in food chains;
    - production of resistant populations;
- understand that biological control involves using natural predators or parasites to kill the pests;
- describe some of the risks associated with biological control;
- explain that integrated pest management combines chemical, biological and cultural control.

4.1 Introduction

Monoculture is the agricultural practice of producing or growing one single crop over a wide area. It is widely used in modern industrial agriculture and its implementation has allowed for large harvests from minimal labour. Due to this practice in agriculture, crop protection is essential to ensure a sustained supply of good quality harvests. Crop protection is the branch of horticulture concerned with protecting crops from pests, weeds and disease.

Monoculture

Today many agricultural systems use monoculture, which involves expansion of land devoted to single crops and year-to-year production of same crop species on the same land. In these conditions **weed** competitors and pest and disease populations can multiply rapidly, reducing sustainability.



Crop production

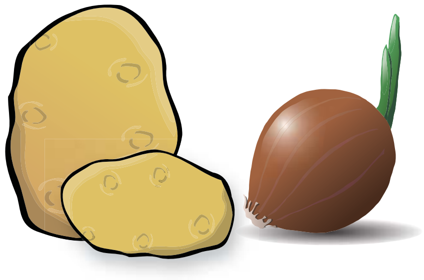
The diagram above is an estimation of the contribution made by world-wide crop protection to the production of eight principal food and cash crops. As can be seen in the diagram, losses prevented by chemical crop protection are about 27% (weeds 16%, animal pests 7% and diseases 4%) of attainable production in the eight principal crops. Nevertheless, about 42% of the total production of these crops is lost to weeds (13%), animal pests (16%) and pathogens (13%), representing a market value of about 244 billion US$.

4.2 Weeds, pests and diseases

A **weed** in a general sense is a plant that is considered to be a nuisance, and is normally applied to unwanted plants in human-controlled settings, especially farm fields and gardens. Generally, a weed is a plant in an undesired place.

Annual weed plants grow, flower, set seed and die all within the space of one year. Due to the fact that they are short-lived, they are often vigorous and are a common problem in cultivated areas such as farmland, where constant tilling of the soil unearths seeds that germinate and grow quickly. The properties of annual plants that make them successful weeds include rapid growth, short life cycle, high seed output and long-term seed viability.

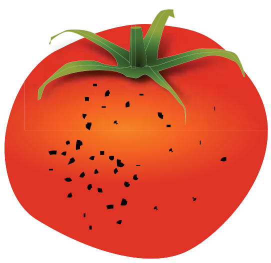
Perennial weed plants live for more than two years. Perennial weeds are able to compete with crop plants because they are already well established in the area the crop is being planted. Perennial weeds have storage organs which provide food when rates of photosynthesis are low. Some perennial weeds are also capable of vegetative reproduction; this means they have reproductive structures such as bulbs and tubers which new plants can grow from.



Tubers and a bulb

Most of the pests of crop plants are invertebrate animals such as insects, **nematode** worms, and **molluscs**. Insects cause damage to plant crops by feeding on them. Damage caused to leaves can reduce the rate of photosynthesis and therefore reduce crop yield. Nematode worms are found in the soil and attack plant's root systems. Snails and slugs are examples of molluscs; they cause damage to plants by eating them.

Plant diseases can be caused by fungi, bacteria or viruses. Invertebrates often act as vectors, facilitating the spread of diseases caused by microorganisms. Diseased plants have a reduced yield and a proportion of the crop may be unmarketable due to its appearance. Bacterial speck disease in tomato plants is caused by a bacterium called *Pseudomonas syringae*; this results in black lesions on the fruit, leaves and stems. Bacterial speck disease results in reduced growth due to a lower rate of photosynthesis and therefore reduced yield.



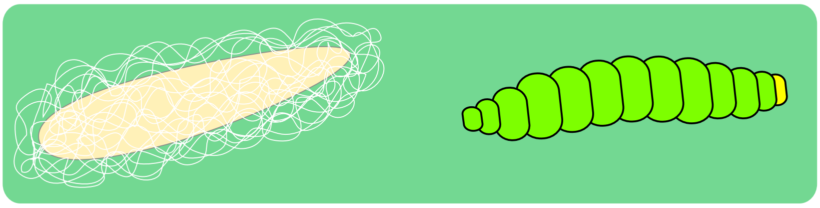
Bacterial speck disease symptoms

4.3 Control of weeds, pests and diseases

Weeds, pests and diseases can be controlled by cultural means. This form of control does not require chemicals but involves farmers adopting practices which make the environment unfavourable for the pest. One example of control of weeds, pests and diseases by cultural means is crop rotation. Crop rotation involves growing a different crop in the same area each successive year, this denies pests repeated access to their food source. A further example is ploughing, this buries crop residues that frequently harbour pests and diseases.

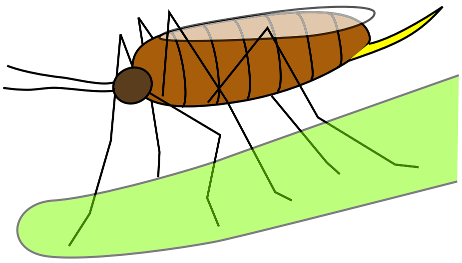
Other examples include:

- **polyculture**: the planting of several crops together in the same field. For instance, intercropping cowpeas with cassava reduces the abundance of whiteflies on the cassava;
- trap crops; plants grown amongst a main crop simply because they are more attractive to pests. For instance, Indian mustard is more attractive than cabbage for diamondback moths and leafrollers. In India, farmers grow one row of mustard between every five rows of cabbage allowing caterpillar populations build up on the mustard which can be treated by handsprayer with a high dosage of **insecticide**;



Diamondback moth: pupa (left) and larva stages

- **sanitation**; refers simply to the removal of crop residues and unharvestable plants that might harbour pest insects from outside the crop area;
- in some cases planting times can be delayed such that a crop is planted after a pest has emerged and died off. For instance, hessian fly populations are monitored in Georgia, USA, and farmers are advised when it is safe to plant their wheat crop.



Hessian fly

Cultural means of controlling weeds, pests and diseases aim to prevent their spread, often this is not enough to ensure a high crop yield and pesticides must be used. Pesticides provide farmers with a cost-effective way of improving the yield and quality of their crops. They also make harvesting more straightforward and maintain consistent yields from year to year.

Pesticides are chemicals which are used to kill pests such as insects, **nematodes** and **molluscs**. Pesticides include herbicides to kill weeds, fungicides to control fungal diseases, insecticides to kill insect pests, molluscicides to kill mollusc pests and nematicides to kill nematode pests.

Systemic insecticides, molluscicides and nematicides spread through the vascular system of plants. When a pest feeds on the plant they ingest the chemical and die. Systemic pesticides can be incorporated into the soil of crop plants. The chemical is absorbed by roots and translocated to leaves, stems, and flowers. An insect that feeds on a treated plant may acquire a lethal dose of insecticide or at least be deterred from further feeding.

Herbicides are chemicals used to kill weeds. Herbicides can be applied to control the growth of weeds which would otherwise grow amongst a crop, competing with it for water, nutrients and sunlight and reducing its yield.

Selective herbicides can be applied to crops which are established in a field; because they are selective they only kill the weeds. Many selective herbicides contain synthetic plant hormones which encourage the growth of plants which absorb them. Weeds often have broad leaves and take up large quantities of the chemical. This causes their growth to speed up; they use up their food stores and die. Crop plants such as cereals have narrow leaves therefore they do not take up as much of the chemical and are largely unaffected. Selective herbicides mimic natural plant hormones and therefore do not cause harm to the environment.

Broad leaved weed (left), narrow leaved crop plant (right)

Systemic herbicides kill all plant matter they come into contact with. They can be used to prepare a field before planting to clear it of all weeds. When systemic herbicides are sprayed on plants, they are absorbed and transported throughout the plant. This kills all parts of the plant including any reproductive structures under the soil. Systemic herbicides are biodegradable therefore they do not persist in the environment.

Fungicides are used to kill fungi which can cause disease in plants. Systemic fungicides are absorbed by crops and transported to all parts of the plant giving them protection from disease-causing fungi. Different fungal diseases require different environmental conditions. For example potato blight is caused by a fungus which requires specific humidity levels and temperatures to grow. By monitoring these conditions, farmers can give their crops protective applications of fungicide to prevent growth of the fungus. Protective applications of fungicide based on disease forecasts are often more effective than treating a diseased crop.

Potato blight: potato infected by the fungus Phytophthera

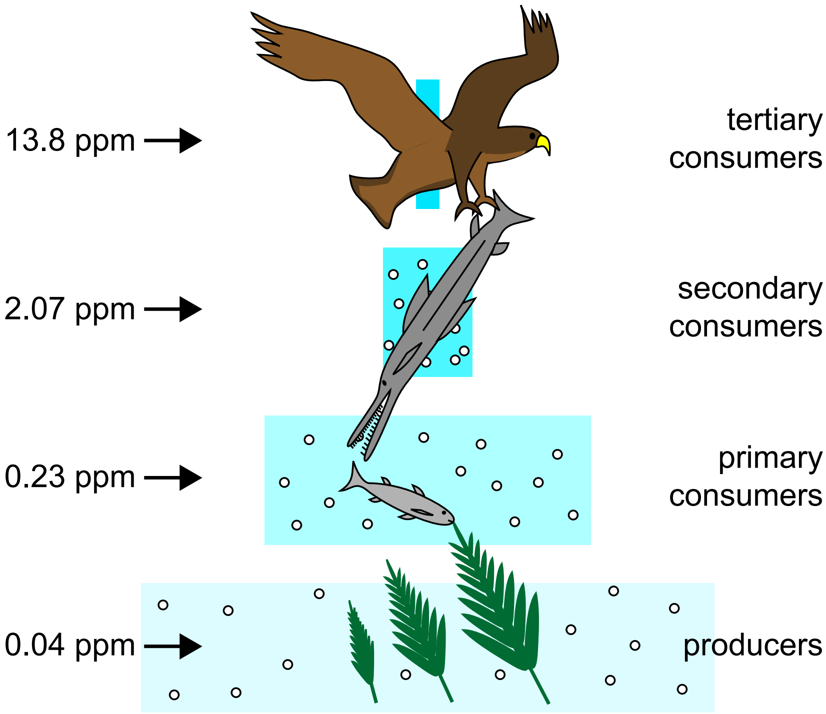
4.4 Problems with pesticides

Pesticides may be toxic to animal species. Chemical **insecticides** are generally intended for particular insect pests. Nevertheless, problems often arise because these chemicals are usually toxic to a broader range of organisms.

The potential for devastation is illustrated by the consequences of applying massive doses of dieldrin (an insecticide) to large areas of Illinois (USA) farmland from 1954 to 1958 in order to eradicate a grassland pest, the Japanese beetle *Popillia japonica*. Cattle and sheep on the farm were poisoned; 90% of the cats on the farms and a number of dogs were killed; and amongst the wildlife, 12 species of mammals and 19 species of birds suffered with meadow larks, robins, brown thrashers, starlings and ring-necked pheasants being virtually eliminated from the area.

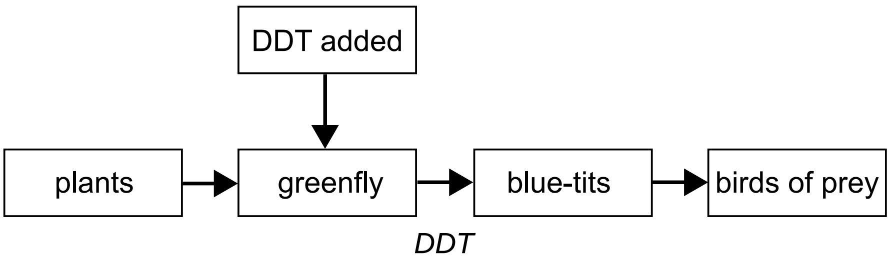
Some pesticides may be persistent in the environment, this means they are not biodegradable and remain in the environment for long periods of time after their application. Pesticides can also accumulate within the body of an organism. Even if levels of the chemical in the environment are relatively low accumulation can occur if the organism absorbs the chemical at a faster rate than it is excreted (lost). This accumulation can mean that chemicals build up to toxic levels in an organism and cause poisoning.

Some pesticides are magnified along food chains. This means the concentration of the chemical increases as it moves from one trophic level to the next. The following diagram shows the process of biomagnification.



DDT is an insecticide which can be used to kill lice, fleas, greenfly and other insects. First used in Britain in 1939, it was important in controlling disease-carrying insects such as fleas and mosquitoes. It was also extensively used as a garden insecticide.

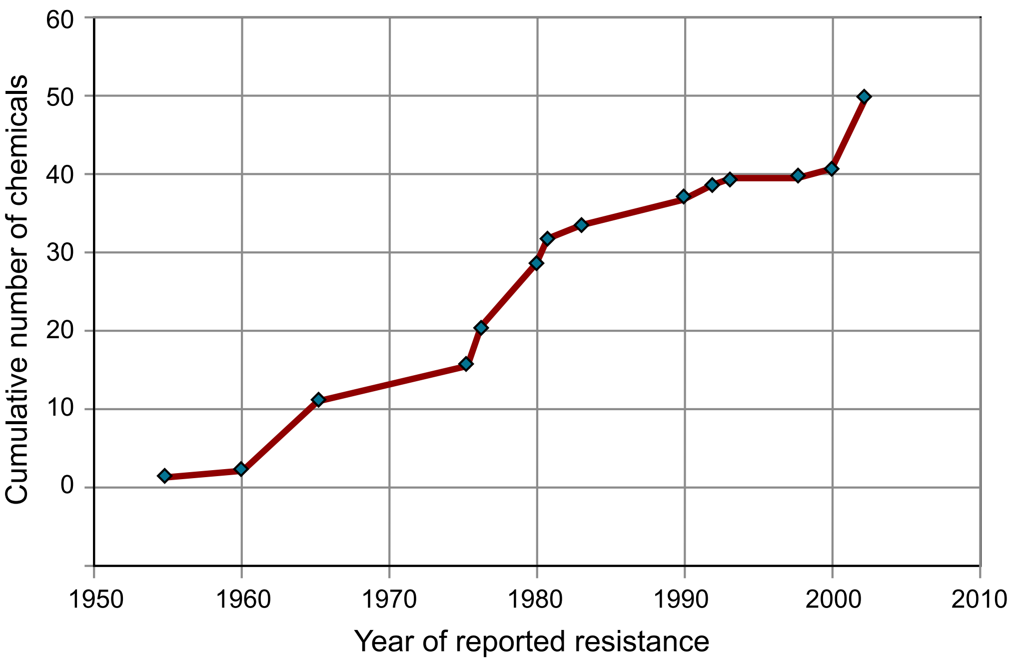
DDT is an example of a pesticide which is persistent; it also accumulates in the tissues of organisms and can be magnified along food chains.



DDT is not biodegradable and therefore it persists in the environment for long periods of time. It is magnified along food chains and can accumulate in quantities large enough to cause thinning of egg shells, reducing successful reproduction rates. By the 1950s and 1960s, populations of birds of prey (such as sparrow hawks, peregrine falcons and eagles) were decreasing, and DDT was banned in Britain.

The use of pesticides may result in a population selection pressure producing a resistant population. The Colorado potato beetle has a legendary ability to develop resistance to a wide range of pesticides used for its control. The high beetle fecundity (birth) rate (on average, about 600 eggs per female) increases the probability that one of the numerous offspring mutates and develops resistance to the pesticide. With the very high fecundity, the pesticide resistance can spread rapidly through the population.

Colorado beetle



Cumulative number of insecticides to which resistance in the Colorado potato beetle has been reported

Problems with pesticides: Questions Go online

The next two questions refer to the accompanying table which shows the concentration of a non-biodegradable pesticide residue in the tissues of the organisms in a marine food chain and the sea-water in their ecosystem.

Phytoplankton → krill → mackerel → tuna fish → dolphin

	Concentration of pesticide (ppm)
Water	0.00001
Phytoplankton	0.05
Krill (herbivore)	0.25
Mackerel (carnivorous fish)	2.0
Tuna fish	6.5
Dolphin	20

Q1: The concentration of pesticide increased by a factor of 400 times between:

a) water and tuna fish
b) krill and dolphin
c) phytoplankton and tuna fish
d) phytoplankton and dolphin

. . . .

Q2: The concentration of pesticide in the tuna fish is greater than that in the phytoplankton by a factor of:

a) 5
b) 10
c) 130
d) 400

4.5 Biological control and integrated pest management

In biological control the control agent is a natural predator, parasite or pathogen of the pest. Examples of biological control include:

- using the caterpillar moth to kill cacti; the caterpillars feed on the cacti;
- using a parasitic wasp to kill whitefly; the wasp lays its eggs in the larvae of the whitefly;
- using a virus to kill rabbits; the myxoma virus kills rabbits;
- using ladybirds to kill aphids; ladybirds prey upon aphids;

- using bacteria to control blackfly caterpillars; the bacteria infects caterpillars and kills them using a poison.

Biological control (http://www.flickr.com/photos/ektogamat/2578779839/in/photostream/ by http://www.flickr.com/photos/ektogamat/, licensed under http://creativecommons.org/licenses/by/2.0/)

Advantages of biological control include its specificity, the predator/parasite only kills the pest. The predators will breed in the environment, so they do not need to be constantly reapplied and they do not cause harm to other organisms or accumulate in food chains. The predator/parasite is unlikely to harm humans and pests cannot become resistant.

There are also some disadvantages to biological control. The predator/parasite does not kill all the pests; they work by controlling pest numbers, and keeping them at manageable levels. Also, the predator itself may become a problem in the environment. For example, cane toads were introduced into Australia to kill beetles (the pest), but there are now such a large number of cane toads that they are regarded as a pest.

Chemical control of pests involves using **herbicides**, **fungicides** or **insecticides** (together these are called pesticides) to kill the pests.

Advantages of chemical control are that the chemicals can kill all the pests and they are easy to use. Disadvantages include the fact that the chemicals are expensive and non-specific so they may kill other organisms as well as pests. Many pesticides are **persistent** and remain in the environment or the bodies of organisms for a long time. Pests may become resistant to them as a result of mutation, so they are no longer effective.

There is no single ideal method for killing pests. Chemical control is effective, but is likely to harm other organisms. Biological control is specific, but will not get rid of all pests. Integrated pest management is a combination of chemical, biological and cultural control.

4.6 Learning points

Summary

- Weeds compete with crop plants, while other pests and diseases damage crop plants, all of which reduce productivity.
- Properties of annual weeds include rapid growth, short life cycle, high seed output and long-term seed viability.
- Properties of perennial weeds include storage organs to provide a food source and the ability to reproduce by vegetative reproduction.
- Most of the pests of crop plants are invertebrate animals such as insects, nematode worms and molluscs.
- Pests feed on crop organisms and/or compete with crop organisms for resources, so yield is reduced.
- Pests can directly cause disease in crop organisms.
- Plant diseases can be caused by fungi, bacteria or viruses, which are often carried by invertebrates.
- Ploughing, weeding and crop rotation are cultural methods of pest control.
- The chemical control of pests involves using herbicides, fungicides, insecticides, molluscicides and nematicides - together these are called pesticides.
- Pesticides include herbicides to kill weeds, fungicides to control fungal diseases, insecticides to kill insect pests, molluscicides to kill mollusc pests and nematicides to kill nematode pests.
- Pesticides can be selective or systemic.
- Selective chemicals have a greater effect on certain plant species (broad leaved weeds).
- Systemic herbicide spreads through vascular system of plant and prevents regrowth.
- Systemic insecticides, molluscicides and nematicides spread through the vascular system of plants and kill pests feeding on plants.
- Protective applications of fungicide based on disease forecasts are often more effective than treating a diseased crop.
- Problems with pesticides include toxicity to non-target species, persistence in the environment, bioaccumulation or biomagnification in food chains, and the production of resistant populations of pests.
- Bioaccumulation is a build-up of a chemical in an organism.
- Biomagnification is an increase in the concentration of a chemical moving between trophic levels.
- In biological control the control agent is a natural predator, parasite or pathogen of the pest.

Summary continued

- There are risks associated with biological control, such as the control organism may become an invasive species, parasitise, prey on or be a pathogen of other species.
- Integrated pest management is a combination of chemical, biological and cultural control.

4.7 End of topic test

End of Topic 4 test Go online

Farmers growing soya beans have a problem because weeds compete with their crop. A genetically engineered variety of soya bean may solve their problem. A bacterial gene which can boost photosynthesis has been inserted into the plant. The new soya bean plants can withstand glyphosate, a herbicide, which disrupts photosynthesis and kills the plants.

Q3: A field of genetically engineered soya beans is sprayed with glyphosate. Explain the effects this would have on the yield.

. . . .

Q4: Sometimes crop plants can interbreed with weeds. Explain one problem which could be caused if the genetically engineered soya beans did this.

. . . .

Q5: The following table summarises the results from an investigation into the impact of a new pesticide on four pests.

Crop	Pest	Region of host attacked	Average loss of crop (acres/year) Without insecticide	Average loss of crop (acres/year) With insecticide
Apple	Aphid	Leaf and flower	12000	600
Pea	Weevil	Leaf and pod	4500	450
Potato	Leather jacket	Root and tuber	1800	1700
Cabbage	Caterpillar	Leaf and stalk	3200	400

The number of acres of pea crop saved per year by the use of the chemical was:

a) 450
b) 4005
c) 4050
d) 4500

. . . .

Q6: On which crop did the chemical have the **greatest** effect relative to the others?

a) Apple
b) Pea
c) Potato
d) Cabbage

. . . .

Q7: On which pest was the insecticide **least** effective?

a) Aphid
b) Weevil
c) Leather jacket
d) Caterpillar

. . . .

Q8: Give one property of an annual weed.

. . . .

Q9: The following table shows the concentration of a non-biodegradable pesticide residue in the tissues of the organisms in a food chain and the water in their ecosystem.

	Concentration of pesticide (ppm)
Water	0.00005
Plankton	0.04
Herbivorous fish	0.23
Carnivorous fish	2.07
Fish-eating birds	6.00

The concentration of pesticide increased by a factor of nine between:

a) herbivorous fish and carnivorous fish.
b) carnivorous fish and fish-eating birds.
c) plankton and herbivorous fish.
d) water and plankton.

. . . .

Q10: The concentration of pesticide in the fish-eating bird is greater than that in the water by a factor of:

a) 1.2×10^3
b) 1.2×10^4
c) 1.2×10^5
d) 1.2×10^6

. . . .

Q11: Complete the sentences using words from the list.

- Pesticides can cause problems in the environment because they can _________ within the body of an organism.
- They can also _________ along food chains.
- This means each successive organism in the food chain has a _________ concentration of the chemical in its tissues than the previous organism.

Word list: degrade, accumulate, concentrate, magnify, higher, lower.

. . . .

Q12: The table below shows the energy content and amount of insecticide in the organisms of a food chain.

Organisms in food chain	**Energy content as percentage of original energy**	**Amount of insecticide in body mass (mg/kg)**
Human	1	1.0
Fish	4	0.1
Microscopic animals	20	0.01
Microscopic plants	100	0.001

Calculate the percentage loss of energy between the microscopic water plants and microscopic animals.

. . . .

Q13: How are insecticides useful to farmers?

. . . .

Q14: Explain why fish contain insecticides.

. . . .

Q15: The use of pesticides may result in a population selection pressure producing a _______ population.

. . . .

Q16: Which control methods are used in integrated pest management?

a) Chemical and cultural
b) Biological and chemical
c) Cultural and biological
d) Chemical, cultural and biological

Topic 5

Animal welfare

Contents

Learning objective

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

- describe the costs, benefits and ethics of providing different levels of animal welfare in livestock production;
- describe behavioural indicators of poor welfare;
- describe stereotype behaviour, misdirected behaviour, failure in sexual and parental behaviour and altered levels of activity.

5.1 Animal welfare

Animal welfare refers to both the physical and mental well-being of animals. The term animal welfare can also mean human concern for animal health. Animal welfare is measured by indicators including behaviour, physiology, longevity, and reproduction.

In the 1960s, the British Government commissioned the Brambell Report on intensive animal production. Intensive animal production refers to large farms raising a great number of animals in small spaces compared to traditional farms. The Brambell committee listed the five freedoms animals should have. The first three refer to physical welfare and the last two refer to mental welfare.

1. *Freedom from hunger and thirst* - the animal should be able to drink fresh water whenever they need it and they should be fed on a diet which keeps them healthy and strong.
2. *Freedom from chronic discomfort* - the animals should be kept in a comfortable environment. The animals should not be too hot in summer or too cold in winter, there should be plenty of fresh air and they should have a comfortable, dry place to lie down.
3. *Freedom from pain, injury and disease* - the environment that the animal lives in shall be safe for them and not cause them injury. If the animals have any problem of injury or disease, a vet should be called immediately.
4. *Freedom to express normal behaviour* - the animals should be able to move around easily and mix with others in their group.
5. *Freedom from fear and the avoidance of stress whenever possible* - the animals should not be kept in conditions where they are afraid or where they might suffer any unnecessary pain or distress. This also applies when they are in transport, at market or abattoirs.

Most farming practices have been developed over the years to meet the demand from the public for sufficient supplies of food at relatively low cost. However, some of these practices may be considered by some people to be inappropriate for the welfare of the animals involved.

Ensuring farm animals are given the five freedoms detailed above can be costly for farmers; however they can give long-term benefits. Animals which have experienced good welfare have a better growth rate, increased reproductive success and produce products of a higher quality than animals which have experienced poor welfare. The UK maintains some of the highest animal welfare standards in Europe; while this may provide benefits, such as increased growth rate, it means animal products produced in the UK are more expensive than those from other parts of Europe.

When considering **animal welfare** issues, ethical considerations must also be taken into account. Battery reared chickens present an example of an ethical issue surrounding animal welfare. The chickens are kept in small cages with sloping mesh floors - the eggs roll down into a channel to be collected and the droppings fall through the mesh. The chickens have limited movement and often show unusual behaviours such as feather pecking. Rearing chickens in this way is much cheaper than rearing free-range chickens, however, can we justify this treatment of chickens to ensure we have a plentiful and cheap supply of eggs?

In general, intensive farming is less ethical than free range farming due to poorer animal welfare. Intensive farming often creates conditions of poor animal welfare but is usually more cost effective, generating higher profit as costs are low. Free range requires more land and is more labour intensive, but products produced in this way can be sold at a higher price and animals have a better quality of life.

Battery reared chickens (http://en.wikipedia.org/wiki/File:Battery_hens_-Bastos,_Sao_Paulo,_Brazil-31March2007.jpg by http://commons.wikimedia.org/wiki/User:Snowmanradio, licensed under http://creativecommons.org/licenses/by/2.0/deed.en)

Animal welfare: Animal freedoms Go online

Q1: Complete the following table with the correct examples of freedom.

Freedoms for Animals	**Example**
Freedom from hunger and thirst.	
Freedom from chronic discomfort.	
Freedom from pain, injury and disease.	
Freedom to express normal behaviour.	
Freedom from fear and the avoidance of stress whenever possible.	

Examples:

- Animals should be able to move around freely and mix with other animals in the group.
- Animals should not be exposed to unnecessary pain.
- Environment should be safe for animals and not cause them injury.
- Animals should be able to drink fresh water when they need it.
- Animals should be kept in a comfortable environment.

5.2 Behavioural indicators of poor welfare

When animals experience poor welfare standards they may display certain unusual/uncharacteristic behaviours. The behavioural indicators of poor welfare include the following:

- **stereotype**;
- **misdirected behaviour**;
- failure in sexual and parental behaviour;
- altered levels of activity.

A stereotype is a behaviour which involves unusual repetitive movement quite unlike those shown by wild animals. These behaviours are invariant (performed over and over again in the same way) and have no obvious function. The most common types of stereotypies can be grouped in the following ways:

- pacing-type - constantly walking back and forth or walking the same circuit around an enclosure;
- oral-type - among these are obsessive object licking and tongue rolling. Oral stereotypes are common in all grazing animals. Sows confined in stalls may repeatedly rub their mouths backwards and forwards over the bars, even making themselves bleed;
- others - include rocking backwards and forwards or side to side, rubbing continually against an object, head shaking, eye rolling (seen in veal calves), sham chewing for hours day after day (seen mainly in tethered sows) and tongue rolling (seen often in cows).

Misdirected behaviour

The freedom to express normal behaviour for domesticated animals is complicated and hard to apply in the real world. In many cases it is impossible to give a domesticated or captive animal the freedom to express a normal behaviour. The most effective indicator of suffering is the observation of abnormal misdirected behaviour in confined animals.

Misdirected behaviour involves a normal behaviour being displayed in a different/inappropriate situation. This behaviour may be misdirected towards the individual itself, other members of its species or its surroundings. Abnormal misdirected behaviour comes in a variety of forms. Examples are:

- feather pecking amongs battery hens;
- tail biting in pigs;
- chewing cage bars or other inanimate objects in pigs.

All of these misdirected behaviours are clear signs of suffering by the animal. They can be reduced by providing animals with members of its own species to interact with in a large stimulating enclosure.

Battery chicken recovering outside after feather pecking

Failure in sexual or parental behaviour

Reproductive success can be used as a measure of **animal welfare**. Those animals kept in low welfare conditions often have low reproductive success; these animals may fail to perform sexual behaviour or may reject/neglect any offspring they do produce. For an animal to develop normal sexual and parental behaviour it must be allowed to interact with members of its own species in a suitable enclosure.

Altered levels of activity

Altered levels of activity are also behavioural indicators of poor welfare. Examples are:

- apathy, particularly apparent in sows confined in stalls;
- hysteria that occurs among chickens and turkeys which can lead to the birds piling on top of each other, thereby causing death.

5.3 Learning points

Summary

- The costs of providing different levels of animal welfare in livestock production are financial.
- The benefits of good animal welfare include faster growth rate, better quality products and increased reproductive success.
- There are also ethical considerations which must be taken into account when providing different levels of animal welfare in livestock production.
- Intensive farming is less ethical than free range farming due to poorer animal welfare.
- Intensive farming often creates conditions of poor animal welfare but is often more cost effective, generating higher profit as costs are low.
- Free range requires more land and is more labour intensive, but can be sold at a higher price and animals have a better quality of life.
- There are behavioural indicators of poor welfare. These behavioural indicators include:
    - stereotypes of behaviour patterns - a repetitive movement;
    - misdirected behaviour - a normal behaviour displayed in a different/inappropriate situation;
    - failure in sexual and parental behaviour;
    - altered levels of activity.

5.4 End of topic test

End of topic 5 test Go online

Q2: The following list describes observed behaviour of pigs on a farm.

1. Repeated wounding of other pigs by biting.
2. Sham chewing for hours.
3. Biting of own tail.

Which of these behaviours indicate poor animal welfare?

a) 1 and 2 only
b) 1 and 3 only
c) 2 and 3 only
d) 1, 2 and 3

. . . .

Q3: The following are all examples of behaviour patterns exhibited by animals.

1. Sows rubbing mouth backwards and forwards over bars of cage
2. Lions pacing backwards and forwards on the exact same path
3. Chickens pecking their own feathers out
4. Red jungle fowl scratching and pecking food from soil surfaces

Which of the above are examples of stereotypic behaviour?

a) 1 and 2
b) 1 and 3
c) 2 and 4
d) 3 and 4

. . . .

Q4: Complete the following table by matching the examples of abnormal behaviour with the types.

Type of abnormal behaviour	Example of abnormal behaviour
Stereotype behaviour	
Misdirected behaviour	
Failure in sexual behaviour	
Altered levels of activity	

Examples:

- Hysteria among turkeys
- Tail biting in pigs
- Polar bears pacing in a zoo
- Cheetahs unable to breed in captivity

Topic 6

Symbiosis

Contents

Learning objective

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

- state that symbiotic relationships are coevolved, intimate relationships between members of two different species;
- know that a parasite benefits in terms of energy or nutrients;
- know that the parasite's host is harmed by the loss of these resources;
- understand that parasites often have limited metabolism so often cannot survive without a host;
- know that transmission of parasites to new hosts involves one of the following:
    - using direct contact;
    - resistant stages;
    - vectors;
- understand that evolution of parasitic lifestyles involves intermediate (secondary) hosts;
- state that in mutualism both partner species benefit in an interdependent relationship.

6.1 Symbiosis

Symbiosis refers to a relationship between two organisms from different species. Symbiotic relationships involve direct contact between members of the two species and have usually evolved over millions of years. In symbiosis, both individuals usually show adaptations which allow the relationship to take place.

In many symbiotic associations, one partner lives inside the other. For example, a variety of micro-organisms, mainly bacteria, live in the alimentary canal of animals such as cows. The bacteria provide the enzyme cellulase to aid the breakdown of cellulose into simple sugars which the cow uses for respiration. In return the bacteria are provided with enough food to live and a suitable environment in which to grow.

A well-known example of a symbiotic relationship is found in lichens. Lichen is a composite organism formed as a result of a union between a green alga and a fungus. The fungus gains oxygen and carbohydrates from the alga, whilst the alga obtains water, carbon dioxide and mineral salts from the fungus as well as protection from drying out. The result of this symbiotic relationship is an extremely hardy organism which can survive in extreme places, for example on exposed rocks at high altitudes and in Arctic and Antarctic regions.

Lichen

Lichens provide an example of an extremely well balanced relationship. The two partners do nothing but good for one another. However, not all symbiotic partnerships are as harmonious as this. In some cases the benefits enjoyed by one of the participants may be marginal, and in others the relationship may be detrimental to one participant.

A tapeworm is a type of flatworm which is capable of living in the guts of animals such as humans, cows and pigs. Once inside the gut of an animal (the parasite's host), the tapeworm is provided with a warm environment and a plentiful supply of food. This is detrimental to the host which loses nutrition and suffers weight loss.

Symbiotic relationships can be grouped into one of two categories:

- Parasitic - where one organism benefits from the relationship and the other is harmed;
- Mutualistic - where both organisms benefit from the relationship.

6.2 Parasitism

Parasitism refers to a relationship where one species benefits at the expense of the other. A parasite benefits in terms of energy or nutrients, whereas its host is harmed by the loss of these resources. Parasites often have a limited metabolism so cannot survive out of contact with its host.

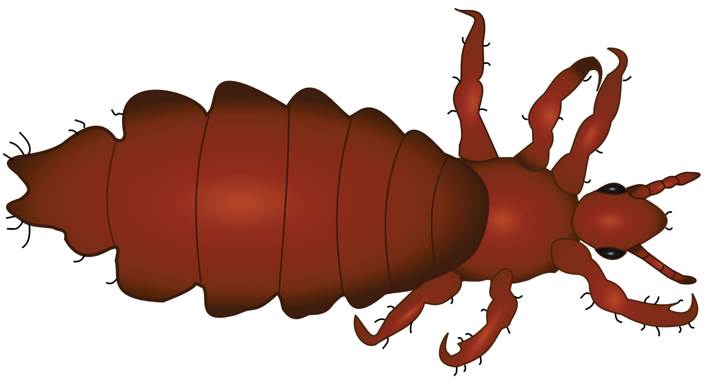
In a parasitic relationship, the host species is always exploited to some degree, although often in such a way that its health is impaired only slowly. This allows the parasite to exploit its host over a longer period of time.

The transmission of parasites to new hosts can occur by the following methods:

- Using direct contact;
- Resistant stages;
- Vectors.

Using direct contact

Some parasites spread from one host to the next by physical contact. For example head lice pass from one person to another by direct contact. Living with our furry friends exposes us to many canine and feline parasites, for example dogs can transmit 65 types of parasites to humans through direct contact.

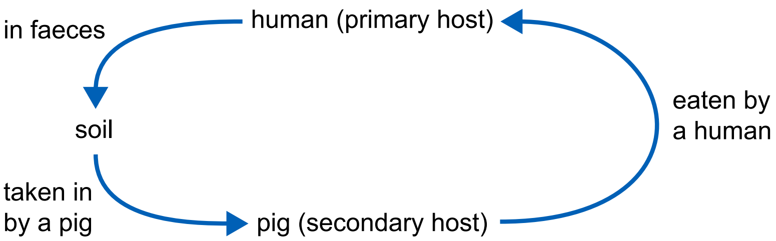


Human head louse - spread by direct contact

Resistant stages

Some parasites have resistant stages in their lifecycle. Resistant stages are a part of the parasites lifecycle where they are resistant to adverse environmental conditions and can survive for long periods of time.

The human tapeworm has resistant stages in its life cycle. *Taenia solium* is the human tapeworm which can be contracted from pork. The pig becomes infected from ingesting the eggs and once inside the intestine, the eggs release the oncosphere (first-stage larvae). The oncosphere then migrates to the muscles, where it develops into a cyst-like structure. The cyst can survive for several years in the tissue of the pig; this is the resistant stage of the lifecycle. Humans become infected by ingesting raw or undercooked infected meat. When a human becomes infected by tapeworms they can suffer from symptoms such as stomach pains, vomiting and weight loss.



Tapeworm life cycle

Many parasites use only one type of host organism for all stages of their life cycle for example the cat flea. Some parasites have developed the use of intermediate (secondary) hosts, as describe in the example shown above. In this case part of the lifecycle is spent in a different organism, known as an intermediate (secondary) host. In most cases this is beneficial to the parasite as it increases the chance of its offspring being transmitted to the primary host and many parasites are capable of increasing in numbers inside their intermediate (secondary) host by asexual reproduction.

Vectors

A vector is a carrier which allows a parasite to pass from one host to another. The most common example of a vector is the mosquito which carries the *Plasmodium* protozoa (which causes malaria) from human to human.

6.3 Malaria

Malaria is caused by a unicellular parasite known as *Plasmodium*. This enters the body after a bite from an infected mosquito. The mosquito acts as the vector which carries the malarial parasite. The *Plasmodia* invade red blood cells and multiply inside them. When they burst out of the red blood cells, toxins are released and the person develops a fever. The *Plasmodia* then infect more red blood cells and liver cells, causing serious damage. If the infected person is bitten by another mosquito which sucks their blood, *Plasmodia* are transferred to another mosquito ready to infect another human. In this example, mosquitoes act as vectors; they do not suffer from the disease, but they carry it from one person to another.

Malaria is a serious disease which kills about 2 million people each year. Incidences of malaria can be greatly reduced by:

- preventing mosquito bites using insect repellents or mosquito nets;
- killing the *Plasmodium* in the body by using anti-malarial drugs such as quinine;
- killing mosquitoes with insecticides;
- preventing mosquitoes breeding by draining swamps.

Malaria: Transmission Go online

Step 1: the mosquito injects the material *plasmodium* into the host

↓

Step 2: *plasmodium* moves to the liver and divides repeatedly

↓

Step 3: liver cells burst and *plasmodium* enters red blood cells or other liver cells

↓

Step 4: red blood/liver cells burst - steps 3 and 4 are repeated many times

↓

Step 5: mosquito feeds on person and sucks up red blood cells containing *plasmodia*

Steps in malaria transmission

6.4 Mutualism

Mutualism describes a relationship where both participants benefit from the interaction. Mutualistic relationships are described as interdependent, this means one cannot live without the other. Two examples of mutualistic relationships are outlined below.

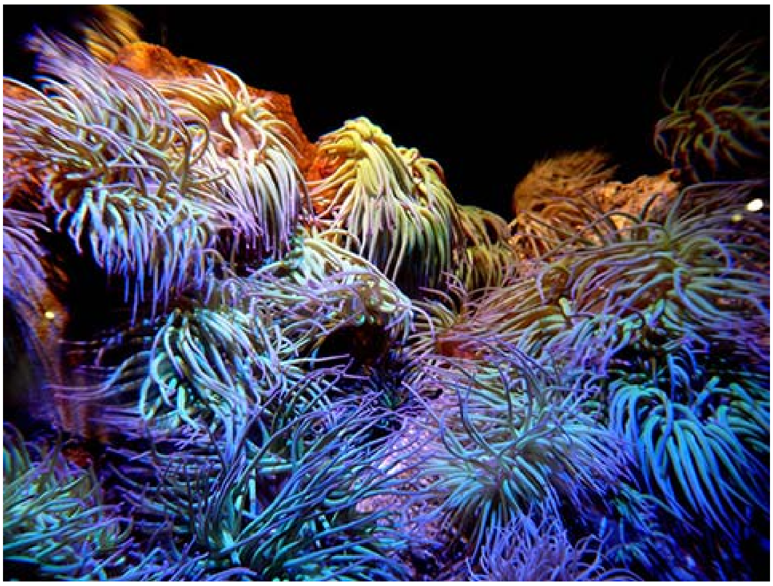
Cellulose-digesting protozoa/bacteria in the guts of many herbivores

Animals such as cows feed by grazing on plant matter. This plant matter contains large quantities of cellulose which makes up the cell wall of plant cells. In order to break down cellulose, the enzyme cellulase is required. Cows are not capable of producing this enzyme; therefore they rely on a mutualistic relationship with the micro-organisms (mainly bacteria and protozoa) in their gut to help digest their food.

The micro-organisms found in parts of a cow's stomach produce the enzyme cellulase which allows cellulose to be broken down into its constituent sugars. These sugars can be used by the cow as a source of energy. Other metabolites are also produced which are useful for the cow. In return the micro-organisms are provided with a warm and safe place to live, which has a plentiful food supply.

Photosynthetic algae in the polyps of corals

Coral reefs rely heavily on mutualistic **symbiosis**. The living coral organisms are animals called polyps, close relatives of the jellyfish. Each polyp lives in a small cup-like skeleton of calcium carbonate that it secretes itself, and over thousands of years, the layers of calcium carbonate build up to form coral reefs. Like jellyfish they use feathery tentacles to capture crustaceans and other small animals.



Coral polyps

Polyps also depend on the energy provided by single-celled algae (*Zooxanthellae*) which they shelter within and between their cells. The algae carry out photosynthesis to produce carbohydrates. These carbohydrates are used by both the algae and the polyp as a source of energy. In return, the algae are provided with a sheltered place to live and a supply of nitrogen compounds from the polyps wastes which can be used to produce proteins.

6.5 Learning points

Summary

- Symbiotic relationships are described as co-evolved, intimate interactions between the members of two different species.
- In parasitism, one organism benefits whilst the other is harmed by the interaction.
- A parasite benefits in terms of energy or nutrients, whereas its host is harmed by the loss of these resources.
- Parasites often have limited metabolism so often cannot survive without a host.
- Normally a balance exists between parasitic damage and host defense, resulting in a relatively stable relationship.
- Parasites may be transmitted between hosts by vectors, direct contact or through resistant stages.
- In mutualism, both organisms benefit from the interaction.
- Organisms in mutualistic relationships exchange metabolites and are structurally compatible.

6.6 Extended response question

The activity which follows presents an extended response question similar to the style that you will encounter in the examination.

You should have a good understanding of mutualism and parasitism before attempting the question.

You should give your completed answer to your teacher or tutor for marking, or try to mark it yourself using the suggested marking scheme.

Extended response question: Mutualism and parasitism

Discuss interactions between species under the following headings:

A) Mutualism *(2 marks)*

B) Parasitism *(4 marks)*

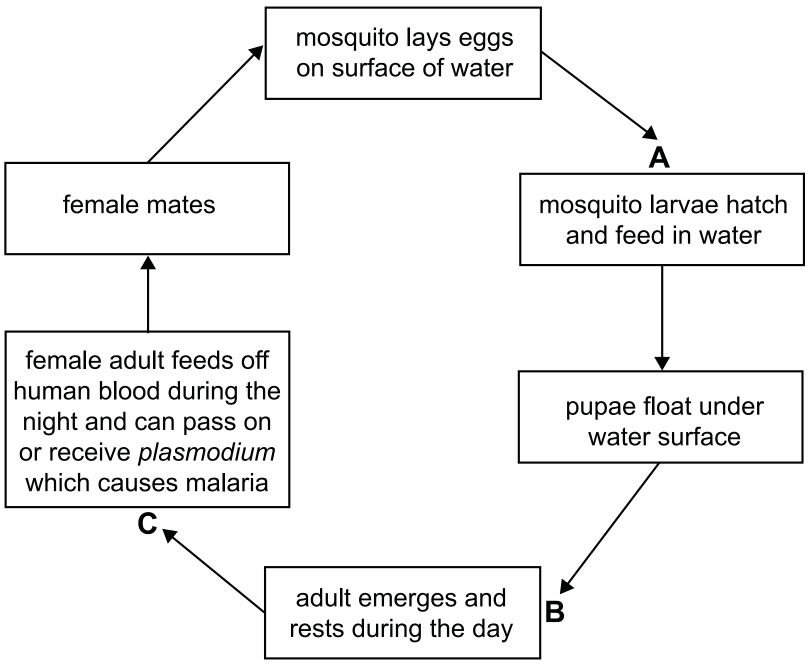
6.7 End of topic test

End of Topic 6 test Go online

Q1: Malaria is a disease which kills many people in tropical parts of the world. The female mosquito acts as a vector for the disease. What is meant by the term vector? (*2 marks*)

. . . .

Q2: The following diagram shows the life cycle of the mosquito.



Match the correct control method to each lettered stage on the diagram.

- Add fish to the water to eat eggs or larvae/drain wet areas/spray water with insecticide.
- Use insecticides to kill adults/use mosquito nets or repellent to prevent being bitten.
- Add oil or detergent to the water surface to stop pupae breathing and prevent adults emerging.

. . . .

Q3: A species of ant which is found in Latin America inhabits the thorns of a tropical shrub know as Acacia. The ants receive nectar and shelter from the plant. The plant receives protection from the ants.

This is an example of:

a) parasitism.
b) predation.
c) grazing.
d) mutualism.

. . . .

Q4: Hydra is a small freshwater animal that uses its tentacles to catch food. One variety (green hydra) has photosynthetic algae living in its tissues. Another variety (colourless hydra) has no algae.

The relationship between Hydra and the algae is believed to be an example of mutualism.

Under what conditions would a comparison of the growth rates of green and colourless Hydra test this hypothesis?

a) Light; food supplied
b) Light; no food supplied
c) Dark; food supplied
d) Dark; no food supplied

. . . .

Q5: Parasites may be transmitted between closely related species. State one way in which parasites can be transmitted.

. . . .

Q6: Symbiosis is the term used to describe close interactions between organisms. For each of the following statements, indicate which type of symbiosis it describes.

1. One species benefits and the other is harmed.
2. Both species in the interaction benefit.

. . . .

Q7: The following table shows four examples of interactions between species. Which column in the table shows correctly the benefits (+) or costs (-) which result from each interaction?

Interaction	A	B	C	D
Sheep grazing in a field of grass	+/-	+/-	+/+	+/-
Owls and foxes hunting for the same food	+/-	-/-	-/-	+/-
Corals acting as hosts for *zooxanthellae*	+/-	+/+	+/-	+/+
'Cleaner fish' feeding on parasites which they remove from other fish	+/+	+/+	+/-	+/+

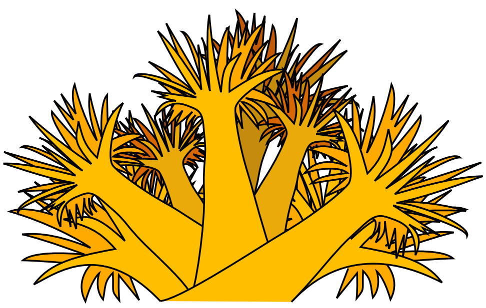
. . . .

Q8: Adult beef tapeworms live in the intestine of humans. Segments of the adult worm are released in the faeces, and embryos which develop from them remain viable for five months. The embryos may be eaten by cattle and develop in their muscle tissue. Which row in the following table correctly identifies the various roles in the tapeworm life cycle?

Role of human		**Role of embryo**	**Role of cattle**
A	Intermediate (secondary) host	Resistant stage	Vector
B	Intermediate (secondary) host	Vector	Host
C	Primary Host	Vector	Intermediate (secondary) host
D	Primary Host	Resistant stage	Intermediate (secondary) host

. . . .

Q9: The tentacles of coral polyps have a symbiotic relationship with photosynthetic algal cells. The coral polyps provide shelter to the algal cells and the algal cells provide the coral polyps with a source of energy in the carbohydrates they produce.



What type of symbiosis is found in the relationship between coral polyps and photosynthetic algae?

Topic 7

Social behaviour

Contents

Learning objective

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

- understand that many animals live in groups and have behaviour that is adapted to group living;
- state that adaptations to living in groups include social hierarchy, cooperative hunting and defence;
- describe the features of social hierarchy;
- describe the features and benefits of cooperative hunting;
- give examples of social defence in animals;
- describe the features of altruistic behaviour;
- identify examples of altruistic behaviour;
- explain reciprocal altruism;
- understand that behaviour that appears to be altruistic can be common between a donor and a recipient if they are related (kin);
- describe the features and advantages of kin selection;
- describe the structure of insect societies such as bees, wasps, ants and termites;
- give examples of primate behaviours that support social structure to reduce unnecessary conflict;
- give examples of primate group behaviour;
- state that the long period of parental care in primates gives an opportunity to learn complex social behaviours.

7.1 Social behaviour

Many animals live in social groups and have behaviours that are adapted to group living. Group members use social signals to establish behaviours which benefit both individuals and the group as a whole. The table below outlines some benefits and costs of living in a social group.

Benefits	Costs
Individual risk of predation diluted by joining a group	Greater risk of contracting disease
Groups can tackle larger prey than individuals	Greater chance of mistakenly feeding someone else's offspring
Grouping confuses predators, making it harder for them to target prey	Investment in foraging, courtship, or other activities exploited by other group members
Huddling in groups help thermoregulation	Young may be cannibalised by neighbours
Energetic advantages to swimming or flying in a group through 'slipstreaming'	Greater risk of inbreeding

Social grouping

7.2 Social hierarchy

Within a group of animals, a social hierarchy is often found to operate. A social hierarchy is a rank order within a group of animals consisting of a dominant and subordinate members. In a social hierarchy, dominant individuals carry out ritualistic (threat) displays whilst subordinate animals carry out appeasement behaviour to reduce conflict. Animals often form alliances in social hierarchies to increase their social status within the group. Social hierarchies benefit species as they increase the chances of the dominant animal's favourable genes being passed on to offspring.

Examples of social hierarchy are often seen in groups of newly hatched birds where one will soon emerge as the dominant member of the group. This bird is able to peck and intimidate all other members of the group without being attacked in return. It therefore gets first choice of any available food. Below this dominant bird there is a second one which can peck all others except the first and so on down the line. This linear form of social organisation is called a **pecking order**.

The following table summarises the results from observing a group of newly hatched chickens over a period of time. Chicken A dominates all of the others, B dominates all of the others except A and so on down the line to chicken H.

Chicken		**receiving pecks**							
		A	B	C	D	E	F	G	H
giving pecks	A		√	√	√	√	√	√	√
	B			√	√	√	√	√	√
	C				√	√	√	√	√
	D					√	√	√	√
	E						√	√	√
	F							√	√
	G								√
	H								

Pecking order in chickens

Social hierarchies can also be observed in groups of mammals such as wolves and baboons. Social signals, such as aggressive behaviour, are used to establish a rank order within the group with the most dominant individual getting first choice of food, preferred sleeping places and available mates.

Dominant behaviour (http://en.wikipedia.org/wiki/File:Wolves_Kill.jpg by http://commons.wikimedia.org/wiki/User:Ipuser, licensed under http://creativecommons.org/licenses/by/2.0/deed.en)

Social hierarchy: Questions Go online

Five male zebra finches, P, Q, R, S and T, were kept together and observed over a period of several days. During this time, a record was kept of the results from 20 confrontations between each pair of birds. The bird which successfully dominated its rival in each contest was given a score of one point.

Q1: The results are shown in the following table.

Contest	Score out of 20 (points)	Winner	Net number of contests won
T v Q	T 17, Q 3	T	14
T v R	T 3, R 17		
P v Q	P18, Q 2		
Q v R	Q 0, R 20		
Q v S	Q 8, S 12		
R v P	R 13, P 7		
P v T	P 14, T 6		
S v T	S 5, T 15		
R v S	R 19, S1		
S v P	S 4, P 16		

Complete the two right-hand columns in the table. (The first example has been done for you.)

....

Q2: Which bird has the lowest status and is at the bottom of the pecking order? Explain your choice.

....

Q3: Which bird is at the top of the dominance hierarchy? Explain your answer.

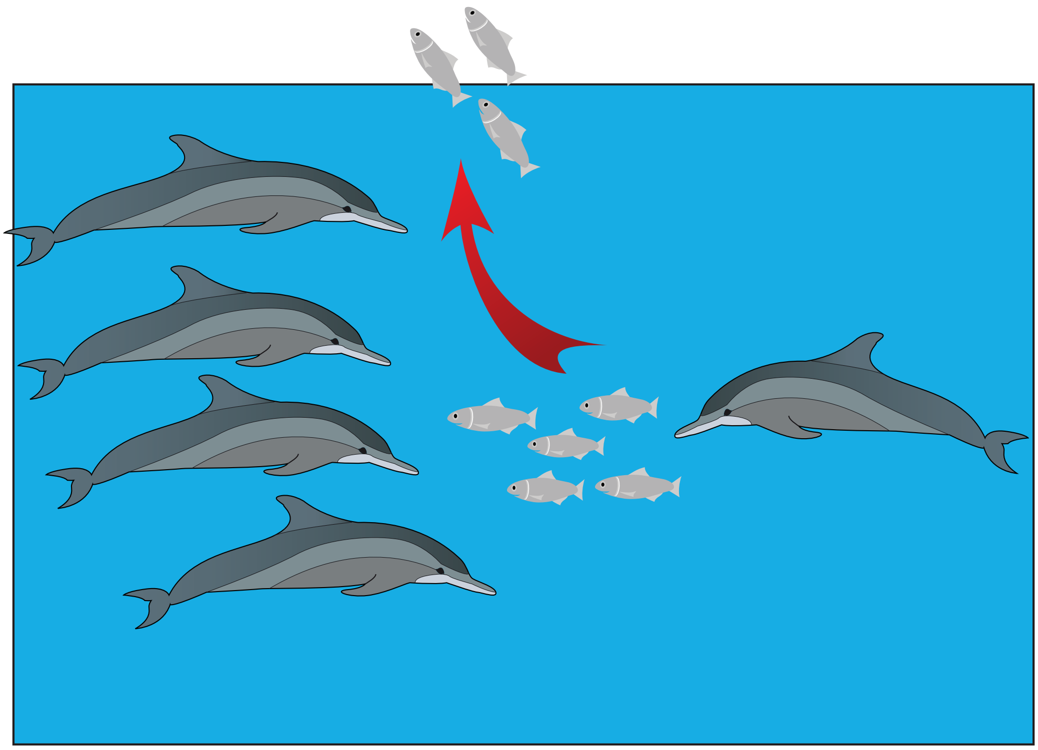
....

Q4: Give the pecking order of the five birds.

7.3 Cooperative hunting

Cooperative hunting involves a group of animals working together to find and catch prey. Cooperative hunting benefits all members of a social group, including lower ranking individuals as the subordinate animals may gain more food than by foraging alone. Food sharing will occur as long as the reward for sharing exceeds that for foraging individually.

Many animals rely on cooperation between individuals to catch prey. Dolphins often work in groups to catch their prey, one dolphin (the driver) herds a shoal of fish towards the rest of the dolphin group who form a barrier. The fish are forced to leap out of the water into the air, where the dolphins catch them.



Dolphins: cooperative hunting

Lions hunt in groups of three to seven and perform one of two roles, centre or wing. The lions on the edge of the group are the wings, they run around their target and drive it towards the centres who are lying waiting to ambush the prey. The centres leap up and attack the prey; the kill is then shared amongst the group.

Advantages of cooperative hunting

The main advantage of cooperative hunting lies in the fact that the kill is shared between all members of the group. This means that even those organisms at the bottom of the social hierarchy (subordinate individuals) obtain food. Group hunting also allows larger prey animals to be hunted meaning all individuals gain more food than they would by foraging alone. One final benefit of cooperative hunting is that by working as a group, less energy is used per individual in obtaining the prey, this maximizes energy gain.

In the case of lions, an additional advantage to group hunting lies in the fact that after the kill, there will be more individuals to keep scavengers and other potential thieves away from the carcass. Therefore, the defence of the kill is also a benefit of cooperative hunting.

7.4 Social mechanisms for defence

Many animals live in social groups, not only to benefit from increased access to food, but also for defence. Social defence is often thought of as 'safety in numbers' and can operate in several different ways. In some species having many individuals means the group is able to fend off attacks by predators. In other species it means there are more eyes looking out for danger and the group can take cover when alerted to the presence of a predator.

Colonial nesting birds - gulls and terns, for example - may provide formidable opposition to an invading predator such as a fox by mobbing it, even hitting the predator with their feet.

Terns

Even though each bird is responding individually to defend its own nest, the proximity of other birds all doing the same thing means that their combined efforts can be much more effective than that of a single bird on its own. As a result, the nesting success of gulls in a large colony is considerably greater than that of gulls that nest singly or in small groups.

In meerkats, social defence can be seen by particular individuals who undertake vigilance duties and take turns to go to a high look-out point such as a tree and keep watch for predators while the others feed. If the area is safe the sentry makes quiet peeping sounds. When the sentry sees a predator, he barks loudly and all the meerkats in the group retreat into their burrows.

Meerkat lookout

Some species of antelope live on open grassy plains with very little cover. As well as being able to run away from predators, some species encircle their young when under attack. This means predators must risk being gored by the antelopes' horns to get their prey and vulnerable individuals (who are likely to be caught) are protected.

Social mechanisms for defence: Questions Go online

An experiment was set up to investigate the attacks of a predatory bird, a goshawk, on pigeons. The attack success of the goshawk against different sized flocks of pigeons was studied. The results are shown in the table.

Number of pigeons in flock	Percentage attack success of goshawk
1 - 5	80
6 - 10	60
11 - 49	18
50 +	10

Q5: Using the information from the table, draw a bar-graph for the results obtained.

. . . .

Q6: Calculate the percentage decrease in percentage attack success from a flock of pigeons of numbering 1-5 and a flock of pigeons numbering 50+.

. . . .

Q7: Describe what the results of the experiment show.

. . . .

Q8: Suggest a possible explanation for the results.

7.5 Altruism and kin selection

Animals usually show behaviours which are beneficial to their own chances of survival. In some cases an animal will behave in a manner which is harmful to itself but beneficial to another individual. This behaviour is described as altruism. An example of altruism can be seen in wolves which bring meat back to members of the group who were not present at the kill. The 'donor' wolf must expend energy carrying the kill back and the 'recipient' wolf benefits as it gains access to food.

The social insects, such as termites, ants, bees and wasps, show extreme altruistic behaviour. There is usually just one reproductive female (the queen) and large numbers of sterile workers. The workers perform all the tasks of the society such as foraging, rearing young, nest construction and defence, and do not reproduce at all themselves.

A queen bee (centre) with attendants (http://commons.wikimedia.org/wiki/File:Adult_queen_bee.jpg by http://en.wikipedia.org/wiki/User:Pollinator, licensed under http://creativecommons.org/licenses/by-sa/3.0/deed.en)

Donor vs recipient

Reciprocal altruism is a behaviour whereby an organism (donor) acts in a manner that temporarily reduces its fitness while increasing another organism's (recipient) fitness with the expectation that, the roles of donor and recipient later reverse. Grooming in primates can be thought of as an example of reciprocal altruism. An individual will expend time and energy grooming another member of the group in the expectation that the favour will be returned in the future.

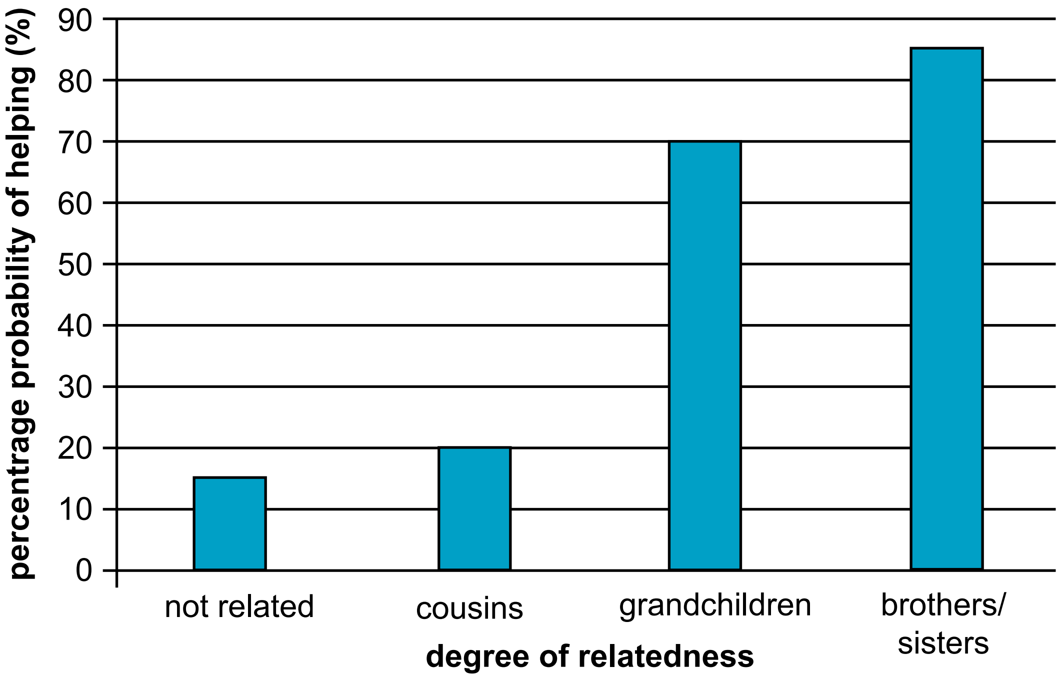
A typical group of vampire bats exhibit reciprocal altruism by regurgitating blood meals to other bats. Although members of the group are largely unrelated, they share their meal with others in the group. To avoid starvation, vampire bats require frequent blood meals. Individuals often regurgitate part of their blood meal to other bats, but they are more likely to do so for those who have shared a meal with them in the past. Therefore, it can be seen that vampire bats employ some sort of reciprocal altruistic strategy when it comes to blood sharing.

Behaviour that appears to be altruistic can be common between a donor and a recipient if they are related (kin). The donor will benefit in terms of the increased chances of survival of shared genes in the recipient's offspring or future offspring.

Favourable conditions for kin-selected cooperation are widespread. Around 96% of birds and 90% of mammals that live in family groups show cooperative breeding by helping others to rear offspring. There is also evidence that helping is directed towards more closely related recipients within family groups. For example, in white-fronted bee-eaters, helpers often chose to aid the pair they themselves were most closely related to.

White-fronted bee-eater (https://en.wikipedia.org/wiki/File:Merops_bullockoides_1_Luc_Viatour.jpg by https://commons.wikimedia.org/wiki/User:Lviatour, licensed under https://creativecommons.org/licenses/by-sa/3.0/deed.en)

Altruism and kin selection: Questions Go online



Kin-selected cooperation

Q9: From the graph, calculate the percentage increase in the degree of relatedness in white-fronted bee-eaters between cousins and grandchildren.

. . . .

Q10: Calculate the percentage for the overall percentage probability of helping relatives as opposed to non-relatives.

. . . .

Q11: What conclusion can you come to from the results of the graph?

Q12: Which of the terms listed match with the following definitions?

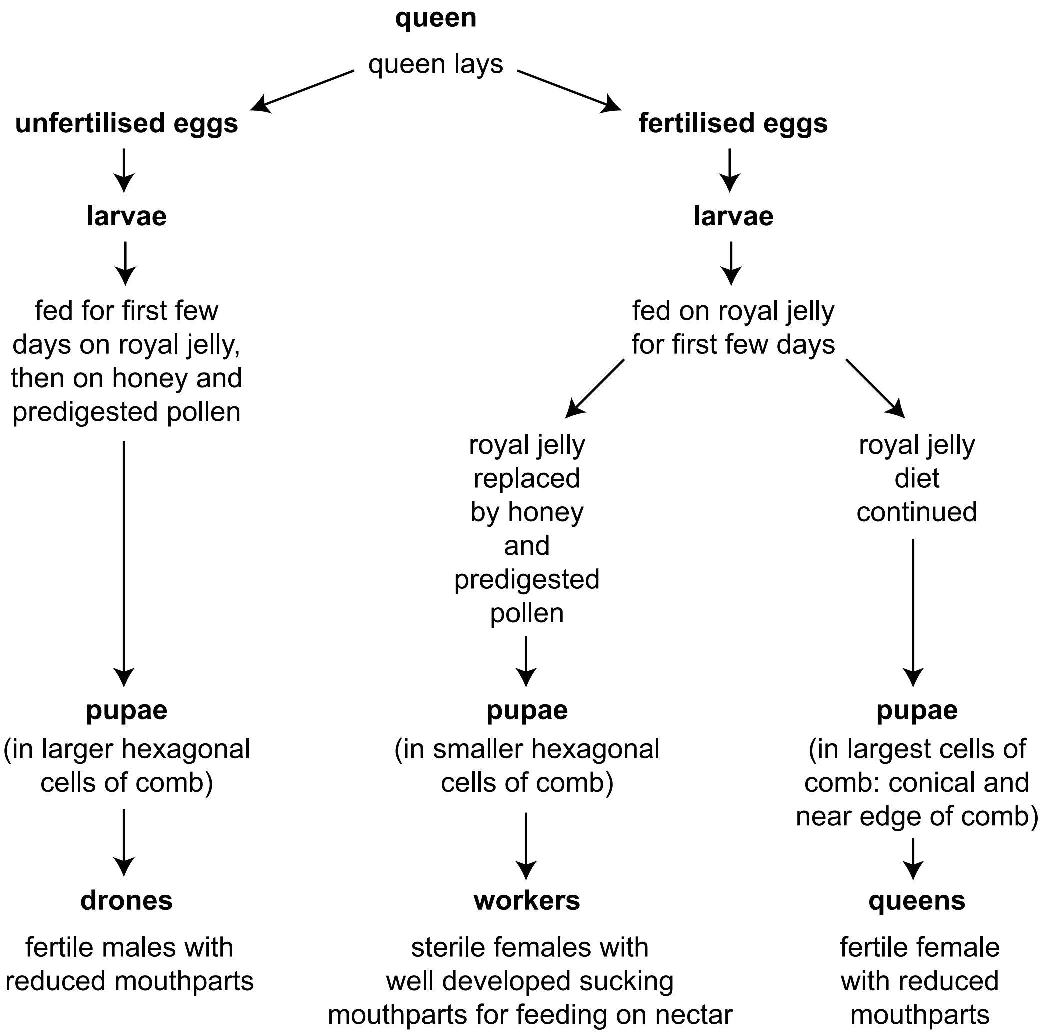
- A behaviour in which an organism acts in a manner that temporarily reduces its fitness while increasing another organism's fitness with the expectation that the other organism will act in a similar manner later on.
- Society in which some individuals are dominant to others who are submissive to the dominant ones.
- Strategies in evolution that favour the reproductive success of an organism's relatives even at the cost of an organism's own survival and reproduction.

Terms: Kin selection, Reciprocal altruism, Social hierarchy.

7.6 Social insects

The evolution of the societies of insects can be seen in such social insects as bees, wasps, ants and termites, in which only some individuals contribute to reproduction. The rest of the group is involved in gathering food and defending the colony. This benefits the species as a whole, because the 'workers' become specialised in performing their function; although they are not directly involved in the reproductive process, the tasks they complete ensure the survival of the species.

The 'workers' can be thought of as a rank within the insect society. One of the most important factors determining rank is what the insects are fed when young. In bees, wasps and termites, all eggs laid by the queen are potentially equal, but most larvae are fed a restricted diet and develop into workers. Only richly fed individuals develop into the reproductive rank.



Bee colony structure

In the honey bee colony the queen is solely responsible for laying eggs, the drones for fertilising her, and the workers for gathering food and performing sundry duties in the hive such as defending the hive, collecting pollen and carrying out waggle dances to show the direction of food. Each rank is adapted for its particular job: thus the queen is the fertile female, the drones fertile males, and the workers sterile females with well-developed mouth parts and other structural adaptations for collecting nectar and pollen.

7.7 Primate behaviour

In primates, dominance and subordination are important features of their relationship with others. Dominance always involves the threat of physical displacement or attack, even though it is rarely observed once rank is established. It is important to remember that relationships within primate groups are as much characterised by positive interactions as by negative ones.

There are many friendly contacts between primates, such as moving and resting together, inviting grooming or offering to groom another. Mutual grooming is very important as a **placatory** gesture in primates. Often a dominant animal will allow itself to be groomed by a subordinate following a brief threat to which the subordinate has deferred.

To reduce unnecessary conflict, social primates use ritualistic display and appeasement behaviours. Ritualistic display involves one individual asserting its dominance over another by displaying aggressive behaviour. Appeasement behaviours include grooming, submissive facial expressions/body posture and sexual presentation. Sexual presentation as an appeasement gesture is very common in baboons and chimpanzees and is often made by females towards a dominant male.

The social **hierarchies** found within primate groups are complex and subject to change. In some monkeys and apes, alliances form between individuals which are often used to increase social status within the group.

Vervet monkeys grooming (https://www.flickr.com/photos/wwarby/2404512619/ by https://www.flickr.com/photos/wwarby/, licensed under http://creativecommons.org/licenses/by/2.0/deed.en)

Primate groups such as lemurs have been extensively researched. There is a social hierarchy within the troop which allows it to work well as a cohesive unit. Lemurs have group territories within their woodland habitat whose boundaries are very stable. They are marked by scent, and are defended by calling, which is usually sufficient to cause a neighbouring troop to retreat without further threat or fighting.

There is always close contact between a mother lemur and her infant, who clings continuously to her at first and is carried around everywhere. As it grows older other adults approach and play with the infant. This long period of parental care in primates gives an opportunity to learn complex social behaviours and to establish networks among other individuals in the troop. Lemurs have thick, dense fur and groom frequently. Mothers groom their infants and adults frequently groom each other.

Lemur

7.8 Learning points

Summary

- Many animals live in social groups and have behaviour that is adapted to group living.
- Social **hierarchy** is a rank order within a group of animals consisting of a dominant and subordinate members.
- In a social hierarchy, dominant individuals carry out ritualistic (threat) displays whilst subordinate animals carry out appeasement behaviour to reduce conflict.
- Social hierarchies increase the chances of the dominant animal's favourable genes being passed on to offspring.
- Animals often form alliances in social hierarchies to increase their social status within the group.
- **Cooperative hunting** may benefit subordinate animals as well as dominant.
- By cooperative hunting, large prey can be killed which would prove impossible for solitary animals.
- Subordinate animals may gain more food than by foraging alone.
- Food sharing will occur as long as the reward for sharing exceeds that for foraging individually.
- Co-operative hunting enables larger prey to be caught and increases the chance of success.
- Social defence strategies increase the chance of survival as some individuals can watch for predators whilst others can forage for food. Groups adopt specialised formations when under attack protecting their young.
- Altruistic behaviour harms the donor individual but benefits the recipient.
- Reciprocal altruism is a behaviour whereby an organism acts in a manner that temporarily reduces its fitness while increasing another organism's fitness with the expectation that the other organism will act in a similar way later on.
- Reciprocal altruism often occurs in social animals.
- Behaviour that appears to be altruistic can be common between a donor and a recipient if they are related (kin).
- Kin selection involves strategies that favour the reproductive success of an organism's relatives even at a cost to an organisms own survival and reproduction.
- The donor will benefit in terms of the increased chances of survival of shared genes which can be passed to recipient's offspring or future offspring.
- Social insects such as bees, wasps, ants and termites have a social structure where only some individuals contribute reproductively; most members of the colony are workers who cooperate with close relatives to raise relatives.

Summary continued

- Other examples of workers' roles include defending the hive, collecting pollen and carrying out waggle dances to show the direction of food.
- Sterile workers raise relatives to increase survival of shared genes.
- Primates display complex behaviours that support social structure to reduce unnecessary conflict.
- To reduce unnecessary conflict, social primates use ritualistic display and appeasement behaviours including grooming, facial expression, body posture and sexual presentation.
- Long period of parental care in primates gives an opportunity to learn complex social behaviours.
- In some monkeys and apes, alliances form between individuals which are often used to increase social status within the group.

7.9 Extended response question

The activity which follows presents an extended response question similar to the style that you will encounter in the examination.

You should have a good understanding of social behaviour before attempting the question.

You should give your completed answer to your teacher or tutor for marking, or try to mark it yourself using the suggested marking scheme.

Extended response question: Social behaviour

Write notes on social behaviour under the following headings:

A) Altruism and kin selection (*5 marks*)

B) Primate behaviour (*5 marks*)

7.10 End of topic test

End of Topic 7 test Go online

Q13: A pack of African wild dogs catches large prey animals (such as wildebeest) by running it down to the point of exhaustion. Give two advantages gained by the dogs from this form of cooperative hunting.

. . . .

Q14: Hawks are predators which attack flocks of pigeons. The table shows how the percentage of attack success of a predatory hawk varies with the number of pigeons in the flock.

Number of pigeons in the flock	% attack success
2	80
10	50
20	40
40	15

1. Calculate the percentage decrease in the % attack success when the number of pigeons in the flock increases from 10 to 40.
2. Suggest an explanation for the effect of flock size on attack success shown in the table.
3. Some hawk species show cooperative hunting behaviour. Explain one advantage of this type of behaviour.

. . . .

Q15: Match the following descriptions with the terms listed.

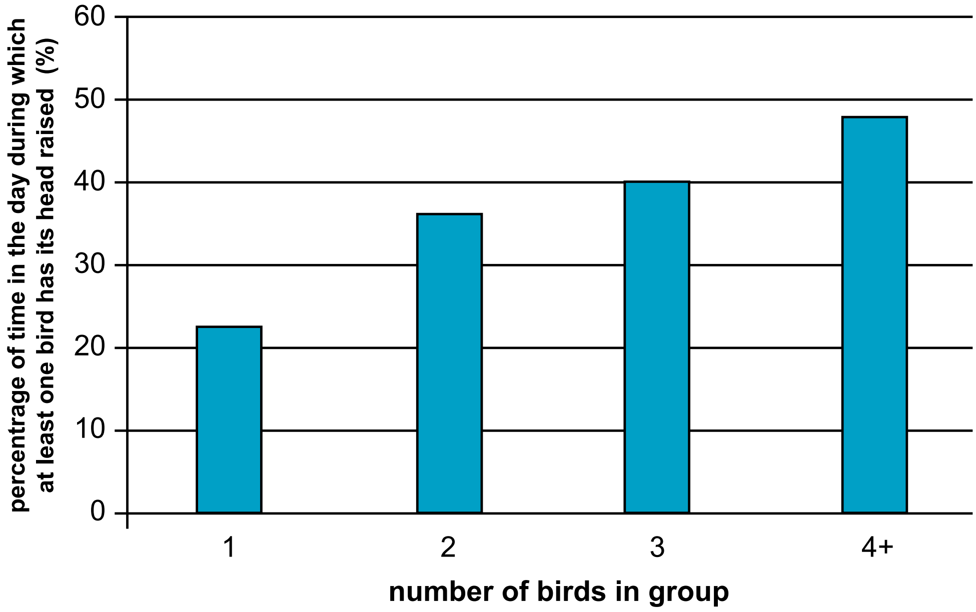
- Social signal used by the leader in a dominance hierarchy to assert authority
- Social signal used by low-ranking member of a social hierarchy to indicate acceptance of the dominant leader
- System of social organisation where the members are graded into a rank order
- Type of foraging behaviour employed by a group of predators resulting in mutual benefits

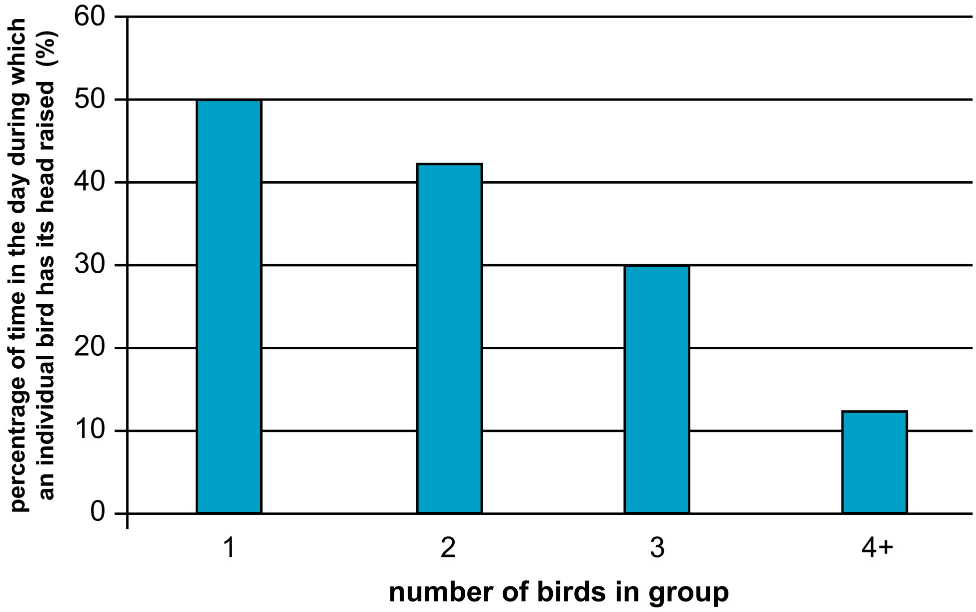
Terms: Cooperative hunting, Dominance hierarchy, Ritualised threat gesture, Subordinate response.

. . . .

Q16: Ostriches are large birds which live on open plains in Africa. They divide their time between feeding on vegetation and raising their heads to look for predators.

The following graphs show the results of a study on the effect of group size on the behaviour of ostriches.





Which of the following is a valid conclusion from these results?

In larger groups, an individual ostrich spends:

a) less time with its head raised so the group is less likely to see predators.
b) less time with its head raised but the group is more likely to see predators.
c) more time with its head raised so the individual is more likely to see predators.
d) more time with its head raised but the group is less likely to see predators.

....

Q17: Which of the following examples of bird behaviour might be the result of social mechanisms for defence?

a) Great Tits with the widest stripe on their breast feed first when food is scarce.
b) Sooty Terns feed on larger fish than other species of tern which live in the same area.
c) Pelicans searching for food form a large circle round a shoal of fish, then dip their beaks into the water simultaneously.
d) Predatory gulls have difficulty picking out an individual puffin from a large flock.

. . . .

Q18: The following list refers to pecking behaviour observed amongst six hens (P, Q, R, S, T and U).

P pecked U	P pecked T
R pecked T	S pecked P
S pecked U	T pecked Q
U pecked R	U pecked Q

Which bird was third in the pecking order?

. . . .

Q19: What name is given to the type of social organisation that results in a rank order of individuals?

. . . .

Q20: State two ways it is of advantage to the animals concerned.

. . . .

Q21: Which of the following statements referring to advantages gained by hunting behaviour could be true of cooperative hunting?

1. Individuals gain more energy than from hunting alone.
2. Both dominant and subordinate animals benefit.
3. Much larger prey may be killed than by hunting alone.

a) 1 and 2 only
b) 1 and 3 only
c) 2 and 3 only
d) 1, 2 and 3

. . . .

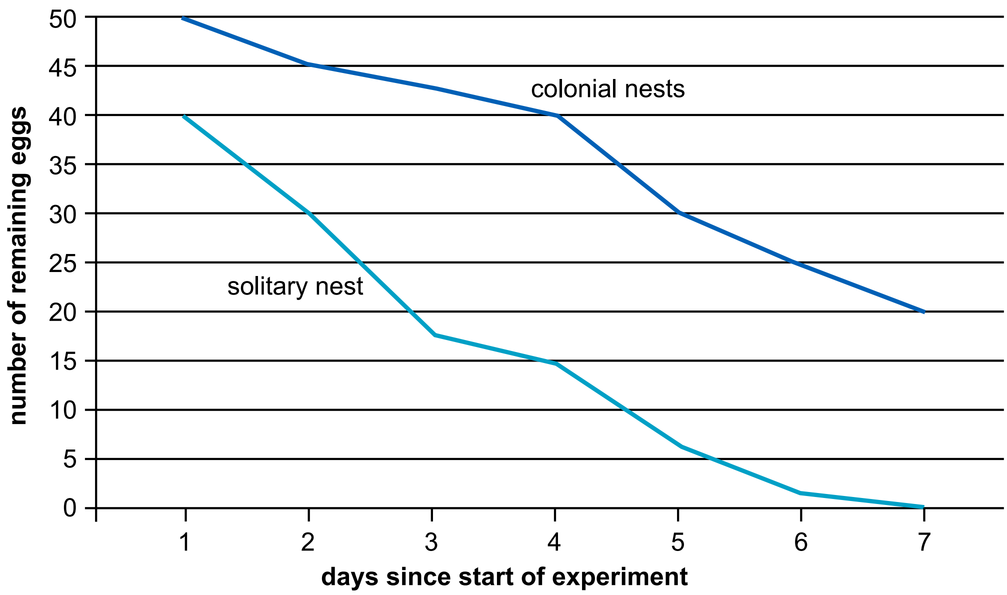
Q22: The honey bee is a social insect which lives in colonies. The queen is the only female in a colony that reproduces. Other females are workers which collect food, maintain the colony and care for the developing offspring.

Explain the advantage to the worker bees of caring for the offspring of the queen. (*2 marks*)

. . . .

Q23: Colonial nesting birds - gulls and terns, for example - may provide formidable opposition to an invading predator such as a fox by mobbing it, even hitting the predator with their feet.

The graph below shows the pattern of predation on experimental eggs laid out near nests of colonial and solitary pairs of common gulls. 50 experimental eggs were placed out at the start of the experiment near each nest.



1. From the graph, calculate the percentage eggs left near solitary nests after 4 days from start of experiment.
2. Calculate the percentage decrease in eggs left near colonial nests after 7 days from start of experiment.
3. What conclusion can you reach from these results. Give a reason for your answer.

. . . .

Q24: Termites and bees are examples of social insects. Give another example.

. . . .

Q25: Complete the following sentence by picking a word from each bracket.

In social insects, (all/few) individuals breed and the offspring are raised by the (queen/workers). Most of the bees in a colony are (drones/queens/workers) that help to raise close relatives but do not themselves reproduce. This is an example of (social hierarchy/kin selection/reciprocal altruism).

. . . .

Q26: Primates are social animals which often live in large groups. They display characteristic behaviours which enable group living.

Give one example of appeasement behaviour.

Topic 8

Components of biodiversity

Contents

Prerequisites

You should already know that:

- biotic, abiotic and human influences are all factors that affect biodiversity in an ecosystem;
- various factors can increase or decrease the biodiversity of an ecosystem.

Learning objective

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

- understand that measurable components of biodiversity include:
  - genetic diversity;
  - species diversity;
  - ecosystem diversity;
- state that genetic diversity comprises the genetic variation represented by the number and frequency of all the alleles in a population;
- understand that if one population dies out then the species may have lost some of its genetic diversity;
- state that loss of genetic diversity may limit a species' ability to adapt to changing conditions;
- know that species diversity comprises the number of different species in an ecosystem (species richness) and the proportion of each species in the ecosystem (the relative abundance);
- explain how a community with a dominant species has lower species diversity than one with the same species richness but no particularly dominant species;
- state that ecosystem diversity refers to the number of distinct ecosystems within a defined area.

8.1 Introduction

Biodiversity refers to the variation of life on Earth. Studies indicate that the environments with the greatest biodiversity are:

- tropical rain forests;
- coral reefs;
- the deep sea;
- large tropical lakes.

Coral reef

Humans rely on the biodiversity of our planet to provide us with raw materials, foods, industrial chemicals and medicines. We also rely on biodiversity to provide ecosystem services such as pollination, purification of water, recycling of nutrients and natural pest control.

Loss of biodiversity reduces the availability of ecosystem services and other useful products. It also decreases the ability of species, communities, and ecosystems to adapt to changing environmental conditions. Biodiversity is nature's insurance policy against natural disasters. By maintaining high biodiversity it is likely that at least a few species will be able to adapt to any change in conditions which may occur.

Scientists measure biodiversity to gather information which will help them to conserve as many species and ecosystems as possible for the future. The measurable components of biodiversity include genetic diversity, species diversity and ecosystem diversity.

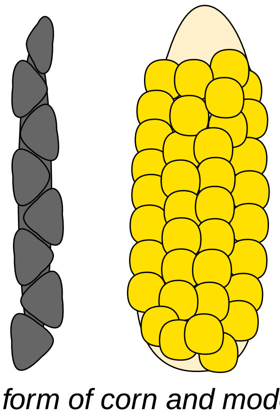
8.2 Genetic diversity

The Earth supports an extraordinary variety of interdependent life forms, upon which natural selection has been acting for millions of years. Each member of a species possesses hundreds or even thousands of genes. Since two or more alleles exist for most genes, the number of genetic combinations possible is enormous. The potential for genetic diversity amongst the members of a species is therefore immense.

In most natural populations, individuals vary slightly in their genetic makeup, which is why they do not all look or behave exactly alike. This is known as genetic diversity. Genetic diversity comprises the genetic variation represented by the number and frequency of all the alleles in a population. If one population dies out then the species may have lost some of its genetic diversity, and this may limit its ability to evolve successfully by adapting to changing environmental conditions.

The genetic diversity among individuals of a snail species is reflected in the variations in shell colour and banding patterns

Maintaining genetic variation among crop species, may be vital to the continuing success of crop development programmes. For example, in 1977 scientists discovered a previously unknown wild corn species, in South-central Mexico. This species happens to carry particularly useful genes, such as those for resistance to several viral diseases that affect domestic corn. Using these genes, scientists developed virus-resistant domestic corn varieties. Because corn is the third largest food crop on Earth, this discovery could prove critical to the global food supply.



Ancestral form of corn and modern maize

8.3 Species diversity

The second level of **biodiversity** concerns species diversity upon which much public attention is focused. Species diversity comprises the number of different species in an ecosystem (the species richness) and the proportion of each species in the ecosystem (the relative abundance). Because species diversity is dependent upon both the species richness and their relative abundance, a community with a dominant species will have a lower species diversity than one with the same species richness but no particularly dominant species. This is shown in the table below. Both the grazed field and open meadow have the same species richness. However, the dominance of the grasses in the open meadow means the other species have a lower relative abundance, therefore reducing species diversity in this ecosystem.

Species	**Grazed field**	**Open meadow**
Grass	25	60
Buttercup	10	5
Broad-leaved plantain	15	10
Daisy	20	10
White clover	15	5
Dandelion	15	10

Relative abundance (%) of species in a grazed field and an open meadow

It is thought that there are about 5 to 10 million species on Earth at present. However, species are not constant unchanging units. Their number and kind are always changing. At any given moment, some species will be enjoying a stable relationship with the environment, some will be moving towards extinction and others will be forming new species.

8.4 Ecosystem diversity

Ecosystem diversity refers to the number of distinct ecosystems within a defined area. A great deal of attention has been paid to the level of species diversity in species-rich ecosystems such as tropical forests, but some scientists have argued that other relatively species-poor ecosystems are highly threatened and similarly need to be conserved.

In North America, prairie grassland once covered large expanses of the middle region of the country. Due to its fertility large areas have been used for agriculture and today less that 1% of the original tallgrass prairie remains. Some states such as Minnesota, Nebraska and Montana have put conservation programmes in place to conserve this ecosystem.

American prairie

8.5 Learning points

Summary

- The measurable components of biodiversity include genetic diversity, species diversity and ecosystem diversity.
- The genetic diversity comprises the genetic variation represented by the number and frequency of alleles in a population.
- If one population dies out then the species may have lost some of its genetic diversity. This loss may limit its ability to adapt to changing conditions.
- Species diversity comprises the number of different species in an ecosystem (the species richness) and the proportion of each species in the ecosystem (the relative abundance).
- A community with a dominant species has lower species diversity than one with the same species richness but no particular dominant species.
- Ecosystem diversity refers to the number of distinct ecosystems within a defined area.

8.6 Extended response question

The activity which follows presents an extended response question similar to the style that you will encounter in the examination.

You should have a good understanding of biodiversity before attempting the question.

You should give your completed answer to your teacher or tutor for marking, or try to mark it yourself using the suggested marking scheme.

Extended response question: Biodiversity

Describe the measurable components of biodiversity. (*4 marks*)

8.7 End of topic test

End of Topic 8 test Go online

Q1: Give two components of biodiversity.

. . . .

Q2: What do we call the number of different species in a habitat?

a) Species diversity
b) Relative abundance
c) Species richness

. . . .

Q3: Which term refers to the variety of habitats?

a) Genetic
b) Ecosystem
c) Species

. . . .

Q4: Which term refers to the variety in the gene pool of a species?

a) Genetic
b) Ecosystem
c) Species

. . . .

Q5: Which term refers to the variety of living organisms found in different habitats?

a) Genetic
b) Ecosystem
c) Species

. . . .

Q6: Which of the following ecosystems would tend to remain most stable?

	Relative state of the ecosystem	**Predator-prey relationships**
A	Simple	Only one prey species for each predator
B	Complex	Only one prey species for each predator
C	Simple	Many prey species for each predator
D	Complex	Many prey species for each predator

. . . .

Q7: Which of the following best defines 'species diversity' of a habitat?

a) The maximum number of individuals which the resources of the island can support.
b) The number of different species in an ecosystem and the species richness.
c) The proportion of each species in an ecosystem and their relative abundance.
d) The number of different species in an ecosystem and the proportion of each species in the ecosystem.

. . . .

Q8: The number and frequency of ______ in a population is a measure of genetic diversity.

Topic 9

Threats to biodiversity

Contents

Prerequisites

You should already know that:

- biotic, abiotic and human influences are all factors that affect biodiversity in an ecosystem;
- various factors can increase or decrease the biodiversity of an ecosystem.

Learning objective

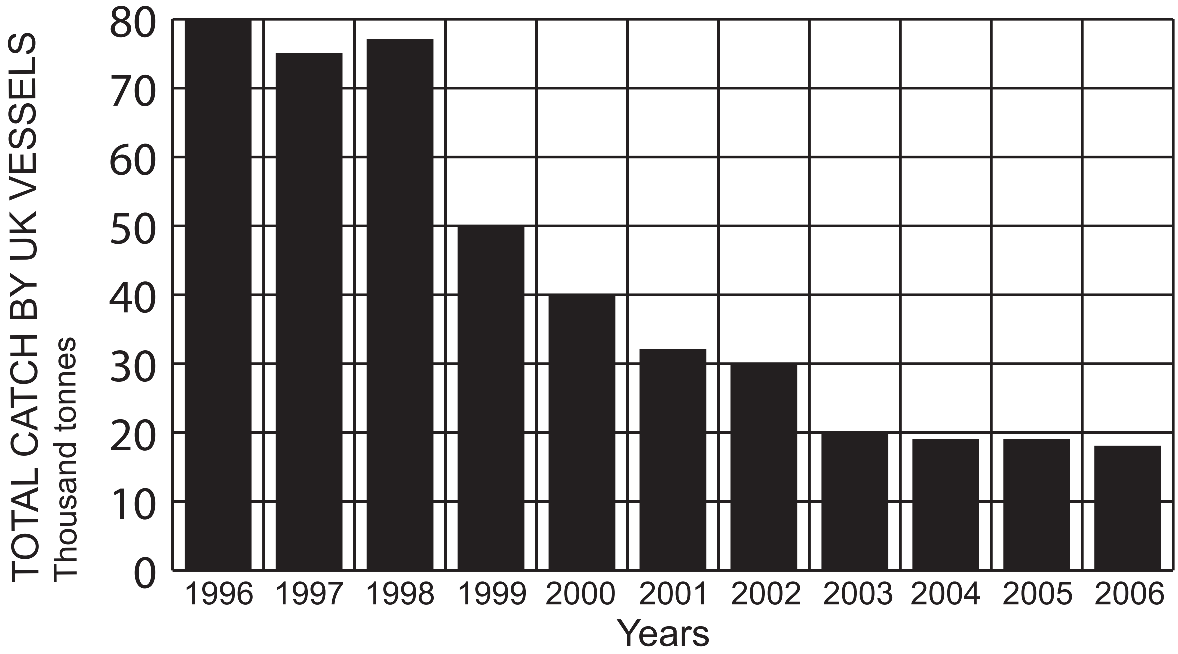
By the end of this topic you should be able to:

- describe the problems associated with overexploitation of particular species and the impact on the genetic diversity of that species;
- state that small populations can lose the genetic variation necessary to enable evolutionary response to environmental change;
- understand that this phenomenon is known as the bottleneck effect;
- understand that loss of genetic diversity can be critical for many species, as inbreeding results in poor reproductive rates;
- state that some species have a naturally low genetic diversity in their population and yet remain viable;
- state that habitat fragments typically support lower species richness than a large area of the same habitat;
- understand that habitat fragments suffer from degradation at their edges and this may further reduce their size;
- state that species adapted to the habitat edges (edge species) may invade the interior of the habitat at the expense of interior species;
- state that, to remedy widespread habitat fragmentation, isolated fragments can be linked with habitat corridors;
- understand that habitat corridors allow species to feed, mate and recolonise habitats after local extinctions;
- give the meaning of the terms introduced, naturalised and invasive species and describe their impact on indigenous populations;
- understand that invasive species may be free of the predators, parasites, pathogens and competitors that limit their population in their native habitat;
- state that invasive species may prey on native species or outcompete them for resources.

9.1 Overexploitation

Humans make use of many different species to gain useful products such as raw materials and food; this is referred to as exploitation of natural resources. Overexploitation applies to a situation where individuals are being removed from a population at a greater rate than can be replaced by reproduction. If overexploitation continues, the species could become extinct from the area and the natural resource could be lost. A common example of overexploitation of a natural resource is overfishing.

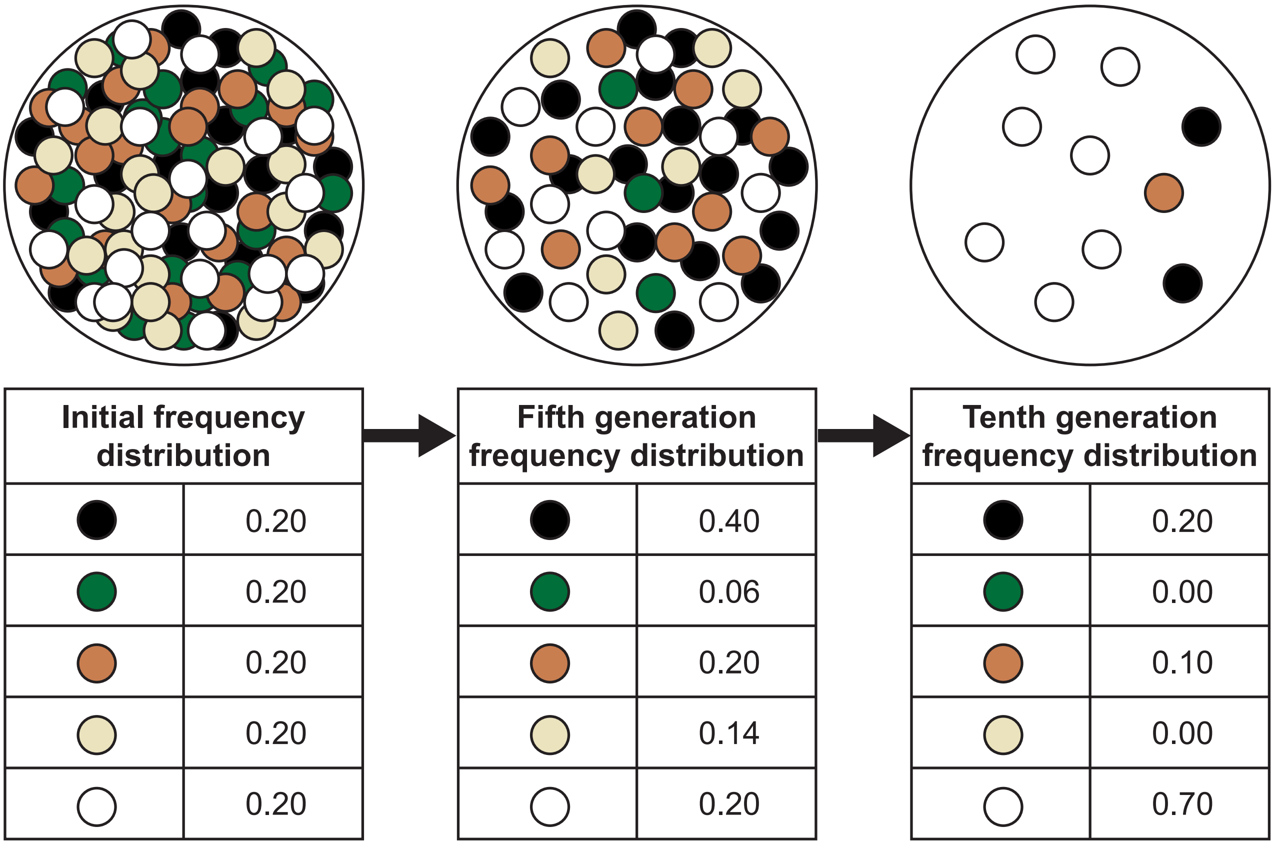
During the 1970s more than 300,000 tonnes of cod were caught from the North Sea. This size of catch proved to be unsustainable and by 2006 it had fallen to less than 30,000 tonnes; a reduction of 90%. The population of cod in the North Sea had reduced in numbers to a level which could result in their extinction from the area. Thanks to conservation methods, such as reduced quotas and limits on the number of days fishing vessels can spend at sea, cod stocks are now on the increase, although they are still far from the level considered to be safe from collapse. It seems that in this instance, although overfishing reduced the numbers of cod in the North Sea the population is capable of recovering.



UK cod catch from the North Sea

The bottleneck effect

Loss of many individuals from a small species may result in a loss of the genetic variation necessary to enable evolutionary responses to environmental change. The **bottleneck** effect refers to a loss of large numbers of individuals within a species. This can occur by natural means such as forest fires or it can occur due to human activities such as overhunting. A bottleneck event results in a small population which may have lost some of its genetic variation. It is possible for the population to recover in numbers, however, this loss of **genetic diversity** effectively results in inbreeding which causes poor reproductive rates. The next diagram explains how a population bottleneck can result in loss of certain alleles (loss of genetic diversity) and a change in allele frequency.



Population bottleneck

Cheetahs are an example of a species which have experienced a population bottleneck. Scientists have speculated that roughly 10,000 years ago, as the last ice age drew to a close, large numbers of cheetahs died out leaving very small populations in Asia and Africa. All the cheetahs now living are descended from this handful of individuals

Scientific research has shown that cheetahs from as far apart as East and Southern Africa - populations isolated by thousands of kilometres - were as similar to one another as 20 generations of deliberately inbred livestock or laboratory mice. When geneticists looked at the level of variation within genes of the cheetah, they found that cheetahs exhibit much lower levels of variation than other mammals. In most species, related individuals share about 80 per cent of the same genes. With cheetahs, this figure rises to approximately 99 percent. This genetic inbreeding in cheetahs has led to:

- low survival rates;
- greater susceptibility to disease;
- poor reproductive rates.

Cheetah (http://commons.wikimedia.org/wiki/File:Cheetah_0592.jpg by http://commons.wikimedia.org/wiki/User:Ltshears, licensed under http://creativecommons.org/licenses/by-sa/3.0/deed.en)

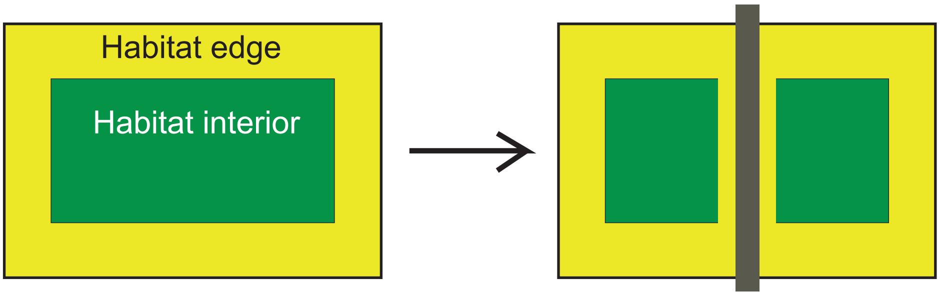
In another experiment, skin grafts were exchanged between members of two groups of cheetahs. In unrelated animals the survival time for skin grafts averages ten to twelve days. But in this experiment, all the grafts were accepted, though some were later slowly rejected. Several grafts persisted for at least 78 days, by which time they appeared to blend in with the recipient's own skin. This result indicated that the cheetahs' immune system did not recognise the tissue as being from another animal, and therefore failed to produce an immune reaction. Yet more evidence to show the **genetic uniformity** of populations of cheetahs.

Some species have a naturally low genetic diversity in their population and yet remain viable. Domesticated species often have low levels of genetic diversity. This is caused by the artificial selection of crops and animals for traits that humans find preferable.

9.2 The impact of habitat loss

An animal's habitat includes feeding sites, breeding grounds, burrowing sites and hunting areas. Human activities can split up such areas, causing animals to lose both their natural habitat and the ability to move between regions of an ecosystem. **Fragmentation** of habitats also means populations can be isolated and thus interbreeding may be prevented leading to a decrease in genetic diversity. Habitat fragments typically support lower species richness than a large area of the same habitat, thus reducing **biodiversity**. An additional issue is that habitat fragments suffer from **degradation** at their edges and this may further reduce their size.

Habitat fragmentation can have even greater effects than simply isolating populations. For example a forest ecosystem is not uniform across its area, within this ecosystem there is an interior which has different characteristics from the edges. Different organisms will be found within different regions of the forest. Fragmentation of ecosystems such as forests can result in changes to the ratio of edge habitat to interior habitat, as shown in the next diagram.



Habitat fragmentation

The centre of the forest is shaded by trees and has less wind and light than the forest edge, which is unprotected. Many forest-adapted species thus shy away from forest edges and prefer forest centres. Habitat fragmentation can result in an increased area of edge type habitat. Species adapted to the habitat edges may increase in number and invade the habitat core at the expense of interior species, reducing biodiversity.

Habitat fragmentation is a major problem across our planet. Roads, urbanisation and agriculture are among the main human activities which break up natural areas, often with disastrous implications for wildlife. A clear example which illustrates the importance of connectivity between fragmented habitats can be seen with the wood ants in the Scottish Caledonian forests. These forest-dwelling insects will not cross distances of more than 100 metres of open ground. Therefore, if wood ants are absent from an isolated area of forest, they will not be able to recolonise it, and the insect fauna of that woodland would be permanently depleted.

Habitat fragmentation due to human development is an ever-increasing threat to biodiversity, and habitat corridors are one possible solution. A habitat corridor is a strip of land that aids in the movement of species between disconnected areas of their natural habitat, allowing species to feed, mate and recolonise habitats after local extinctions. The main goal of implementing habitat corridors is to increase biodiversity. When areas of land are broken up by human interference, population numbers become unstable and many animal and plant species become endangered. By re-connecting the fragments, the population fluctuations can decrease dramatically.

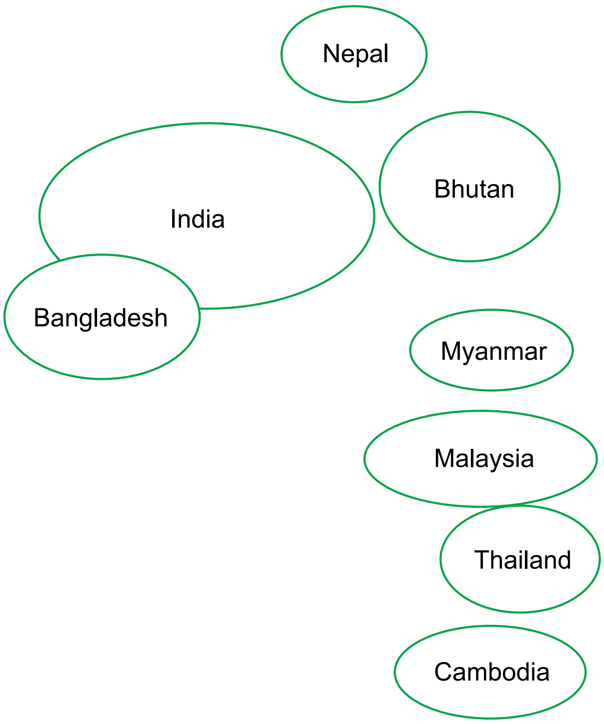
The main benefits of habitat corridors are:

- colonisation: they allow animals to move and occupy new areas when food sources become scarce in their core habitat;
- migration: species can relocate seasonally without the need for human interference;
- interbreeding: animals can find new mates in neighbouring regions so that genetic diversity can increase within the population.

Ecoduct habitat corridor (http://en.wikipedia.org/wiki/File:Cerviduct.jpg by http://nl.wikipedia.org/wiki/Gebruiker:Henkmuller, licensed under http://creativecommons.org/licenses/by-sa/3.0/deed.en)

The impact of habitat loss: Questions Go online

Indian Tigers were formerly distributed evenly from Nepal into Bhutan, Northern India through Thailand, Cambodia and Malaysia. Nowadays, however, due to urbanisation and habitat destruction the tiger is only found in small populations as shown on the following map.



Present day distribution of Indian Tigers

Q1: Give the term used to describe the process which has restricted the tiger to these eight areas.

. . . .

Q2: Suggest one method which could be taken to avoid extinction of the tiger in these countries.

. . . .

Q3: With reference to genetic diversity, explain how this method could improve the survival chances of the tiger. (*2 marks*)

9.3 Introduced, naturalised and invasive species

Introduced (non-native) species are those that humans have moved either intentionally or accidentally to new geographical locations. They are often called exotic species. Those that become established within wild communities are termed **naturalised** species. Most often the species are introduced for agricultural purposes, or as sources of timber, meat, or wool, and these species need humans for their continued survival. Some species have been introduced for **aesthetic** purposes. Others, such as plants, insects, or marine organisms, are unintentionally transported via the movement of cargo by ships or planes. Regardless of their method of introduction, some introduced species become **invasive**. Invasive species are naturalised species that spread rapidly and eliminate native species.

Invasive species often fare better in the new environment due to lack of predators, parasites, pathogens and competitors that limit their population in their native habitat. For example cane toads are native to Central and South America but were introduced to Australia as a form of biological control to kill crop pests. The toads quickly became invasive due to the lack of predators in the Australian ecosystem.

Cane toad (http://commons.wikimedia.org/wiki/File:Adult_Cane_toad.jpg by https://www.flickr.com/photos/briangratwicke/, licensed under http://creativecommons.org/licenses/by/2.0/deed.en)

Other invasive species may prey on native species or outcompete them for resources. For example grey squirrels were introduced to the UK in the late 1800s. Since then, they have caused a dramatic reduction in red squirrel numbers due to their ability to outcompete them for food and nesting sites.

Grey squirrels also carry a disease which kills red squirrels but does not affect the grey squirrels.

Grey squirrel

Red squirrel

Introduced, naturalised and invasive species: Question Go online

Q4: Match the descriptions with the terms listed.

- Established within wild communities
- Moved by humans either intentionally or accidentally to new geographical locations
- Species indigenous to the location
- Spread and outcompeting native species for space and resources

Terms: introduced, invasive, native, naturalised.

9.4 Learning points

Summary

- Overexploitation has greatly reduced the number of organisms in some populations, for example some fish species in the North Sea.
- Some populations of particular species have been able to recover even after the population has been greatly reduced.
- After a large decrease in numbers, a small population may lose the genetic variation necessary for evolutionary responses to environmental changes.
- This reduction in genetic variation is known as the 'bottleneck effect'.
- A population bottleneck is an evolutionary event in which a significant percentage of a population or species is killed or otherwise prevented from reproducing.

Summary continued

- This loss of genetic diversity may be critical to some species, as inbreeding results in poor reproductive rates.
- The clearing of habitats has led to habitat fragmentation.
- Habitat fragments typically support lower species richness than a large area of the same habitat.
- More isolated fragments and smaller fragments exhibit a lower species diversity.
- Habitat fragments suffer from degradation at their edges.
- Species adapted to habitat edges (edge species) may invade the habitat at the expense of interior species.
- Isolated fragments can be linked with habitat corridors.
- The corridors allow movement of animals between fragments increasing access to food and choice of mate. This may lead to recolonisation of small fragments after local extinctions.
- Introduced (non-native) species are those that humans have moved either intentionally or accidentally to new geographic locations.
- These may have an impact on indigenous (native) populations.
- Those that become established within wild communities are termed naturalised species.
- Invasive species are naturalised species that spread rapidly and eliminate native species.
- Invasive species may well be free of the predators, parasites, pathogens and competitors that limit their population in their native habitat.
- Invasive species may also prey on native species and outcompete them for resources.

9.5 Extended response question

The activity which follows presents an extended response question similar to the style that you will encounter in the examination.

You should have a good understanding of introduced species before attempting the question.

You should give your completed answer to your teacher or tutor for marking, or try to mark it yourself using the suggested marking scheme.

Extended response question: Introduced species

Discuss introduced species and their impact on indigenous (native) populations. (*6* marks)

9.6 End of topic test

End of Topic 9 test Go online

Q5: Which of the following correctly describes how the number of species present in a habitat fragment compare to the number of species present in the original habitat?

a) Larger
b) Same
c) Smaller

. . . .

Q6: What name is given to the links which can be made between isolated habitat fragments?

. . . .

Q7: Give one reason why invasive species are able to spread rapidly and eliminate native species.

. . . .

Q8: What term is used to describe the situation whereby a significant percentage of a population or species is killed or otherwise prevented from reproducing?

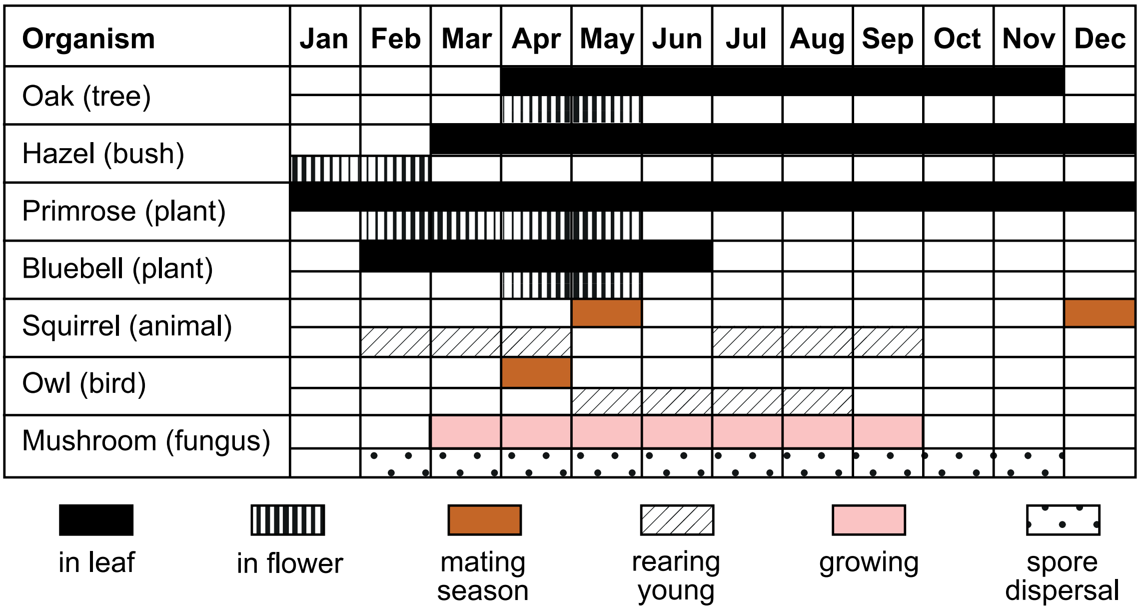
. . . .

Q9: Which of the following statements about genetic diversity are correct?

a) It is a measure of genetic differences within and between individuals, populations and species.
b) It is the variety of genetic material within a single species of organism that permits the organism to adapt to changes in the environment.
c) Genetic variation, required for natural selection, increases after a bottleneck event.
d) If there is enough genetic variation after a bottleneck event, the species can still recover but will lack genetic diversity.

. . . .

Q10: The following table illustrates a small range of biodiversity of organisms found in a wood and what some of the living organisms do at different times of the year.



For how many months are there leaves on the oak tree?

. . . .

Q11: What percentage of the year is the primrose plant in flower?

. . . .

Q12: Bluebells live on the floor of the wood. Explain why it is an advantage to the bluebells to produce leaves in February rather than later in the year.

. . . .

Q13: In terms of biodiversity, explain why this wood could be said to have a wide range of species diversity.

. . . .

Q14: A population of squirrels in a wood were discovered to have a very low genetic diversity. Explain how this could have occurred.

. . . .

Q15: Northern elephant seals experienced a population bottleneck caused by humans hunting them in the 1890s. At the end of the 19th century, hunting by man had reduced their population size to as few as 20 individuals. Their population now has risen to 30,000.

1. What effect has this had on their genetic diversity? Choose from:
   - increased;
   - decreased
   - stayed the same.
2. Give an example of a land animal which has a low genetic diversity.

. . . .

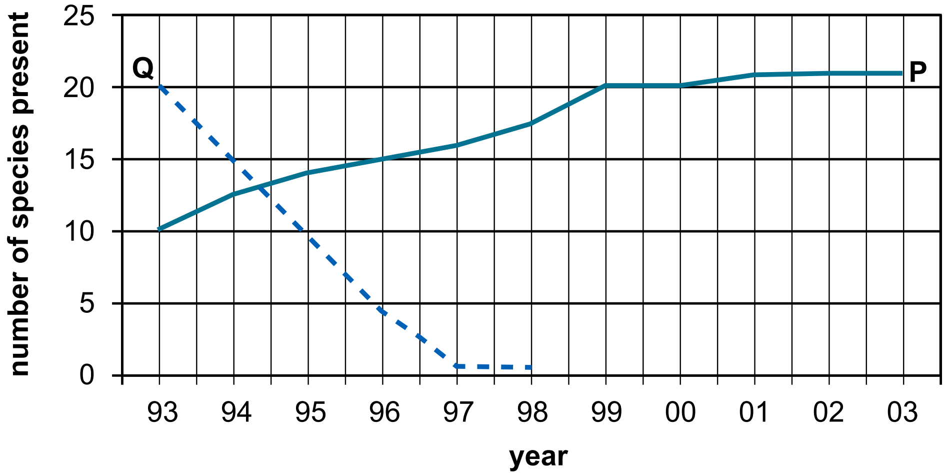
Q16: The following table shows data obtained from an investigation into the biodiversity of species in a heathland food web.

	Species	Mean mass of organisms (g)	Population density (numbers m^{-2})
A	Cricket	0.20	4
B	Ladybird	0.04	30
C	Aphid	0.003	5240
D	Green lacewing	0.004	3225

Which row in the table shows correctly the species with the highest biomass per square metre?

. . . .

Q17: The Sea Star *Pisaster Ochraceous* is a key predator found on rocks on the coast of certain areas of the USA, and it feeds on mussels and other invertebrates. The graph below shows the effect on the biodiversity of other species of removing and not removing *Pisaster* from rock pools in 1993.



Which row in the following table correctly describes the results?

	Line P	Line Q	Role of *Pisaster*
A	With *Pisaster*	Without *Pisaster*	Increases species diversity
B	With *Pisaster*	Without *Pisaster*	Decreases species diversity
C	Without *Pisaster*	With *Pisaster*	Increases species diversity
D	Without *Pisaster*	With *Pisaster*	Decreases species diversity

Topic 10

End of unit test

End of Unit 3 test Go online

Q1: Upon which process does all food production ultimately depend?

. . . .

Q2: Why is food security becoming a global issue?

. . . .

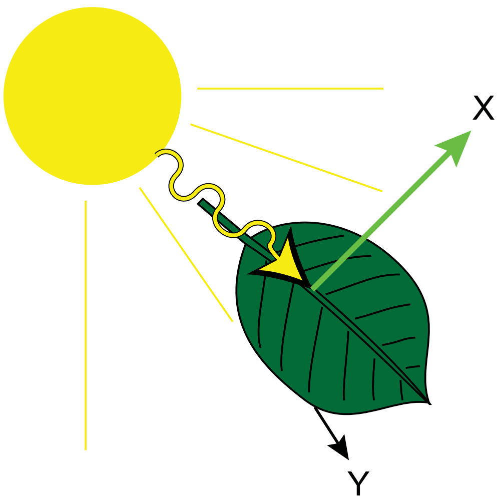
Q3: Which of the following factors will help to increase food production?

1. Breeding higher yielding cultivars.
2. Protecting crops from pests and diseases.
3. Changing land used for crops to livestock production.

a) 1 and 2 only
b) 1 and 3 only
c) 2 and 3 only
d) 1, 2 and 3

. . . .

Q4: The diagram shows the fate of sunlight landing on a leaf.

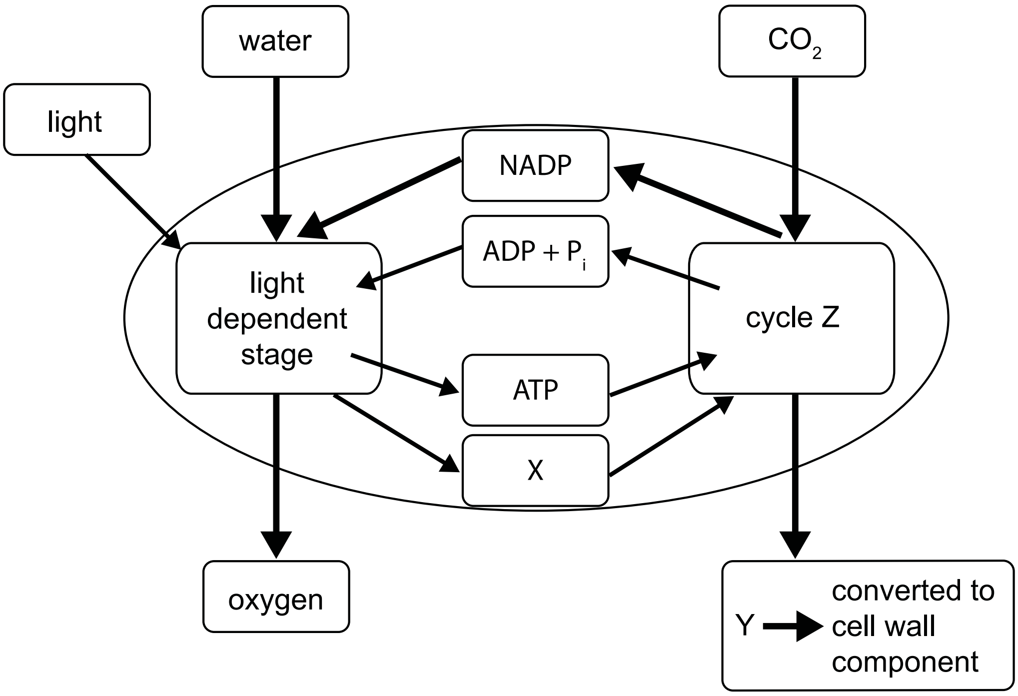


Which line in the following table correctly identifies the fate of sunlight represented by X and Y?

	X	**Y**
A	Transmission	Reflection
B	Absorption	Transmission
C	Reflection	Transmission
D	Reflection	Absorption

. . . .

Q5: The following diagram summarises the process of photosynthesis in a chloroplast.



1. Name molecules X and Y.
2. Name cycle Z.
3. Name the enzyme responsible for fixing carbon dioxide into cycle Z.
4. Name the cell wall component referred to in the diagram.

. . . .

Q6: Plant and animal breeding involves the manipulation of heredity to develop new and improved organisms to provide sustainable food sources. Name one characteristic which breeders may seek to improve in a crop organism.

. . . .

Q7: Which field trial design decision would you take to eliminate bias when measuring treatment effects?

a) Number of replicates.
b) Randomisation of treatment.
c) Selection of treatments.

. . . .

Q8: Which field trial design decision would you take to take account of the variability within a sample?

a) Number of replicates.
b) Randomisation of treatment.
c) Selection of treatments.

. . . .

Q9: Which field trial design decision would you take to ensure fair comparison?

a) Number of replicates.
b) Randomisation of treatment.
c) Selection of treatments.

. . . .

Q10: Selected plants or animals can be bred for several generations until the population breeds true to the desired type due to the elimination of heterozygotes. What is this process known as?

. . . .

Q11: The following are some features of weed species. Which two describe the features of an annual plant weed?

a) Vegetative reproduction
b) Storage organs
c) High seed output
d) Rapid growth

. . . .

Q12: Control of the whitefly with the parasitic wasp *Encarsia* is an example of:

a) natural control.
b) selective control.
c) biological control.
d) integrated control.

. . . .

Q13: Name one problem which pesticides may cause to the environment.

. . . .

Q14: The following list describes observed behaviour of pigs on a farm.

1. Lying in a position which does not allow suckling.
2. Repeated flicking of the head.
3. Frequent wounding of other pigs by biting.
4. Constantly bar biting.

Which of these behaviours indicate poor animal welfare?

a) 1, 2 and 3 only
b) 1, 3 and 4 only
c) 2, 3 and 4 only
d) 1, 2, 3 and 4

. . . .

Q15: Animals in captivity can show different behaviours from wild individuals of the same species. What name is given to a behaviour which involves unusual repetitive movement?

. . . .

Q16: Which of the following lines best describes the effects of a parasitic relationship on the parasite and the host?

a) Benefits the parasite and benefits the host.
b) Benefits the parasite and harms the host.
c) Harms the parasite and benefits the host.
d) Harms the parasite and harms the host.

. . . .

Q17: Like many animals, termites have microorganisms which live in their guts. The termites receive cellulose digesting enzymes from the microorganisms which allow them to use wood as a food source. The microorganisms are provided with a safe place to live. State the term used to describe this type of symbiotic relationship.

. . . .

Q18: State one way in which parasites can be transmitted.

. . . .

Q19: The following list shows benefits which an animal species can obtain from certain types of social behaviour.

1. Aggression between individuals is controlled.
2. Subordinate animals are more likely to gain an adequate food supply.
3. Experienced leadership is guaranteed.
4. Energy used by individuals to obtain food is reduced.

Which statements refer to social hierarchy?

a) 1, 2 and 3 only
b) 1, 2 and 4 only
c) 1, 3 and 4 only
d) 1, 2, 3 and 4

. . . .

Q20: Other than termites, give an example of a social insect.

. . . .

Q21: Altruistic behaviour is often observed between individuals which are closely related. What name is given to this form of altruism?

. . . .

Q22: Primates, such as chimpanzees, often use appeasement behaviour to reduce unnecessary conflict within the group. Give one example of this type of behaviour.

. . . .

Q23: Give one feature of parental care in primates which allows complex social behaviour to be learned.

. . . .

Q24: Which component of biodiversity is indicated by the number and frequency of alleles in a population?

. . . .

Q25: The number of different species in a habitat is called:

a) species diversity.
b) species richness.
c) relative abundance.

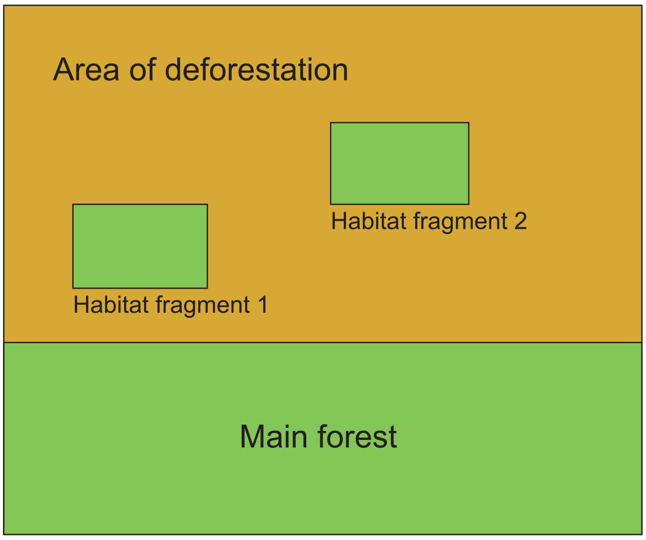
. . . .

Q26: If a dominant grass species invades an open meadow, what effect will this have on species diversity in the area?

a) It will increase.
b) It will decrease.
c) It will stay the same.

. . . .

Q27: The following illustration shows two habitat fragments produced as a result of deforestation and the remaining forest.



Which habitat fragment is likely to have the greatest species diversity?

. . . .

Q28: Suggest one measure which could be taken to link the isolated habitat fragments to the main forest.

. . . .

Q29: At a certain point in their life history, the numbers of cheetahs in the wild reduced drastically. As a result, populations of cheetah now show very little genetic variation. What name is given to this effect?

Read the following passage before answering the following three questions.

> Many species of plant have been removed from their native habitat and brought to the UK, for example pink sorrel. In some cases this has been performed intentionally and in others, by accident. Some species find that they are able to establish themselves in the new environment and compete on an equal footing with the native species, for example the evening primrose. Other species brought to the UK spread rapidly and eliminate native species, for example rhododendron.

Q30: Which of the species is naturalised?

a) Evening primrose
b) Rhododendron
c) Pink sorrel

. . . .

Q31: Which of the species is invasive?

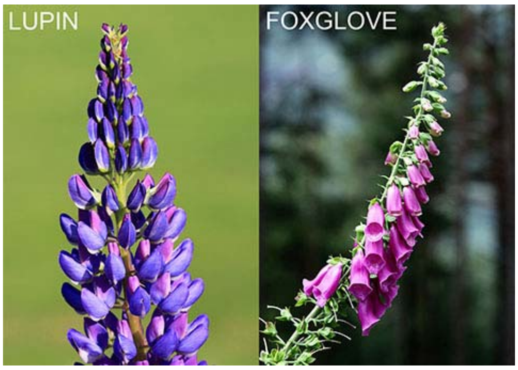
a) Evening primrose
b) Rhododendron
c) Pink sorrel

. . . .

Q32: Which of the species is introduced (non-native)?

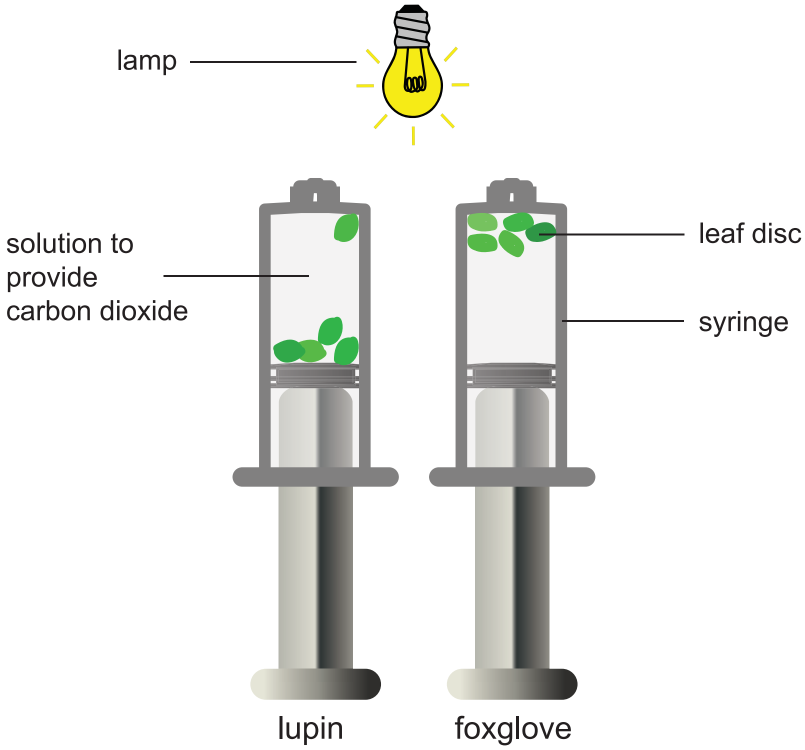
a) Evening primrose
b) Rhododendron
c) Pink sorrel

A group of students performed an experiment to investigate the rate of photosynthesis in lupin and foxglove plants.



Five leaf discs were cut from each plant and suspended in a solution that provided carbon dioxide in syringes. Air was removed from the discs which caused them to sink and the apparatus was placed in a dark room.

The discs were illuminated at a low light intensity by a lamp from above. The more quickly the leaf discs floated, the greater their rate of photosynthesis. The following diagram shows the positions of the leaf discs after fifteen minutes.



Q33: Why were five leaf discs used in each tube?

. . . .

Q34: Name two variables which must be kept constant when setting up this experiment.

. . . .

Q35: Why did the leaves which photosynthesised float?

. . . .

Q36: Foxgloves are shade plants which grow well on the forest floor in the shade of large trees. Explain how the results show that foxgloves are well adapted as shade plants.

. . . .

Q37: In a related investigation, the rate of photosynthesis in a foxglove was measured at different light intensities. The results from this experiment are shown in the following table.

Light intensity (kilolux)	Rate of photosynthesis (units)
10	4
20	20
30	55
40	86
50	90
60	90

Draw a line graph to display the results of this investigation.

. . . .

Q38: Calculate the percentage increase in the rate of photosynthesis when light intensity increases from 20 kilolux to 30 kilolux.

. . . .

Q39: Shade plants, such as foxgloves, have adaptations which allow them to use green light for photosynthesis. Suggest an adaptation which would allow a plant to absorb a wider range of wavelengths of light for photosynthesis.

Glossary

Absorbed

the light which is taken into a plant leaf by pigments

Aesthetic

branch of philosophy dealing with the nature of beauty and art

Agriculture

the process of producing feed and other desirable products by the cultivation of certain plants and the raising of domesticated animals

Allele

a form of a gene - in pea plants the gene for petal colour has two different alleles giving either pink or white petals. Alleles are usually written as capital (A) or small (a) letters

Animal welfare

physical and psychological well-being of animals. The term animal welfare can also mean human concern for animal welfare. Welfare is measured by indicators including behaviour, physiology, longevity, and reproduction

Annual weed

plant which grows, flowers, set seeds and dies within the space of one year

Artificial selection

intentional breeding controlled by humans for particular traits or characteristics

ATP

adenosine triphosphate, coenzyme used as an energy carrier in the cells of all known organisms

Biodiversity

degree of variation of life forms within a given species, ecosystem, biome, or an entire planet

Biomass

the total mass of living matter within a given unit of environmental area

Bottleneck

an evolutionary event in which a significant percentage of a population or species is killed or otherwise prevented from reproducing

Calvin Cycle

a series of biochemical reactions that takes place in the chloroplast and does not require light

Carnivore

animal which eats meat and which derives its energy requirements from a diet consisting mainly or exclusively of animal tissue whether through predation or scavenging

Chlorophyll

the green pigment which is found in almost all plants and green algae. It absorbs light which is essential for photosynthesis

Chloroplast

the photosynthetic unit of a plant cell, containing all the chlorophyll

Colonial

relating to a colony

Competition

an interaction or struggle between organisms or species for a resource such as food, territory or mates, in which the fitness or numbers of one is reduced by the presence of another

Cooperative hunting

animals such as lions hunt as a group to increase their chances of successfully killing prey

Crossbreeding

a crossbreed (adjective crossbred) usually refers to an animal with purebred parents of two different breeds, varieties, or populations. Crossbreeding refers to the process of breeding such an animal, often with the intention to create offspring that share the traits of both parent lineages, or producing an animal with hybrid vigour

Cultivar

plant or group of plants selected for a particular characteristic

Degradation

process by which ecosystems or habitats are broken down or fragmented

Food security

the ability of human populations to access food of sufficient quality and quantity

Fragmentation

habitat fragmentation describes the emergence of discontinuities (fragmentation) in an organism's environment (habitat), causing population fragmentation

Fungicide

a chemical compound or biological organism used to kill or inhibit fungi or fungal spores

G-3-P

glycerate-3-phosphate, which is a substance found in the carbon fixation stage (Calvin Cycle) of photosynthesis

Genetic diversity

comprises the genetic variation represented by the number and frequency of alleles in a population

Genetic uniformity

when the genes or alleles of a population are similar and show little variation

Genome

the entirety of an organism's hereditary information

Genotype

a statement of an organism's alleles for a particular characteristic usually given as symbols - a pea plant could have the genotype CC if it were homozygous for pink petal colour or the genotype Cc if it were heterozygous for pink colour

Herbicide

a chemical compound used to kill unwanted plants

Herbivore

an organism adapted to eat plant-based foods, such as deer, cows and sheep

Heterozygotes

having two different alleles for a characteristic - a pea plant heterozygous for petal colour has two different petal colour alleles Cc

Hierarchy

an organisation arranged in a graded order with member(s) at the top who are dominant over subordinate individuals

Homozygotes

having two identical alleles for a characteristic - a pea plant homozygous for petal colour has two identical petal colour alleles, both pink (CC) or both white (cc)

Inbreeding

the reproduction from mating two genetically related parents

Inbreeding depression

the reduced fitness in a given population as the result of breeding of related individuals

Insecticide

a chemical compound used to kill insects

Invasive

introduced species (also called 'non-indigenous' or 'non-native') that adversely affect the habitats they invade economically, environmentally, and/or ecologically

Legume

a plant which is able to fix atmospheric nitrogen to synthesis amino acids which can then be built up to plant proteins. This is due to the symbiotic relationship with bacteria in the root nodules of these plants

Light reaction

the photosynthetic process in which solar energy is harvested and transferred into the chemical bonds of ATP; can occur only in light

Livestock

one or more domesticated animal raised in an agricultural setting to produce commodities such as food, fibre and labour. The term does not usually involve farmed fish

Metabolites

the intermediates and products of metabolic reactions that take place in organisms

Misdirected behaviour

abnormal behaviour which the animal directs at another object, animal or human

Mollusc

a large group of invertebrate organisms including slugs

Monoculture

the agricultural practice of producing or growing one single crop over a wide area. It is widely used in modern agriculture and its implementation has allowed for large harvests of crops from minimal labour

NADP

nicotinamide adenine dinucleotide phosphate is a coenzyme which is used to carry hydrogen (NADPH) to chemical reactions which require a reducing agent

Naturalised

any process by which a non-native organism spreads into the wild and its reproduction is sufficient to maintain its population

Nematode

organisms which belong to the group known as the roundworms and can be found in almost every ecological system

Outbreeding

the practice of introducing unrelated genetic material into a breeding line

Pecking order

a natural hierarchy in a group of birds, such as domestic fowl

Perennial

a plant which lives for more than two years

Persistent

chemical compounds which do not break down or degrade easily in the environment

Placatory

leading to a reduction in tension, to pacify or appease

Polyculture

agriculture using multiple crops in the same space

Predator

an organism that feeds on another organism

Producer

an organism which uses light energy (green plants) or chemical energy (some bacteria) to manufacture the organic compounds it needs as nutrients from simple inorganic compounds obtained from its environment

Productivity

the rate of generation of biomass in an ecosystem. It is usually expressed in units of mass per unit surface (or volume) per unit time, for instance grams per square metre per day

Reflected light

light which is bounced off a leaf and does not get absorbed and is not available for photosynthesis

RuBisCO

ribulose-1,5-bisphosphate carboxylase oxygenase, is an enzyme involved in carbon fixation (Calvin Cycle) that catalyzes the first major step of carbon fixation, a process by which the atoms of atmospheric carbon dioxide are made available to organisms in the form of energy-rich molecules such as carbohydrates

RuBP

ribulose-1,5-bisphosphate is an organic substance that is involved in photosynthesis

Sanitation

the removal of crop residues and unharvestable (perhaps pest-infected) plants that might harbour pest insects from outside the crop area

Stereotypic behaviour

repetitive or ritualistic movement, posture, or utterance, found in animals with welfare problems

Sustainable

a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for generations to come

Symbiosis

close and often long-term interaction between different biological species

Synthesis

the building up of complex molecules from simpler ones

Transmitted light

transmitted light is light which passes right though the leaf

Trophic level

the position or stage an organism occupies in a food chain. Trophic levels can be represented by numbers, starting at level 1 (or A) for plants

Weed

a plant that is considered to be a nuisance, and normally applied to unwanted plants in human-controlled settings, especially farm fields and gardens

Answers to questions and activities

Topic 1: Food supply

Agricultural production - Food production and photosynthesis: Questions (page 6)

Q1:

Raw materials for photosynthesis	Essential requirements	Products of photosynthesis
Water	Light	Sugar
Carbon dioxide	Chlorophyll	Oxygen

Q2: 32.4

Q3: 142.5

Q4: *Any two from*:

- Climate change may affect increased wheat production.
- New cultivars/crop plants may not yield increases in wheat production.
- Lack of available, high-quality agricultural land may restrict increase in wheat production.

Agricultural production - Trophic levels: Questions (page 9)

Q5: 33

Q6: 4

Q7: Energy transfer is inefficient because energy is lost while moving from one trophic level to another in the following ways:

- not the entire organism is consumed or digested - parts such as woody stems, bones, and scales are not eaten, and some materials such as cellulose cannot be digested;
- energy is used up by organisms in each trophic level for movement;
- energy is used in respiration and is released from the body of the organism as heat;
- energy becomes lost in excretion.

Q8:

- Energy released as respiration is used for movement and other life processes, and is eventually lost as heat to the surroundings.
- Energy is lost in waste materials, such as faeces.

Q9: There is more energy available in plants to human food chain than in plants to meat to human food chain as it is a shorter food chain with subsequently less energy loss. This would mean there would be more energy in plant food available to feed more people using plants-based diet than a meat-based diet.

End of Topic 1 test (page 13)

Q10: d) 0.25

Q11: b) producers.

Q12: c) Increased susceptibility to disease

Q13: a) trophic level A: producers.

Q14: c) 40,000 kJ $m^{-2}year^{-1}$

Q15: c) 1 kJ

Q16: Photosynthesis

Q17: To ensure food security OR because the human population is increasing

Topic 2: Plant growth and productivity

Photosynthetic pigments: Thin layer chromatography (page 20)

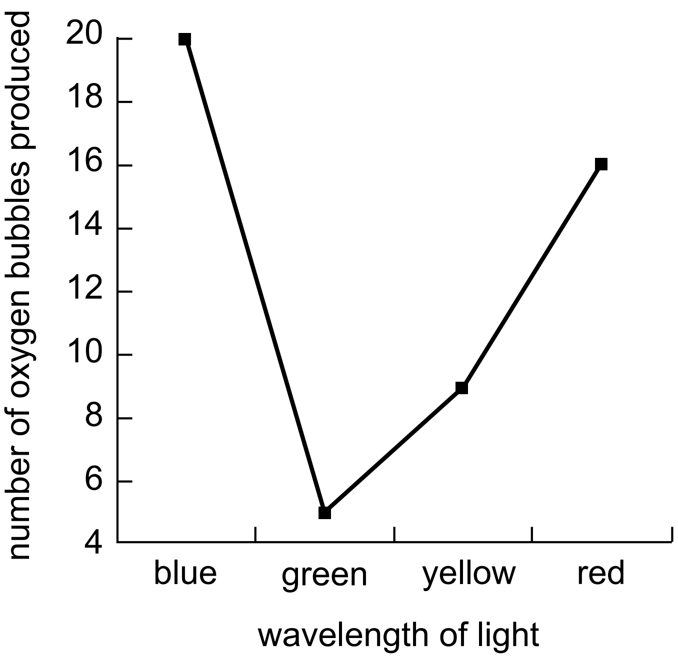
Q1: a) 0.39

Q2: c) 0.48

Q3: d) 0.64

Action spectrum: An experiment to determine an action spectrum for photosynthesis (page 24)

Q4: All four wavelengths contribute to photosynthesis, but the blue and red ends of the visible light spectrum are the major contributors to photosynthesis. The image shows a plot of the number of oxygen bubbles produced against the wavelength of light. This illustrates an action spectrum for photosynthesis.

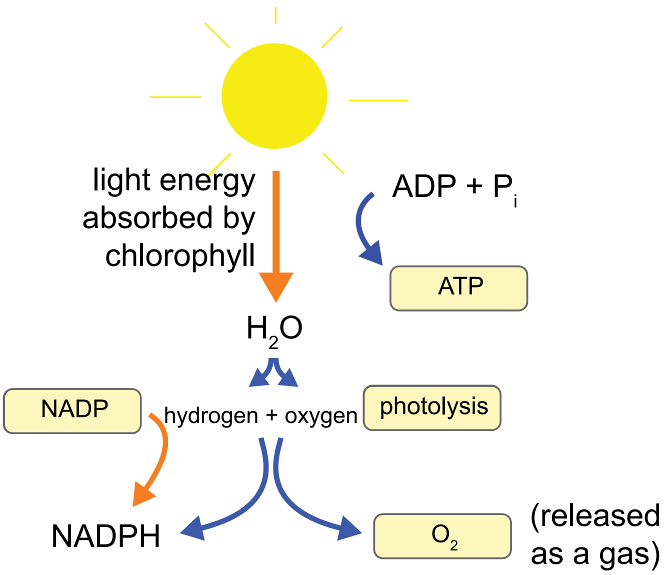


Q5: The rate of photosynthesis is significantly greater at the blue and red ends of the spectrum because chlorophyll can directly absorb light at these wavelengths.

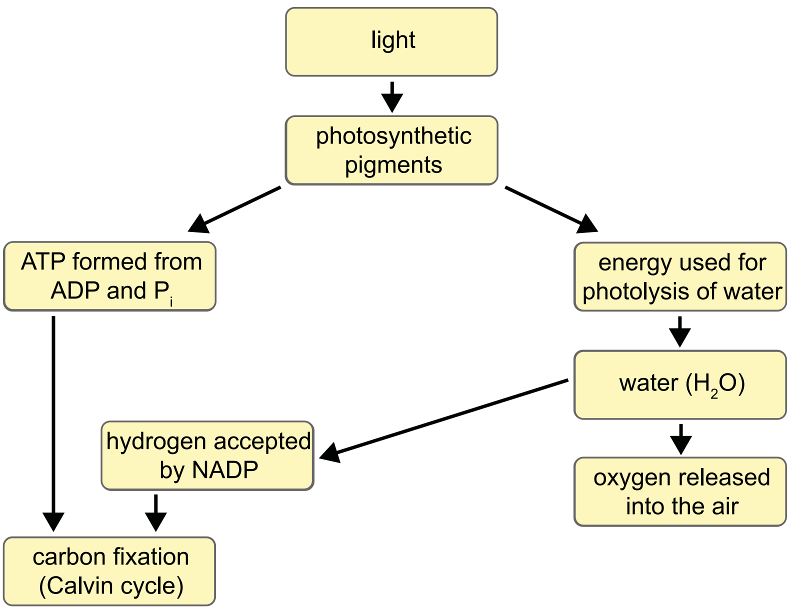
Q6: The plant must be allowed to equilibrate to its new surroundings.

The light-dependent stage (page 26)

Q7:

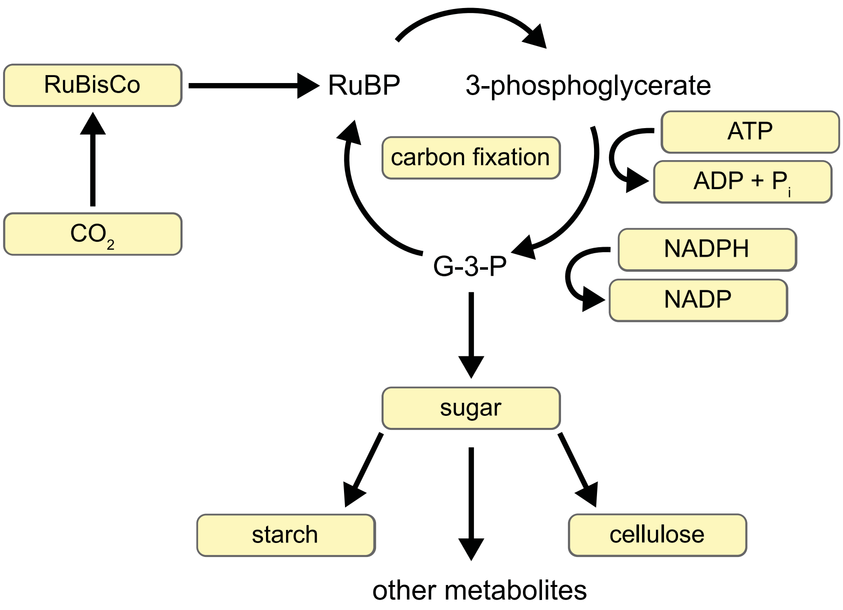


Q8:



The second stage of photosynthesis: The carbon fixation stage (page 27)

Q9:



The second stage of photosynthesis: Questions (page 28)

Q10: X: Oxygen and Y: Glucose/carbohydrate

Q11: Photolysis of water

Q12: Calvin Cycle OR carbon fixation

Q13: Cellulose

Q14: *Any two from*:

- ATP
- NADPH
- hydrogen

Extended response question: Plant growth and productivity (page 30)

Suggested marking scheme

Each line represents a point worth one mark. The concept may be expressed in other words. Words which are bracketed are not essential. Alternative answers are separated by a solidus (/); if both such answers are given, only a single mark is allocated. In checking the answer, the number of the point being allocated a mark should be written on the answer paper. A maximum of sixteen marks can be gained.

A) Light and photosynthetic pigments in photosynthesis *(maximum of 8 marks)*:

1. Plants reflect, transmit and absorb light.
2. Only a small amount of the absorbed light energy is used in photosynthesis.
3. Photosynthetic pigments absorb light energy.
4. Chlorophyll a and chlorophyll b are the main photosynthetic pigments.
5. They absorb light in the red and blue range of the visible spectrum.
6. The carotenoids are accessory pigments.
7. They absorb light from other regions in the visible spectrum.
8. The accessory pigments pass the energy they absorb onto the chlorophyll.
9. The wavelengths of light that are absorbed by a pigment are called its absorption spectrum.
10. The wavelengths of light actually used by a pigment in photosynthesis are called its action spectrum.
11. The absorption spectrum of chlorophyll is closely related to the rate of photosynthesis.

B) Light-dependent stage of photosynthesis and the Calvin Cycle *(maximum of 8 marks)*:

Any four of the following for *4 marks*:

i. Absorbed energy excites electrons in the pigment molecule to raise them to high-energy levels.
ii. Transfer of these high-energy electrons through electron transport chain releases energy.
iii. This energy is used to generate ATP from ADP and P_i (inorganic phosphate).
iv. The enzyme ATP synthase is required for this process.
v. The light energy is used to split water molecules into oxygen and hydrogen.
vi. The hydrogen combines with the co-enzyme NADP forming NADPH.
vii. The oxygen is released from the leaf as a by-product of the reaction.

Any four of the following for *4 marks*:

I. The ATP and NADPH from the light dependent stage are transferred to the ~~Calvin Cycle~~ **carbon fixation stage**.
II. The enzyme RuBisCO fixes carbon dioxide from the atmosphere
III. by attaching it to RuBP.
IV. The 3-phosphoglycerate produced is phosphorylated by ATP and combined with the hydrogen from NADPH to form G-3-P.
V. G-3-P sugar may be synthesised into starch, cellulose or other metabolites.
VI. G-3-P is used to regenerate RuBP to continue the cycle.
VII. Major biological molecules in plants such as proteins, fats, carbohydrates and nucleic acids are derived from the photosynthetic process.

End of Topic 2 test (page 30)

Q15: d) use light of different wavelengths for photosynthesis.

Q16:

1. Transmitted
2. Chloroplasts

Q17:

1. Photolysis
2. NADP
3. Oxygen

Q18: The accessory pigments extend the wavelengths of light which can be absorbed by the plant.

Q19:

1. CO_2
2. RuBisCO

Q20: ATP

Q21: C

Q22:

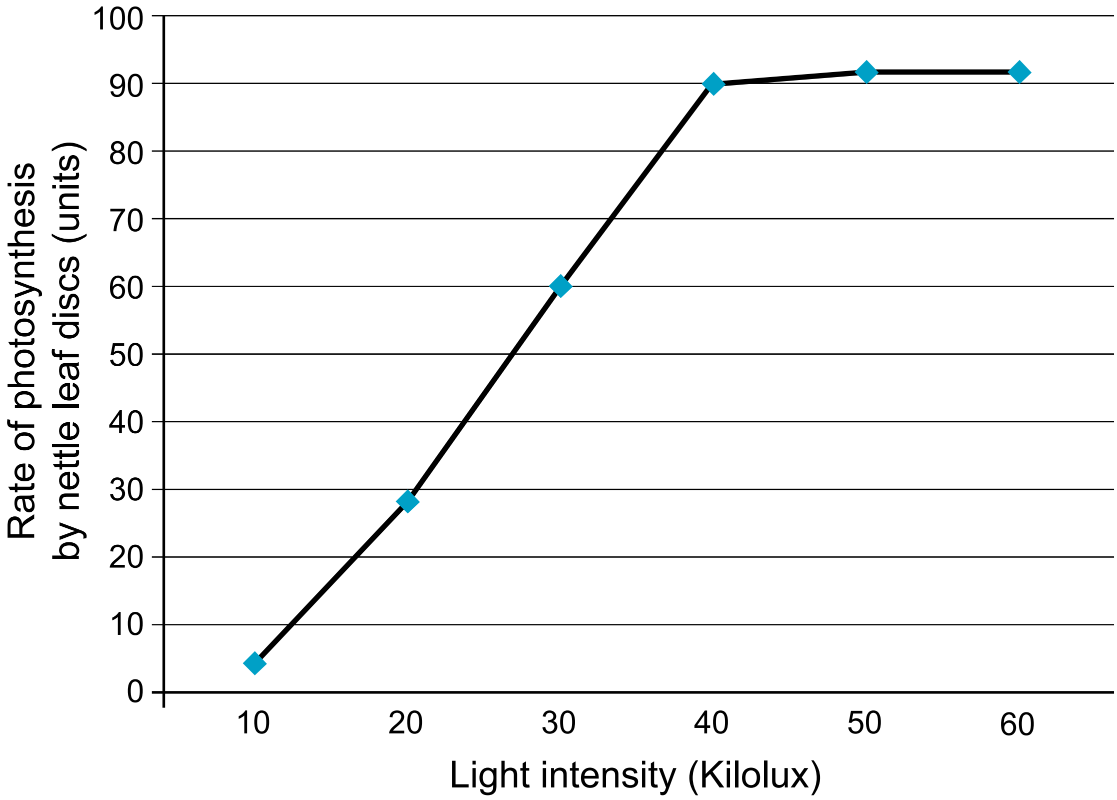
Term	Description
Oxygen	Product of the photolysis of water which is required for aerobic respiration.
NADP	Compound which accepts hydrogen during the photolysis of water.
Water	Raw material which becomes split into oxygen and hydrogen during photolysis of water.
ADP + P_i	Components of a high-energy compound.
Photolysis	Breakdown of water during the light- dependent stage of photosynthesis.
Hydrogen	Product of photolysis of water which becomes attached to NADP.
Chlorophyll	Green pigment which traps light energy.
Light dependent reaction	First stage in photosynthesis in which light energy is converted to chemical energy.

Q23:

Term	Description
Chloroplast	Structure found in a leaf where photosynthesis takes place.
NADPH	Hydrogen acceptor needed for the fixation of carbon in carbohydrates.
RuBP	Carbon compound which acts as a carbon dioxide acceptor.
G-3-P	First stable compound formed in the carbon fixation stage (Calvin Cycle) after carbon dioxide combines with its acceptor molecule.
Carbon dioxide	Raw material which supplies carbon atoms to be fixed into carbohydrates.
ATP	High-energy compound used to phosphorylate the intermediate compound in carbon fixation (Calvin Cycle).
Carbon fixation	Second stage in photosynthesis which is also known as the carbon fixation stage (Calvin Cycle).
RuBisCO	The enzyme which fixes carbon dioxide by attaching it to RuBP.

Q24: Marking Scheme: Axis with appropriate scales plus labels with units (all of table headers): (*1 mark*). Points plotted accurately: (*1 mark*).

1.



2. Effect: (increase/rise) justification: (More CO_2 for photosynthesis to take place)

   Effect: (stays the same) justification: (temperature or other factor limiting rate of photosynthesis)

Q25:

1. rapid increase at low levels of CO_2 (between 200-400 ppm); then increase slows down between 400-800 ppm; and greater increase from 800-1000 ppm; then levels out above 1000 ppm. (Any three points = *2 marks*, two points = *1 mark*, one point = *0 marks*)
2. 5 kg m^{-2}
3. 100%

Q26: Carbon dioxide is an essential material for photosynthesis; increase in carbon dioxide increases rate of photosynthesis. (Two points = *1 mark*, one point = *0 marks*)

Q27:

1. Increase in yield from 1 kg m^{-2} at 15°C to 5.5 kg m^{-2} at 25°C. (Quantitative data = *1 mark*)

   Explanation: increase in temperature increases rate of enzyme reactions; enzymes are involved in the Calvin Cycle. (Two points = *1 mark*, one point = *0 marks*)
2. 450%
3. Any from water / mineral ions / named ion / disease / genetic factors of variety of tomato / pollination factors such as insects.
4. The temperature may be too high after 25°C for the enzymes present in the Calvin Cycle to work at their optimum, therefore photosynthesis will decrease.

Topic 3: Plant and animal breeding

Field trials: Question (page 41)

Q1:

Design feature	Reason for carrying out this procedure
Randomisation of treatment	To eliminate bias when measuring treatment effects.
Number of replicates	To take account of the variability within a sample.
Selection of treatments	To ensure fair comparison.

End of Topic 3 test (page 48)

Q2: Yield, nutritional value, resistance to pests and diseases, physical characteristics suited to rearing and harvesting.

Q3: In inbreeding, selected plants or animals are bred for several generations until the population breeds true to the desired type due to the elimination of **heterozygotes**.

Q4: c) inbreeding depression.

Q5: This prevents/reduces insect attack OR there is less damage to the plant by insects. Photosynthesis is greater/not reduced OR food is available for growth.

Q6: The insect has gained resistance/developed tolerance to the toxin.

Q7: b) the hybrids are heterozygous and therefore not true breeding.

Q8: As sward height increases from 4 cm to 10 cm, milk production increases from 12 kg/day to 18 kg/day; As sward height increases further from 10 cm to 16 cm, milk production remains constant at 18 kg/day; As sward height increases further from 16 cm to 18 cm, milk production decreases from 18 kg/day to 17 kg/day.

Q9: 10 cm

Topic 4: Crop protection

Problems with pesticides: Questions (page 60)

Q1: d) phytoplankton and dolphin

Q2: c) 130

End of Topic 4 test (page 63)

Q3: The crop yield would increase because weeds would be killed. Weeds would no longer compete with crop plants for light, water, minerals. Crop plants will have more resources and grow better.

Q4: They could interbreed and produce weeds which have the gene for glyphosate resistance, therefore weedkiller would be ineffective.

Q5: c) 4050

Q6: b) Pea

Q7: c) Leather jacket

Q8: Rapid growth, short life cycle, high seed output, long-term seed viability.

Q9: a) herbivorous fish and carnivorous fish.

Q10: c) 1.2×10^5

Q11:

- Pesticides can cause problems in the environment because they can **accumulate** within the body of an organism.
- They can also **magnify** along food chains.
- This means each successive organism in the food chain has a **higher** concentration of the chemical in its tissues than the previous organism.

Q12: 80%

Q13: Insecticides kill insects which damage crops/reduce crop yield.

Q14: Insecticides are sprayed onto crops, but rain washes it into rivers. Fish pick up insecticide from water, or from eating microscopic animals which contain it.

Q15: The use of pesticides may result in a population selection pressure producing a **resistant** population.

Q16: d) Chemical, cultural and biological

Topic 5: Animal welfare

Animal welfare: Animal freedoms (page 69)

Q1:

Freedoms for Animals	Example
Freedom from hunger and thirst.	Animals should be able to drink fresh water when they need it.
Freedom from chronic discomfort.	Animals should be kept in a comfortable environment.
Freedom from pain, injury and disease.	Environment should be safe for animals and not cause them injury.
Freedom to express normal behaviour.	Animals should be able to move around freely and mix with other animals in the group.
Freedom from fear and the avoidance of stress whenever possible.	Animals should not be exposed to unnecessary pain.

End of topic 5 test (page 72)

Q2: d) 1, 2 and 3

Q3: a) 1 and 2

Q4:

Type of abnormal behaviour	Example of abnormal behaviour
Stereotype behaviour	Polar bears pacing in a zoo
Misdirected behaviour	Tail biting in pigs
Failure in sexual behaviour	Cheetahs unable to breed in captivity
Altered levels of activity	Hysteria among turkeys

Topic 6: Symbiosis

Extended response question: Mutualism and parasitism (page 82)

Suggested marking scheme

Each line represents a point worth one mark. The concept may be expressed in other words. Words which are bracketed are not essential. Alternative answers are separated by a solidus (/); if both such answers are given, only a single mark is allocated. In checking the answer, the number of the point being allocated a mark should be written on the answer paper. A maximum of six marks can be gained.

A) Mutualism *(maximum of 2 marks)*:

1. Mutualism is a form of symbiosis.
2. Mutualism is a close/intimate/coevolved/long-term relationship.
3. This relationship is one in which both species benefit.
4. Both species have evolved over a long period of time to be dependent upon each other.

B) Parasitism *(maximum of 4 marks)*:

- i. Defined as interaction between two species where host is harmed and parasite benefits.
- ii. Developed by coevolution/coevolved.
- iii. Parasite benefits as it gains energy/nutrients/resources.
- iv. Negative to host since resources/energy are lost.
- v. Parasites can have limited metabolism.
- vi. Often cannot survive outside host/reproduction requires host.
- vii. Brief description of one method of transmission such as direct contact or vector.
- viii. Example of a parasite including the name of the parasite and its host.

End of Topic 6 test (page 82)

Q1: An organism which carries disease from one individual to another ($1\ mark$) without suffering from the disease (*1 mark*).

Q2:

A) Add fish to the water to eat eggs or larvae/drain wet areas/spray water with insecticide.
B) Add oil or detergent to the water surface to stop pupae breathing and prevent adults emerging.
C) Use insecticides to kill adults/ use mosquito nets or repellent to prevent being bitten.

Q3: d) mutualism.

Q4: b) Light; no food supplied

Q5: Vectors, intermediate (secondary) hosts, direct contact or resistant stages.

Q6:

1. One species benefits and the other is harmed. **Parasitism**
2. Both species in the interaction benefit. **Mutualism**

Q7: Column B

Q8: Row D

Q9:

1. Mutualism
2. *Any one from*:
   - alga is afforded shelter and protection;
   - alga obtains carbon dioxide from host;
   - alga obtains nitrogen compounds from hosts' excretory waste.

Topic 7: Social behaviour

Social hierarchy: Questions (page 89)

Q1:

Contest	Score out of 20 (points)	Winner	Net number of contests won
T v Q	T 17, Q 3	T	14
T v R	T 3, R 17	R	14
P v Q	P18, Q 2	P	16
Q v R	Q 0, R 20	R	20
Q v S	Q 8, S 12	S	4
R v P	R 13, P 7	R	6
P v T	P 14, T 6	P	8
S v T	S 5, T 15	T	10
R v S	R 19, S1	R	18
S v P	S 4, P 16	P	12

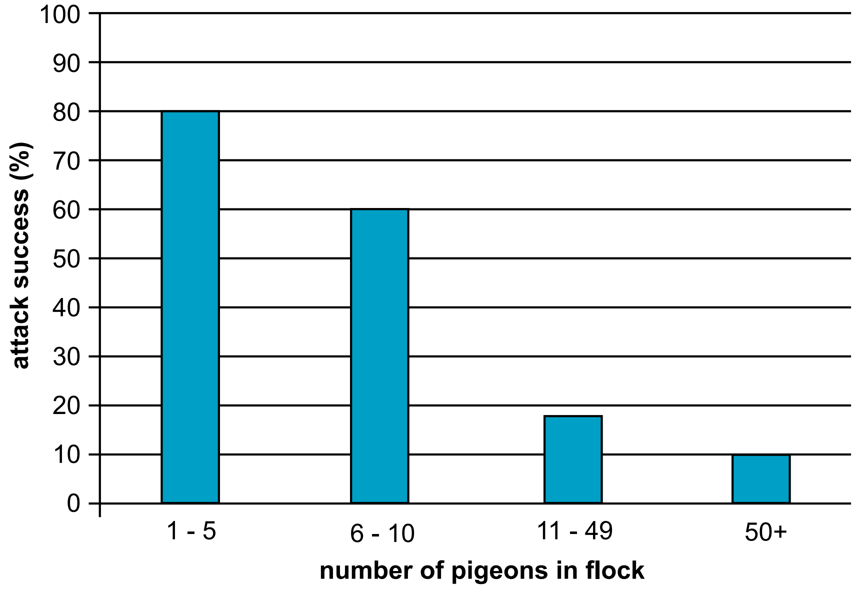
Q2: Bird Q. *Explanation*: Bird Q was dominated by all other birds

Q3: Bird R. *Explanation:* Bird R dominated all other birds.

Q4: R > P > T > S > Q

Social mechanisms for defence: Questions (page 92)

Q5:



Q6: -87.5 %

Q7: Goshawks are more successful when there are fewer pigeons in the flock; the percentage attack success for 1-5 pigeons in the flock is 80% and decreases as number in flock increases until for 50+ pigeons in the flock the percentage attack success is 10%.

Q8: In a large group it is more likely that a pigeon might see a goshawk; the pigeon can raise the alarm and mass movement might confuse the goshawk.

Altruism and kin selection: Questions (page 94)

Q9: 250 %

Q10: 92.1 %

Q11: In white-fronted bee-eaters, individuals are more likely to help those to whom they are more closely related.

Q12:

- Reciprocal altruism: a behaviour in which an organism acts in a manner that temporarily reduces its fitness while increasing another organism's fitness with the expectation that the other organism will act in a similar manner later on.
- Social hierarchy: society in which some individuals are dominant to others who are submissive to the dominant ones.
- Kin selection: strategies in evolution that favour the reproductive success of an organism's relatives even at the cost of an organism's own survival and reproduction.

Extended response question: Social behaviour (page 99)

Suggested marking scheme

Each line represents a point worth one mark. The concept may be expressed in other words. Words which are bracketed are not essential. Alternative answers are separated by a solidus (/); if both such answers are given, only a single mark is allocated. In checking the answer, the number of the point being allocated a mark should be written on the answer paper. A maximum of ten marks can be gained.

A) Altruism and kin selection (*5 marks*):

1. Altruistic behaviour harms the donor **and** benefits the recipient.
2. Reciprocal altruism involves reversal of roles at a later stage / favour returned or a description of reversed roles.
3. Reciprocal altruism often occurs in social animals/social insects OR mention of the Prisoner's Dilemma.
4. Altruism is (more) common between kin / related individuals / kin selection is altruism between kin.
5. Donor can benefit indirectly (through shared genes).
6. Increased chance of shared / their genes surviving / being passed on (in recipient's offspring).

B) Primate behaviour (*5 marks*):

i. Primates have a long period of parental care / spend a long time with their parent(s) / look after young for a long time.
ii. This gives opportunity to learn complex social skills.
iii. (Social) primates use ritualistic display / appeasement (behaviour) to reduce conflict/aggression / ease tension.
iv. Any one example of appeasement / alliance forming / ritualistic behaviour e.g. grooming / facial expression / body posture / sexual presentation.
v. Second example of appeasement / alliance forming / ritualistic behaviour.
vi. Individuals form alliances which increase social status OR Social hierarchy exists.

End of Topic 7 test (page 100)

Q13: *Any two from*:

- the dogs can tackle large prey animals which they would not be able to tackle individually;
- the dogs will gain more food than they would by foraging alone;
- all members of the social group will share food gained by cooperative hunting.

Q14:

1. 70%
2. The larger the flock the more difficult to focus on/target a single pigeon *or* scattering of flock distracts/ confuses hawk *or* greater chance of hawk being spotted *or* large flock can mob/attack the hawk).
3. More chance/easier to catch prey *or* can catch larger prey *or* all members in the group get a share of the food/prey *or* each member uses less energy/gets more food *or* increase in attack success.

Q15:

- Ritualised threat gesture: social signal used by the leader in a dominance hierarchy to assert authority.
- Subordinate response: social signal used by low-ranking member of a social hierarchy to indicate acceptance of the dominant leader.
- Dominance hierarchy: system of social organisation where the members are graded into a rank order.
- Cooperative hunting: type of foraging behaviour employed by a group of predators resulting in mutual benefits.

Q16: b) less time with its head raised but the group is more likely to see predators.

Q17: d) Predatory gulls have difficulty picking out an individual puffin from a large flock.

Q18: U

Q19: Social hierarchy

Q20: *Any two from*:

- aggression between members becomes ritualised;
- real fighting is kept to a minimum;
- serious injury is normally avoided;
- energy is conserved;
- experienced leadership is guaranteed;
- the most powerful animals are likely to pass their genes onto next generation.

Q21: d) 1, 2 and 3

Q22: The workers are closely related to the queen and her offspring and share similar genes (*1 mark*); by helping the queen to reproduce and in caring for her offspring, the workers are effectively aiding the perpetuation of theirs (and the species) genetic complement through their own altruistic behaviour (*1 mark*).

Q23:

1. $\frac{15}{50} \times 100 = 30\%$
2. $\frac{30}{50} \times 100 = 60\%$
3. Conclusion: Predation of eggs was much higher nearer the solitary nests.
   Reason: By day 7, there were no experimental eggs left near the solitary nest but 20 near the colonial nests.

Q24: Wasps or ants.

Q25: In social insects **few** individuals breed and the offspring are raised by the **workers**. Most of the bees in a colony are **workers** that help to raise close relatives but do not themselves reproduce. This is an example of social **kin selection**.

Q26: Grooming / submissive facial expression / submissive body posture / sexual presentation.

Topic 8: Components of biodiversity

Extended response question: Biodiversity (page 111)

Suggested marking scheme

Each line represents a point worth one mark. The concept may be expressed in other words. Words which are bracketed are not essential. Alternative answers are separated by a solidus (/); if both such answers are given, only a single mark is allocated. In checking the answer, the number of the point being allocated a mark should be written on the answer paper. A maximum of four marks can be gained.

1. Genetic diversity is one component of biodiversity.
2. Genetic diversity comprises the genetic variation of a species.
3. It is represented by the number and frequency of all the alleles in a population.
4. Species diversity is one component of biodiversity.
5. Species diversity comprises the number of different species in an ecosystem (the species richness) and the proportion of each species in the ecosystem (the relative abundance).
6. A community with a dominant species has a lower species diversity than one with the same species richness but no particularly dominant species.
7. Small habitat islands have low species diversity (or converse).
8. The more isolated a habitat island is, the lower the species diversity (or converse).
9. Ecosystem diversity refers to the number of distinct ecosystems within a defined area.

End of Topic 8 test (page 111)

Q1: *Any two from*:

- ecosystem;
- genetic;
- species.

Q2: c) Species richness

Q3: b) Ecosystem

Q4: a) Genetic

Q5: c) Species

Q6: D

Q7: d) The number of different species in an ecosystem and the proportion of each species in the ecosystem.

Q8: Alleles

Topic 9: Threats to biodiversity

The impact of habitat loss: Questions (page 119)

Q1: Habitat fragmentation

Q2: Habitat corridors

Q3: Allow interbreeding between other members of the population which may have different genes OR prevents inbreeding of isolated populations (*1* mark) this provides an increase in variation within the population and prevents extinction of the population if attacked by a lethal pathogen (*1* mark).

Introduced, naturalised and invasive species: Question (page 121)

Q4:

- Introduced - moved by humans either intentionally or accidentally to new geographical locations.
- Invasive - spread and outcompeting native species for space and resources.
- Naturalised - established within wild communities.
- Native - species indigenous to the location.

Extended response question: Introduced species (page 122)

Suggested marking scheme

Each line represents a point worth one mark. The concept may be expressed in other words. Words which are bracketed are not essential. Alternative answers are separated by a solidus (/); if both such answers are given, only a single mark is allocated. In checking the answer, the number of the point being allocated a mark should be written on the answer paper. A maximum of six marks can be gained.

1. Introduced species are those that humans have moved (either intentionally or accidentally) to new geographic locations.
2. Those that become established within wild communities are termed naturalised species.
3. Invasive species are naturalised species that spread rapidly and eliminate native species.
4. Invasive species may well be free of the predators/parasites/pathogens/competitors. (*any two*)
5. . . . that limit their population in their native habitat.
6. Introduced species may prey on native species.
7. Introduced species may outcompete native species for resources.
8. Examples of introduced species and their impact on indigenous populations e.g. introduction of the grey squirrel to the UK or cane toad to Australia.

End of Topic 9 test (page 123)

Q5: c) Smaller

Q6: Habitat corridor

Q7: Invasive species may be free from (*any one*):

- predators;
- parasites;
- pathogens;
- competitors.

OR Invasive species may (*any one*):

- prey on native species;
- outcompete native species for resources.

Q8: Bottleneck

Q9: a), b) and d)

Q10: 8 months

Q11: 33.3%

Q12: In February there is more light for photosynthesis on the forest floor, because leaves have not grown on the trees yet.

Q13: Wide variety of different populations/species present in the wood.

Q14: Drastic reduction in numbers/mass extinction of numbers of squirrels caused by climate change/competition/habitat destruction/population bottleneck.

Q15:

1. Decreased
2. Cheetah, tiger.

Q16: C, the aphid.

Q17: A

Topic 10: End of unit test

End of Unit 3 test (page 128)

Q1: Photosynthesis

Q2: The human population is increasing.

Q3: a) 1 and 2 only

Q4: Line C

Q5:

1. X - NADPH, Y - sugar OR glucose
2. Calvin Cycle / carbon-fixation
3. Rubisco
4. Cellulose

Q6: *Any one from*:

- higher yield;
- higher nutritional value;
- resistance to pests;
- resistance to diseases;
- improved physical characteristics suited to rearing and harvesting;
- ability to grow in a particular environment.

Q7: b) Randomisation of treatment.

Q8: a) Number of replicates.

Q9: c) Selection of treatments.

Q10: Inbreeding

Q11: c) High seed output, and d) rapid growth

Q12: c) biological control.

Q13: *Any one from*:

- toxic to animal species;
- persist in the environment;
- accumulate in food chains;
- magnify in food chains;
- produce resistant populations.

Q14: d) 1, 2, 3 and 4

Q15: Stereotype(s) or stereotypy.

Q16: b) Benefits the parasite and harms the host.

Q17: Mutualism

Q18: *Any one from*:

- vectors;
- intermediate (secondary) hosts;
- direct contact;
- resistant stages.

Q19: a) 1, 2 and 3 only

Q20: Bees, wasps or ants.

Q21: Kin selection

Q22: *Any one from*:

- grooming;
- sexual presentation;
- facial expression;
- body posture;
- gesture.

Q23: Long period of/extended parental care. OR Look after/stay with young for many years.

Q24: Genetic

Q25: b) species richness.

Q26: b) It will decrease.

Q27: Habitat fragment 1

Q28: Habitat corridors

Q29: Bottleneck effect

Q30: a) Evening primrose

Q31: b) Rhododendron

Q32: c) Pink sorrel

Q33: To make the results more reliable / to reduce the effect of atypical results.

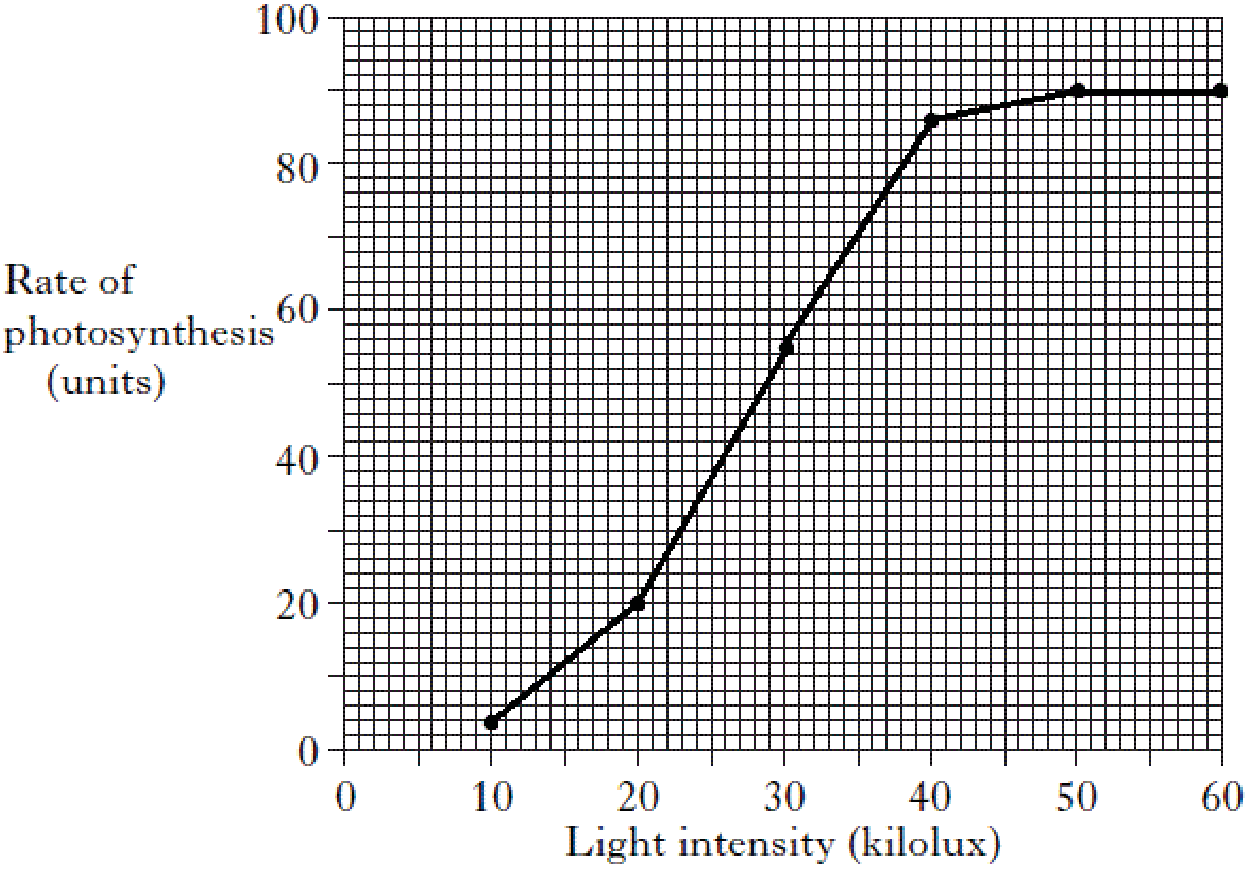
Q34: *Any two from*:

- size of leaf disc;
- diameter of leaf disc;
- mass of leaf disc;
- surface area of leaf disc;
- leaf thickness;
- concentration of solution;
- volume of solution;
- temperature of solution;
- size of syringe;
- distance from light source.

Q35: They produced oxygen which made them more buoyant/lighter.

Q36: They can photosynthesise well at low light intensity.

Q37:



1 mark for correct labels including units.

1 mark for correct scales.

1 mark for plotting the points correctly and connecting them with a ruler.

Q38: 175%

Q39: They have carotenoids / they have more carotenoids.