Space Health and Life (Unit 2)

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

USING ELECTROMAGNETIC RADIATION TO EXPLORE THE UNIVERSE

Planet Earth is just one body that orbits a star that we know as the Sun. The Sun is just one of a very large number of stars that make up our galaxy. There are estimated to be between 100 and 400 billion stars in the galaxy that contains our own solar system, the Milky Way.

View of Milky Way in Chile
Jesse Kraft / Alamy Stock Photo

These stars are very far away and can only be examined by powerful telescopes using the electromagnetic radiation emitted from them. Although space probes have landed on the surfaces of planets in our own solar system, much of the information comes from examining electromagnetic radiation reflected from the planet's surface.

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

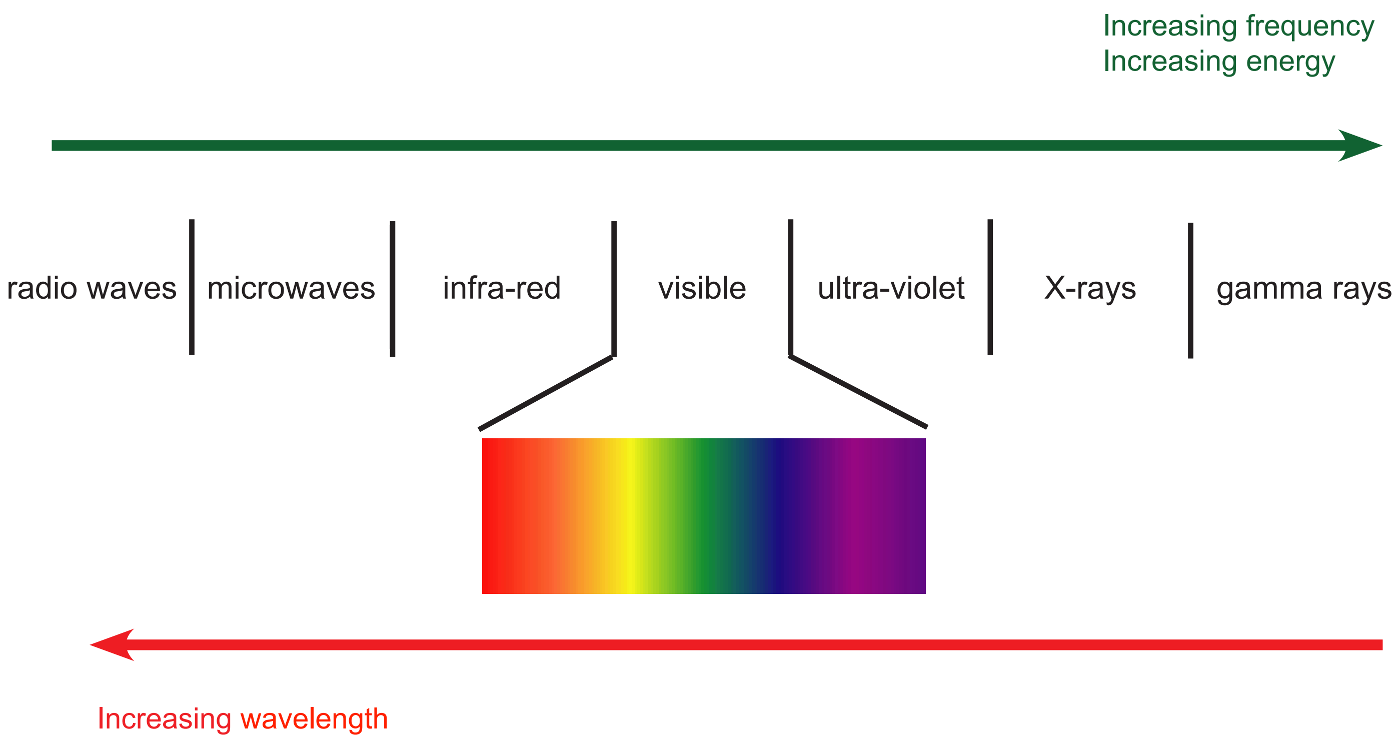
Electromagnetic radiation

Light is a small part of the electromagnetic spectrum which our eyes are able to detect. Light has certain things in common with all other electromagnetic radiation. All forms of electromagnetic radiation:

- travel at the same speed in a vacuum – ‘the speed of light’
- are transverse waves
- can be reflected, refracted and diffracted.

The main parts of the electromagnetic spectrum are shown in the diagram (not drawn to scale) below:

> Make sure you know the order of the different parts of the electromagnetic spectrum in terms of frequency, energy and wavelength



Notice: The greater the frequency or shorter the wavelength, the more energy.

Speed, wavelength and frequency

Speed

In a vacuum all electromagnetic radiation travels at the same speed, ‘the speed of light’.

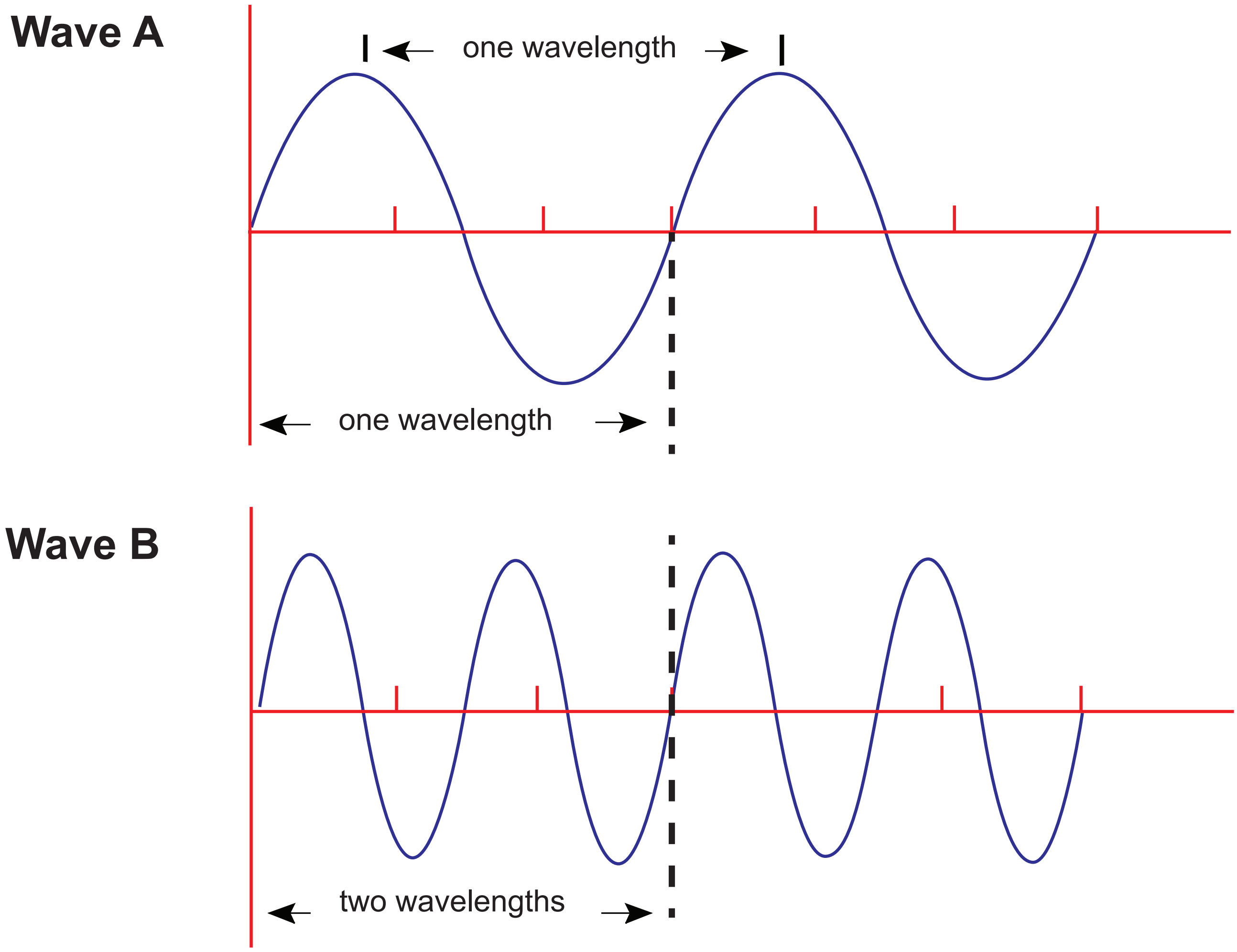
The speed of light is 3 × 108 m/s. That is 300 000 000 m/s

At this speed you could travel around the world 7.5 times in one second!

Runner
Afiat Sukmaraga / gettyimages

Wavelength

The wavelength of a wave is the distance between a point on one wave and the same point on the next wave. The diagram below shows two waves with different wavelengths.



Notice **Wave A** has a wavelength which is twice that of **Wave B**.

Wavelength may be measured in units of metres or parts of a metre (e.g. nanometre, nm).

1 nm = 0.000000001 m = 1×10^{-9} m.

That is 1 millionth of millimetre.
A magnifying glass will not help!

Magnifying glass
Zoonar RF / gettyimages

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Frequency

The frequency of a wave is the number of waves that pass a certain point each second.
The unit of frequency is the hertz (Hz).

It is also common to use kilohertz (kHz), megahertz (MHz) and gigahertz (GHz), where:
1 000 Hz = 1 kHz
1 000 kHz = 1 MHz

Wave speed equation

The speed of a wave is related to its frequency and wavelength, according to this equation:

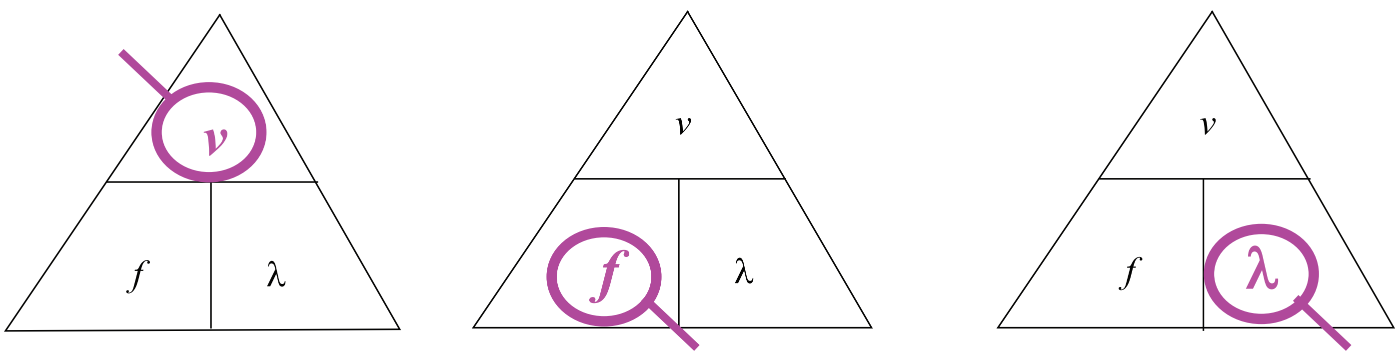
wave speed = frequency × wavelength

$$v = f \times \lambda$$

where:

v is the wave speed in metres per second, m/s
f is the frequency in hertz, Hz
λ (lambda) is the wavelength in metres, m

If you do the higher tier exam paper then you must be able change the subject in the equation. A formula triangle may help you remember what to do.



$v = f \times \lambda$ $\qquad$ $f = v / f$ $\qquad$ $\lambda = v / f$

Foundation tier You will always be given the equation in the form required by the question

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Images from the universe

How can we learn about our universe if we cannot travel beyond our own solar system? The answer to this question is that we look carefully at the messages sent to us from the universe.

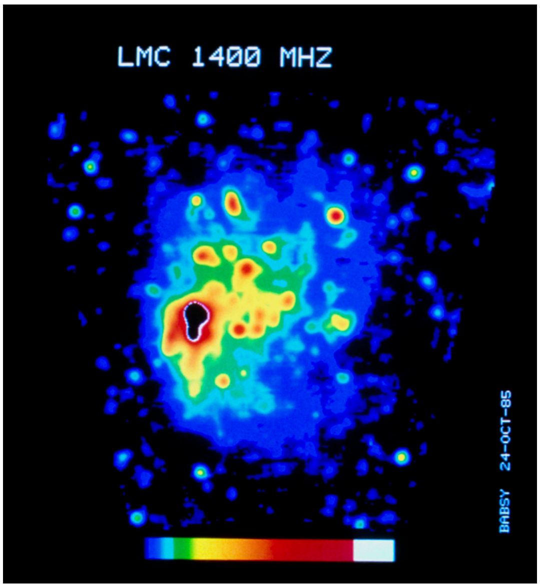
Stars emit electromagnetic radiation. That electromagnetic radiation gives us a lot of information about a star. By using telescopes sensitive to different wavelength ranges of the spectrum, astronomers can see into a wide variety of objects in the universe. We can only see the visible region of the electromagnetic spectrum with our eyes. To help us understand information from other regions of the electromagnetic spectrum, astronomers often convert the information into a false colour image.

Radio waves

If we were to look at the sky with a radio telescope, the sky would appear very different from what we see in visible light. Instead of seeing point-like stars, we would see objects such as:

- quasars - extremely distant objects. These are thought to be a region near the centre of a massive galaxy surrounding a black hole
- pulsars - rapidly rotating stars which are the dead relics of massive stars

In the false colour image below, red is the region of intense radio emission, while blue is the region of least intense radio emission. Black is an area where no radio waves are emitted.



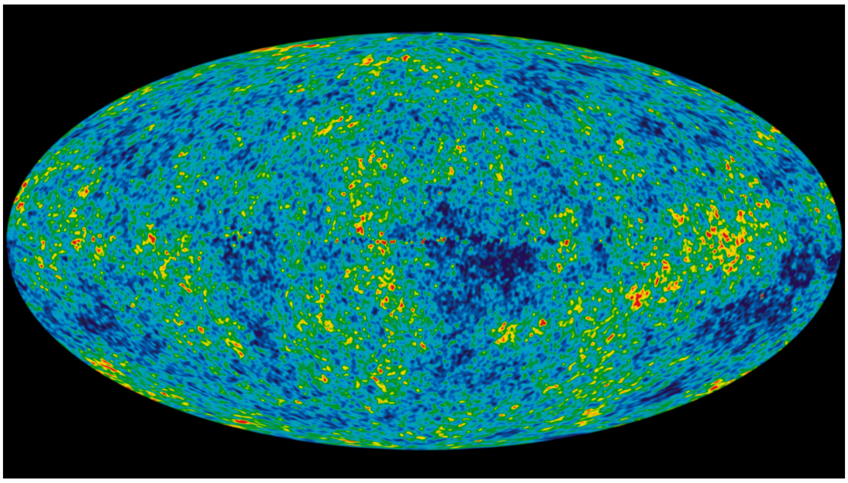
A false colour radio map of the Large Magellanic Cloud (LMC), made with a radio telescope in Australia

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Microwaves

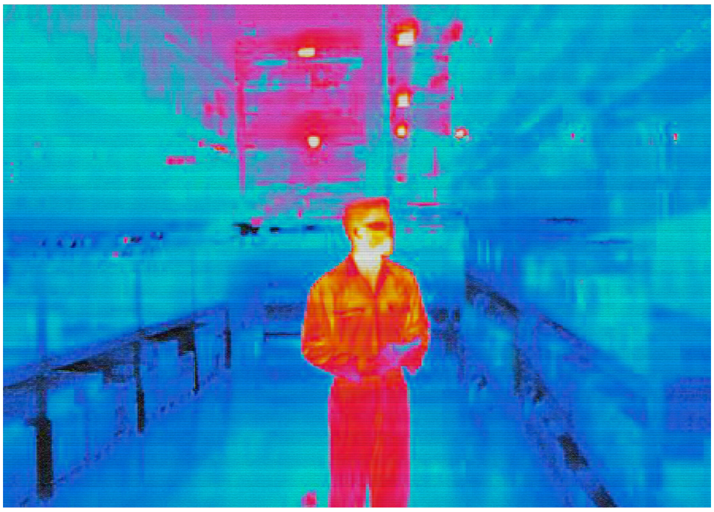
Scientists discovered that there are microwaves coming from every direction in space. This is called the cosmic microwave background radiation (CMBR). CBMR is considered to be evidence for the Big Bang theory (see the end of this section for the Big Bang theory).



Map of Cosmic Microwave Background Radiation (CMBR)
RGB Ventures / SuperStock / Alamy Stock Photo

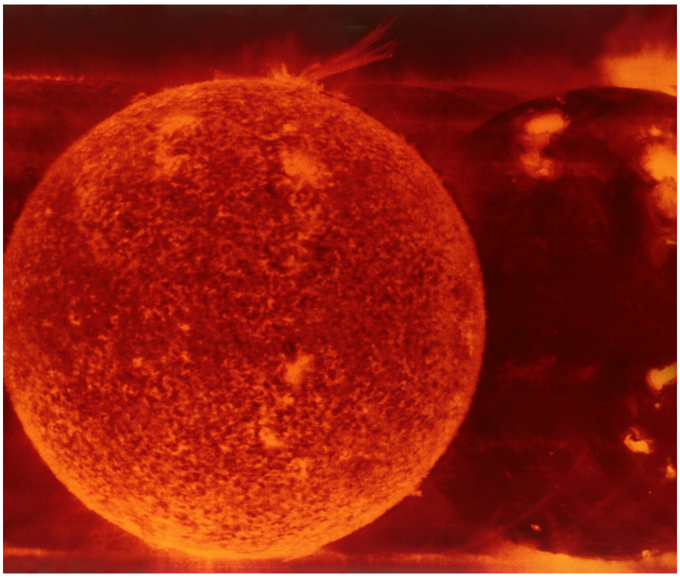
Infrared images

All objects above absolute zero emit infrared radiation.



False colour infrared image of a man in a factory
Cultura Creative (RF) / Alamy Stock Photo

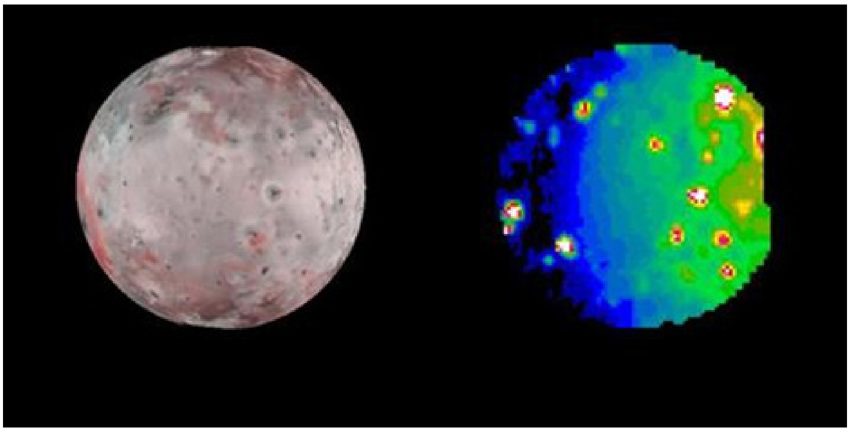
The Earth, the Sun, stars and galaxies also emit infrared radiation. More than half of the Sun's power output is in the form of infrared light.



Gas eruption at the surface of the Sun in the infrared region
mediacolor's / Alamy Stock Photo

Jupiter's moon, Io, is very far from the Sun. The temperatures on Io are cold except for the places near the volcanoes. At the volcanoes, the surface temperature can be as hot as 1 700 °C. Infrared radiation is ideal to pick up differences in temperature.

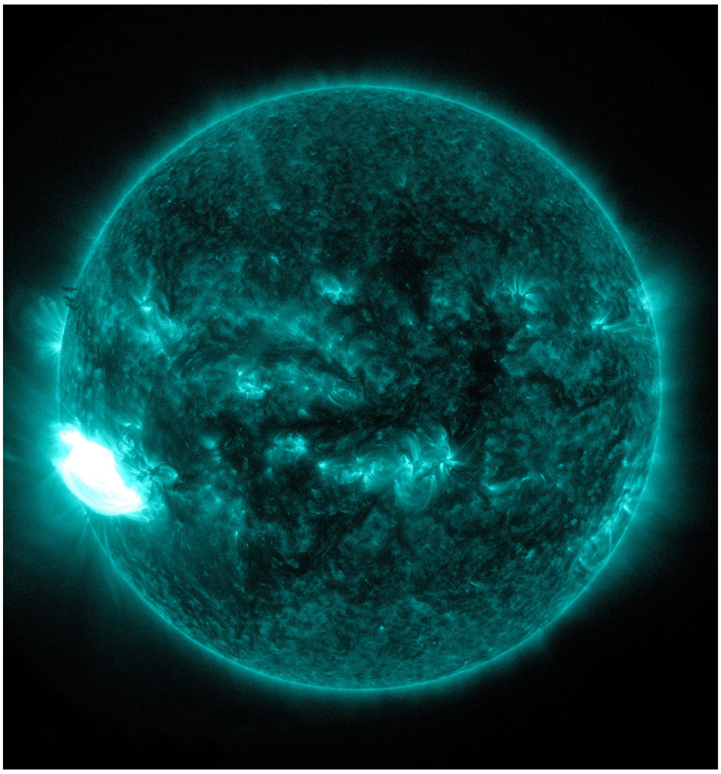
The false colour infrared image on the right below shows the hot areas associated with eruption sites. The visible image to the left helps to match geological features to these sites.



Images of Io taken in the visible and infrared regions
NASA/JPL/University of Arizona

Ultraviolet

The ultraviolet universe appears quite different from that which is seen with visible light. Most stars are relatively cool objects which emit most of their electromagnetic radiation in the visible or near-infrared part of the spectrum. These stars disappear from view when we use an ultraviolet telescope. Ultraviolet telescopes pick out the more energetic stars, such as some very young massive stars and some very old stars and galaxies, growing hotter and producing higher-energy radiation near their birth or death.



Ultraviolet Image of a solar flare
S.E.A. Photo / Alamy Stock Photo

SOMETHING TO WATCH

A short video describing the information that ultraviolet radiation gives us about the galaxy, M31.

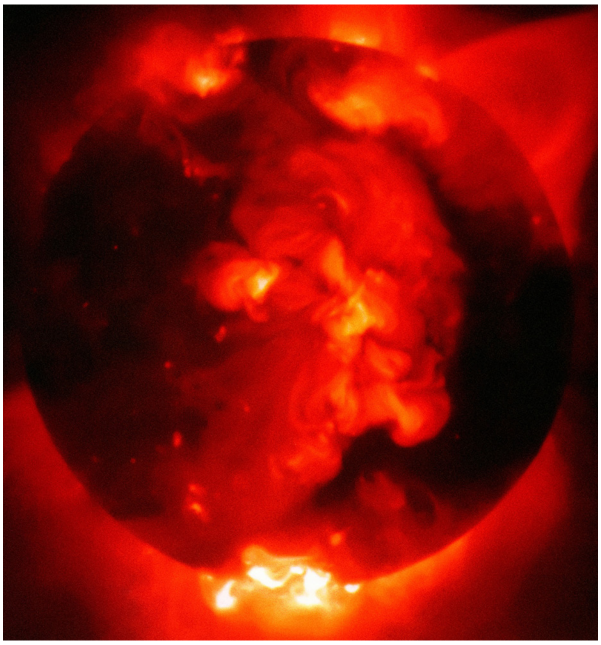
https://www.youtube.com/watch?v=5SEpa55hRO4

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

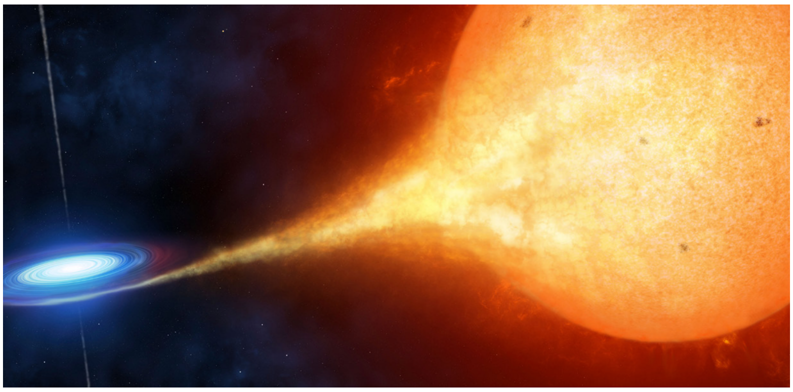
X-ray

Many things in space emit X-rays; among them are black holes, neutron stars, binary star systems, supernova remnants, stars, the Sun, and even some comets.



X-ray image of the Sun
RGB Ventures / SuperStock / Alamy Stock Photo

Many things in deep space give off X-rays, for example, a star orbiting a black hole. Material is pulled off the normal star into the black hole. As it does so it is heated up to very high temperatures and as a result gives off X-rays.



Artist’s impression of a black hole ripping gas from a sun-like companion
Stocktrek Images, Inc. / Alamy Stock Photo

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Visible light

All stars emit at least some light in the visible region of the spectrum. Stars appear to be white at first glance, but closer observation shows a range of colours: blue, white, red, and even gold.

The variation in colour is a direct consequence of their surface temperature. Cool stars radiate most of their energy in the red and infrared region of the electromagnetic spectrum and thus appear red, while hot stars emit mostly at blue and ultra-violet wavelengths, making them appear blue or white.

Summary:

Region of electromagnetic spectrum	Comment
radio wave	map the structure of our galaxy
microwave	sensitive to Cosmic Microwave Background Radiation (CMBR)
infrared	measure the temperatures of planets in other solar systems peer through the dust of the Milky Way into the core of our galaxy the coldest of stars emit hardly any visible light at all; they can only be seen with infrared telescopes
visible light	most stars emit visible light the colour of a star tells us how hot it is: red stars are coolest, blue are hottest examine objects in our own solar system
ultraviolet	most of the stars and gas disappear with a UV telescope used to find the most energetic stars and identify regions of star birth
X-rays	X-rays emitted from the material around a black hole, or clouds of gas in galactic clusters that are heated to many millions of degrees.

Space based and Earth based telescopes

Optical telescopes on the ground can only be used at night and they cannot be used if the weather is poor or cloudy. Visible telescopes in space give much clearer images which are not affected by an atmosphere.

Radio telescopes can be used in bad weather because the radio waves are not blocked by clouds as they pass through the atmosphere. Radio telescopes can also be used in the daytime as well as at night.

UV and X-rays are partly blocked by the Earth's atmosphere and so need to be placed at high altitudes or placed into orbit around the Earth.

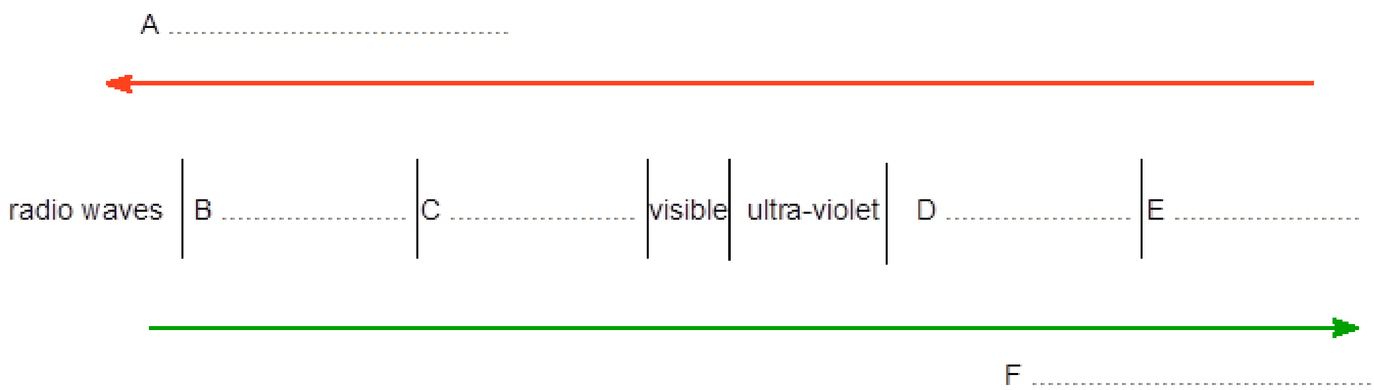
Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

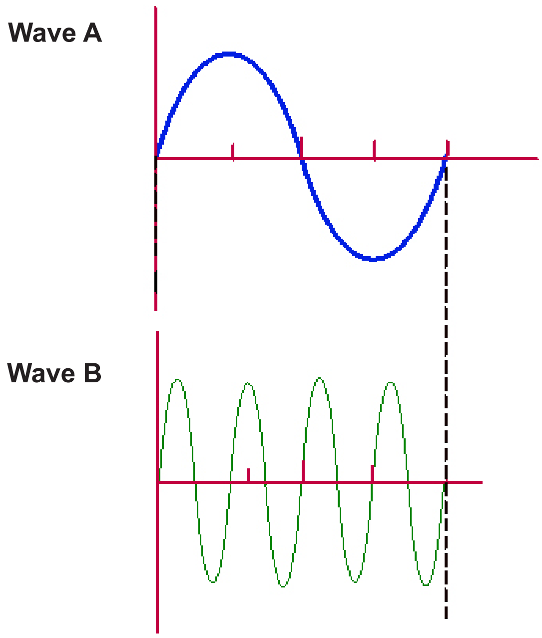
TEST YOURSELF

1. Complete the following diagram, by matching the labels from the box, to the letters in the electromagnetic spectrum.

gamma rays	**microwaves**	**infra-red**
X-rays	**increasing frequency**	**increasing wavelength**



2. The wavelength of wave A is 8 cm. Wave B is drawn to the same scale.



The wavelength of wave **B is:**

A 4 cm **B** 2 cm **C** 1 cm

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

TEST YOURSELF

---

3. Calculate the frequency of a radio wave with a wavelength of 2.0 m.

$$\text{frequency} = \frac{\text{wave speed}}{\text{wavelength}}$$

wave speed = 300 000 000 m/s (3.0×10^8 m/s)

The frequency is:

A 1.5×10^{-9} Hz (0.0000000015 Hz)

B 1.5×10^{9} Hz (1 500 000 000 Hz)

C 1.5 Hz

4. The part of the electromagnetic spectrum used to detect CMBR is:

A microwave

B radio wave

C infrared

5. The part of the electromagnetic spectrum used to detect energetic stars is:

A microwave

B infrared

C ultraviolet

6. The part of the electromagnetic spectrum used to measure the temperature of planets is:

A microwave

B infrared

C ultraviolet

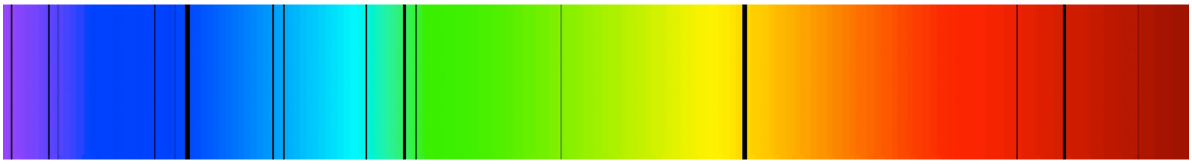
Absorption spectra

How can we know what is in the Sun or a star?

How can we know what elements are present in the Sun or a star? Once more it is by looking at the light coming from the Sun (or star). If you examine light from the Sun (or any star) you will find that there are black lines in the spectrum. These black lines are caused by elements in the **cooler outer part** of the Sun **absorbing** light coming from inside the Sun. This pattern of black lines is known as the **absorption spectrum**.

Each element has its own unique pattern of **absorption lines**; these lines form a fingerprint for each element.

The image below shows the absorption spectrum for the element helium. Helium will always cause the same pattern of lines. We can use this pattern to identify the presence of helium in the Sun (or in any other star).



Absorption spectrum
Phil Degginger / Alamy Stock Photo

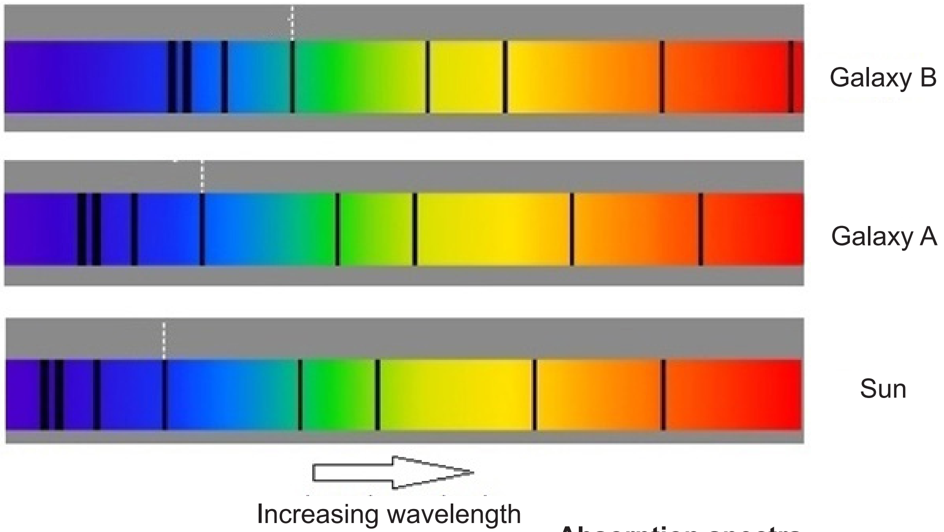
By looking at the absorption spectra of the Sun we know that the Sun is composed of about 72% hydrogen and 26% helium. There are also trace amounts of other elements such as oxygen, carbon, neon, nitrogen, magnesium, iron and silicon.

You do not need to remember the composition of the Sun.

You just need to know that the absorption spectrum of the Sun tells us what elements are present.

How far away?

Absorption spectra can also help us determine how far away an object is.
The diagram below shows the absorption spectra caused by the same element in three different objects. Galaxy B is furthest away from us while the Sun is closest to us.



Absorption spectra
Phil Degginger / Alamy Stock Photo

In each case, the pattern of black absorption lines is the same but they are in different positions. The position of the lines shifts depending on how close the object is to us. **Astronomers have found that the further a star is from us, the more its light is shifted to the red end of the spectrum (i.e. to longer wavelengths)**. This is known as **redshift**.

Redshift tells us that distant galaxies are moving away from us, and that the further away a galaxy is, the faster it's moving away. It suggests that everything is moving away from everything else. This is evidence that the **universe is expanding**.

You will meet redshift at the end of this section when we meet the Big Bang theory.

SOMETHING TO WATCH

This is a short video in which a NASA astronomer explains the idea of redshift.

https://www.youtube.com/watch?v=Iq5BsQZ5Xeo

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Distance and the universe

It is extremely difficult for us to take in the size of the universe. The distances are almost beyond our comprehension.

The Sun is 150 million kilometres from the Earth, but that's a tiny distance compared with the distance to other stars, or other galaxies. We use a larger unit of measurement for these distances known as the light year.

A **light-year** is the distance light travels in a year.

To give you a 'feel' for the distances involved, think about the following information.
Light takes about:

- eight **minutes** to reach us from the Sun
- five **hours** to reach Pluto from the Sun
- four **years** to reach us from the next nearest star, Proxima Centauri
- 100 000 **years** to cross the Milky Way galaxy
- 13 000 **million years** to reach us from the galaxies furthest away.

To put the distance in light years, we say, 'the nearest star is four light years away; the furthest galaxies are 13 000 million light years away'.

Remember however, that measuring distances to other stars and to very distant galaxies is not easy, so the data is uncertain.

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Our Solar System

The Solar System consists of:

- **the Sun** (a star) containing 98.8% of the mass of the Solar System
- **eight planets** and their natural satellite moons containing about 0.2% of the mass of the Solar System
- five smaller **dwarf planets** (e.g. Pluto) and their natural satellite moons
- **asteroids** and **comets**

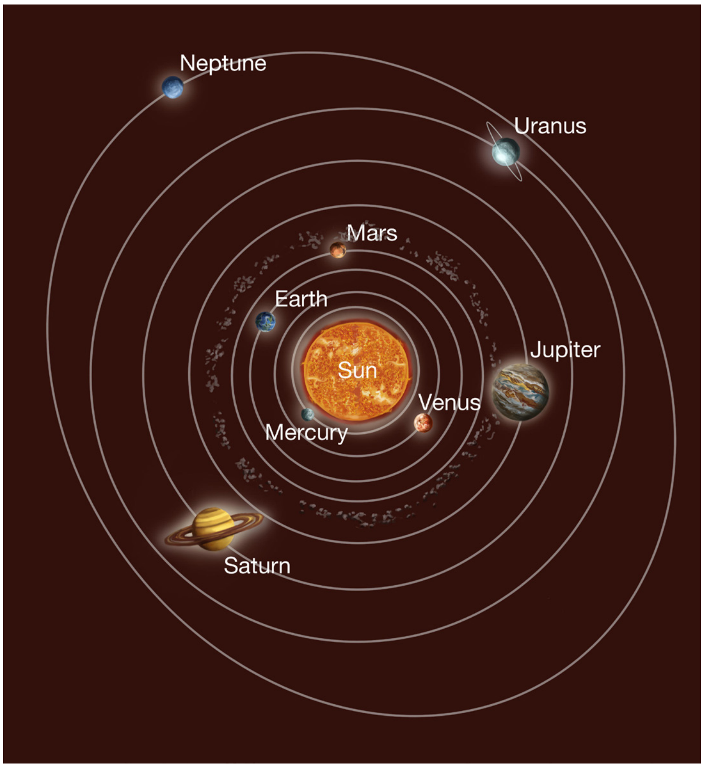


Diagram showing the orbits of the eight planets and the asteroid belt
Photo Researchers, Inc / Alamy Stock Photo

SOMETHING TO WATCH

Diagrams of the Solar System can leave us with a mistaken impression of the relative sizes of the objects and the distances involved in our Solar System. Watch this video to get a true impression of the relative sizes of objects and distances in our Solar System.

http://www.space.com/30610-scale-of-solar-system-amazing-video.html

Our planet (Unit 2.1)

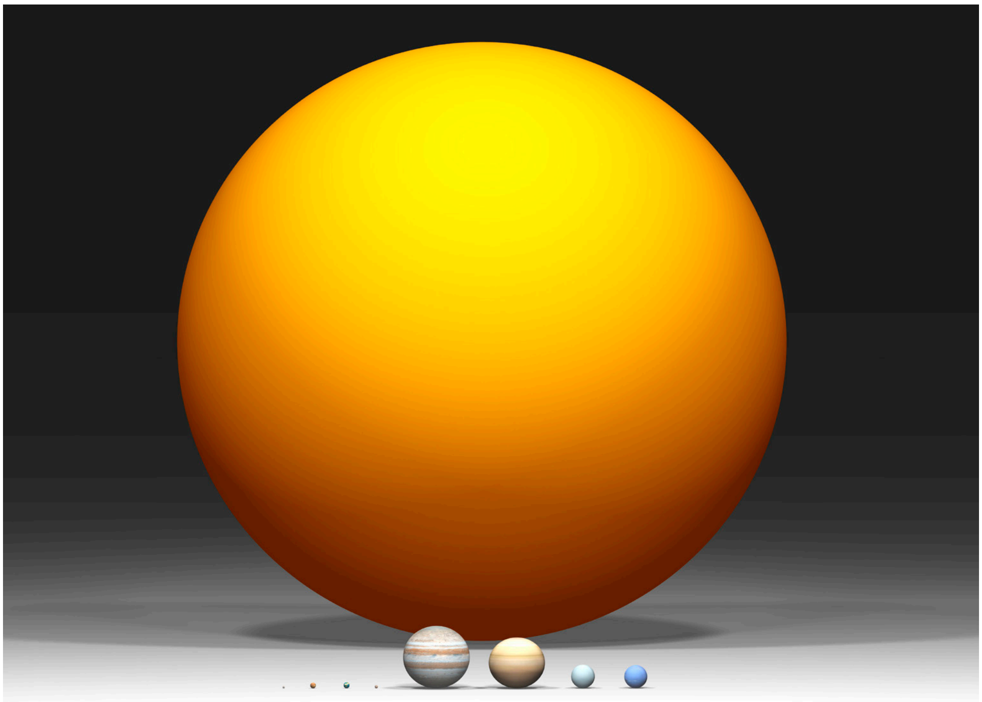
Our place in the universe (specification 2.1.1)

The Sun

The **Sun** is the largest body in the Solar System, containing **98.8%** of the total mass of the entire Solar System. It mostly consists of **hydrogen** and **helium**.

The Sun is massive compared to the Earth. Its diameter is over **100 times** that of the Earth.

Can you pick out Earth from the planets below?



The size of the Earth and other planets compared to the Sun
Science Photo Library

The Sun is the source of nearly all the energy we receive. The energy source is nuclear fusion.

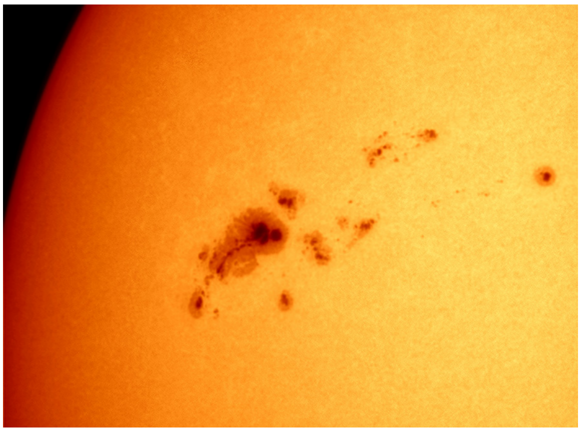
In **nuclear fusion**, hydrogen nuclei are joined together to make helium nuclei.

This releases enormous amounts of energy.

hydrogen nucleus + hydrogen nucleus → helium nucleus (+ energy)

Sunspots

Sunspots are dark spots which appear on the surface of the Sun. The spots are dark because they are cooler than the area of the Sun that surrounds them and they are often as big as the Earth. They often appear in pairs on either side of the equator, and usually last from 50 to 100 days. The number of sunspots on the surface of the Sun seems to vary over an 11 year cycle from almost zero up to over 100.



Sunspots
John Chumack / Science Photo Library

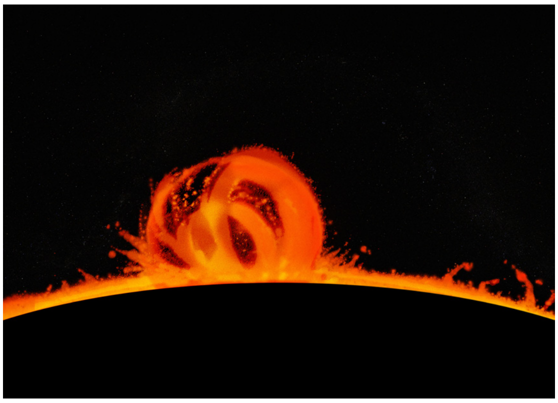
Sunspots

A **solar flare** is an intense burst of radiation coming from the release of magnetic energy associated with sunspots.

Flares are our Solar System's largest explosive events. They are seen as bright areas on the Sun and they can last from minutes to hours.

We typically see a solar flare by the light it releases at almost most every wavelength of the spectrum.

Flares are also sites where particles (electrons, protons, and heavier particles) are accelerated.



Solar flares
Photodisc / gettyimages

Solar flares can disrupt power supplies and communication systems on Earth.

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

In 1989, Quebec experienced power failure due to a solar flare. The solar flare caused high currents in the Earth's magnetosphere causing electric transformers and power stations to blow. The largest known solar flare took place on August 28, 1859. Telegraph systems failed throughout Europe and North America. Aurorae, or northern lights, were seen in many parts of the world. Similar flares would have a much more significant impact on Earth today due to our reliance on satellites and modern communication systems.

SOMETHING TO WATCH

Watch a video of a solar flare on the surface of the Sun in July 2012:
https://www.youtube.com/watch?v=HFT7ATLQQx8

The Planets

The orbits of the planets in the Solar System are almost circular - with the Sun near the centre.

We can divide the planets into two groups: the rocky planets and gas giants.

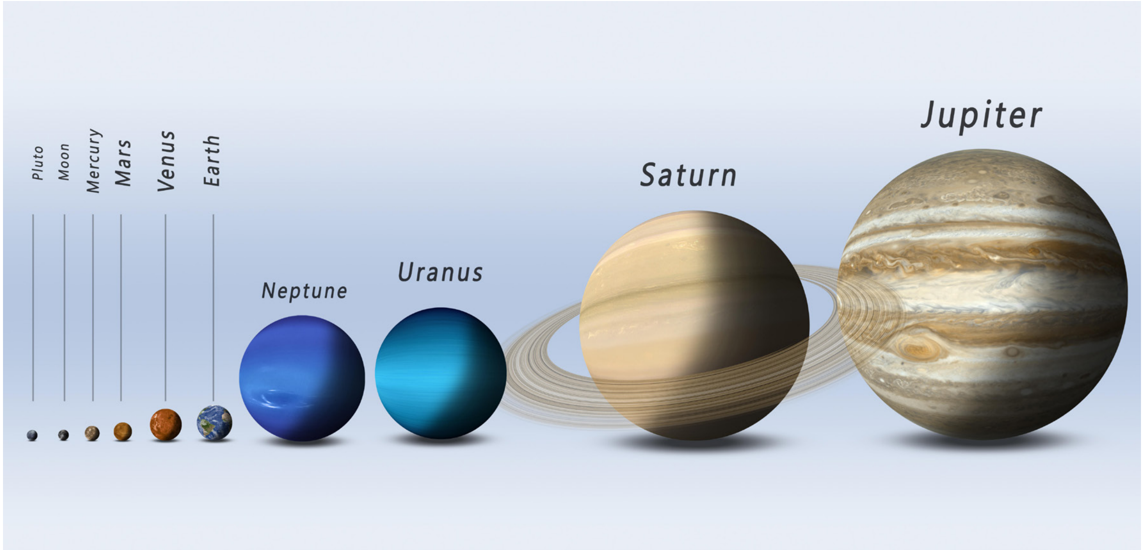
Type of planet	Planets	Composition
inner rocky planets	Mercury, Venus, Earth and Mars	similar to Earth in composition composed primarily of silicate rocks or metals
outer gas giants	Jupiter, Saturn, Uranus and Neptune	composed of gases, such as hydrogen and helium, with a relatively small rocky core

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

Relative sizes of planets

The gas giants are much larger than the inner rocky planets. The relative sizes of the planets are shown by the diagram below.



Planets
Alexander Aldatov / Alamy Stock Photo

Dwarf planets

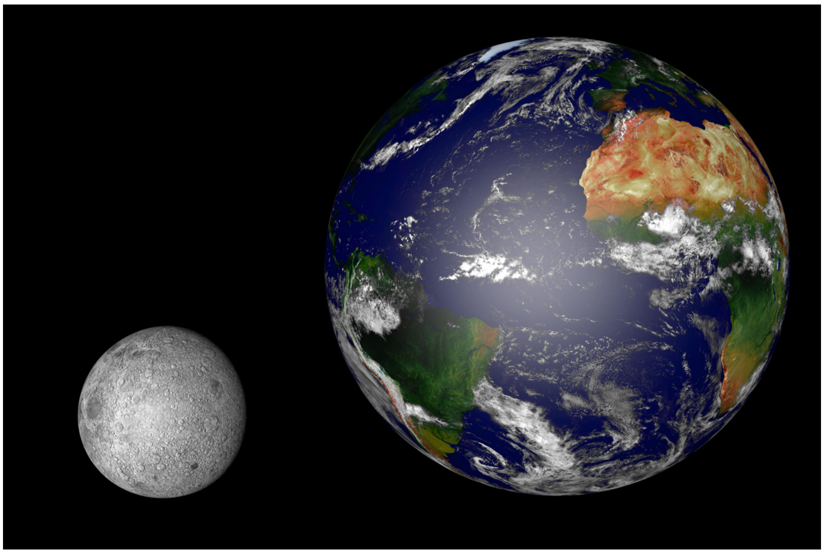
There are five officially recognised dwarf planets in our solar system. The most well-known is Pluto. With the exception of one, the dwarf planets are found in the outer Solar System.

Natural satellites (moons)

Planet	Number of moons	Example
Mercury	0	
Venus	0	
Earth	1	Moon
Mars	2	Phobos & Deimos
Jupiter	67	Io
Saturn	62	Titan
Uranus	27	Oberon
Neptune	14	

The Moon

The Moon is nearly a sixth of the diameter of the Earth.



Moon and Earth shown to realistic sizes
360b / Alamy Stock Photo

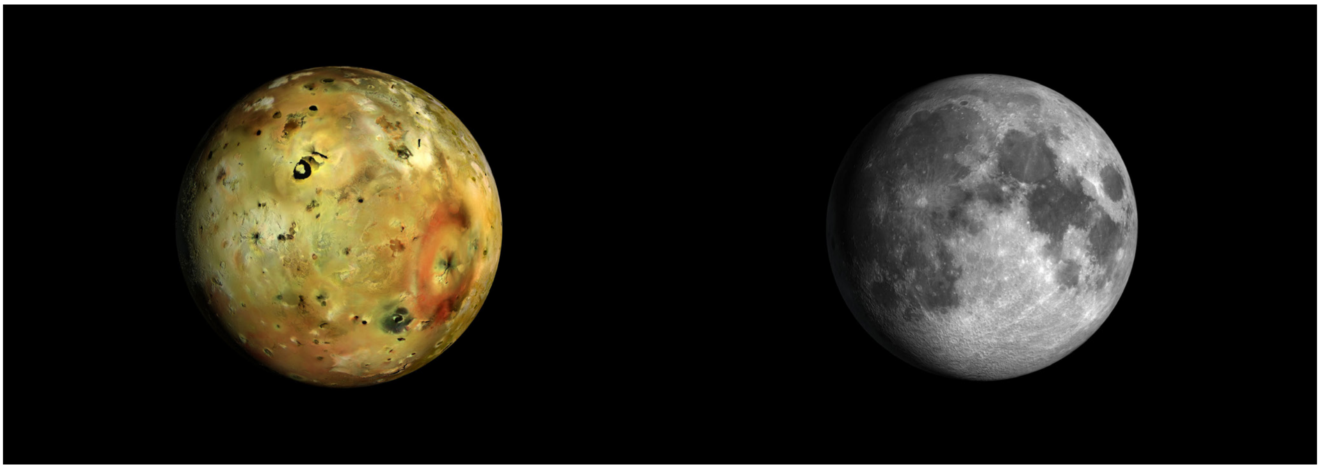
Phobos – a moon of Mars

Phobos is the larger and innermost of the two natural satellites of Mars. It is a small, irregularly shaped rocky object with a mean radius of 11 km. If you stood on the surface of Mars, Phobos would appear about one-third as large as Earth's moon (as seen from Earth).

Phobos
World History Archive / Alamy Stock Photo

Io – a moon of Jupiter

Io has been described as looking like a ‘giant pizza covered with melted cheese and splotches of tomato and ripe olives’. Io is the most volcanically active body in the solar system with hundreds of volcanoes.

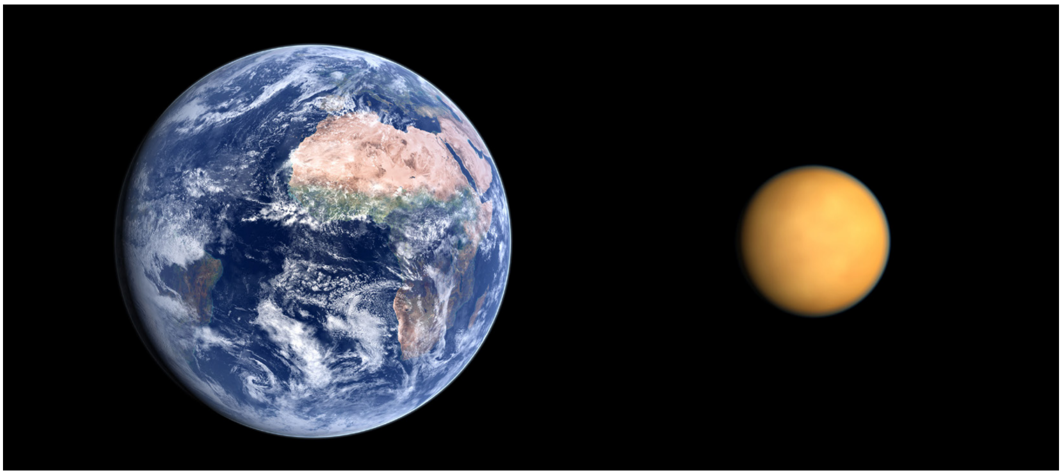


Moons
Tristan3D / Alamy Stock Photo

Titan – a moon of Saturn

Titan is Saturn’s largest moon and the second largest in the solar system. It is the only moon in the solar system with clouds and a dense, planet-like atmosphere mostly of nitrogen and methane. Titan’s surface is shaped by rivers and lakes of liquid ethane and methane. These form clouds and occasionally it rains from the sky.

A comparison of the relative sizes of Earth and Titan:



Earth and Titan
Tristan3D / Alamy Stock Photo

Oberon - a moon of Uranus

This is an old, heavily cratered moon of Uranus:

Uranus moon
World History Archive / Alamy Stock Photo

Asteroids

Asteroids are smaller than planets. They are believed to be rocks left over from the formation of the Solar System. Most are found in an 'asteroid belt' in orbit around the Sun between Mars and Jupiter.

Asteroids may crash into each other which can result in a change in their orbit. The orbits of some asteroids cross the Earth's orbit.

Comets

Comets are balls of ice and dust in orbit around the Sun. Unlike the planets which have circular orbits, the orbits of comets are elliptical. A comet's orbit takes it very close to the Sun and then far away again.

The time to complete an orbit varies - some comets take a few years, while others take millions of years to complete an orbit.

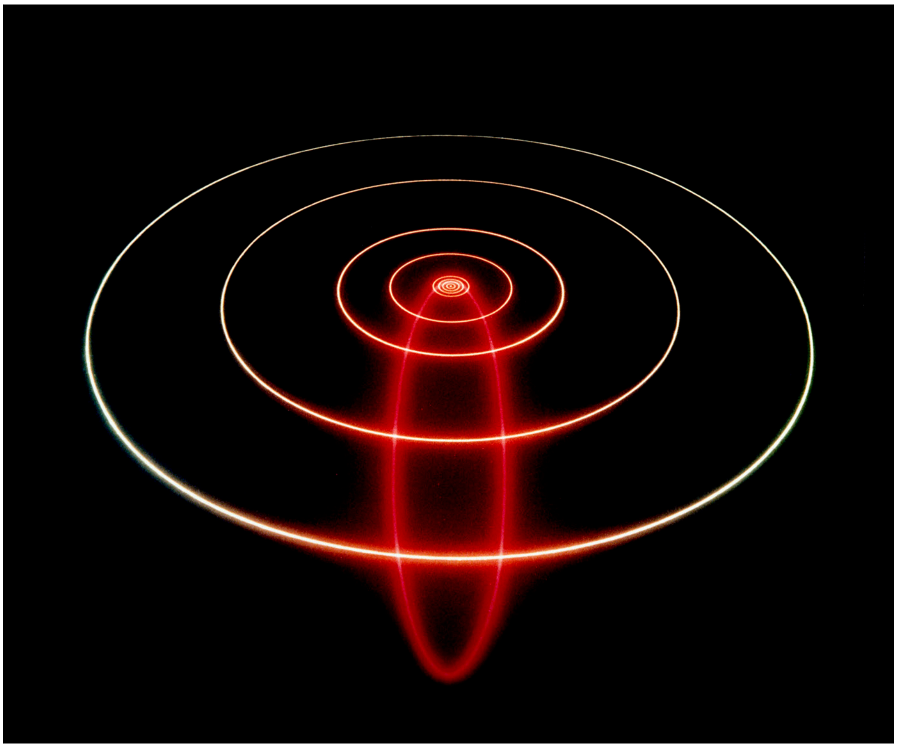


Diagram showing orbit of Halley's Comet

Julian Baum / Science Photo Library

The Oort cloud

In 1950 Jan Oort suggested that there is an enormous spherical cloud, beyond the orbit of Neptune surrounding our solar system. This is known as the Oort cloud. It is thought to extend out into space, perhaps to a distance of a light year and contains many millions of objects of different sizes.

At present, there is no direct evidence for the existence of the Oort cloud.

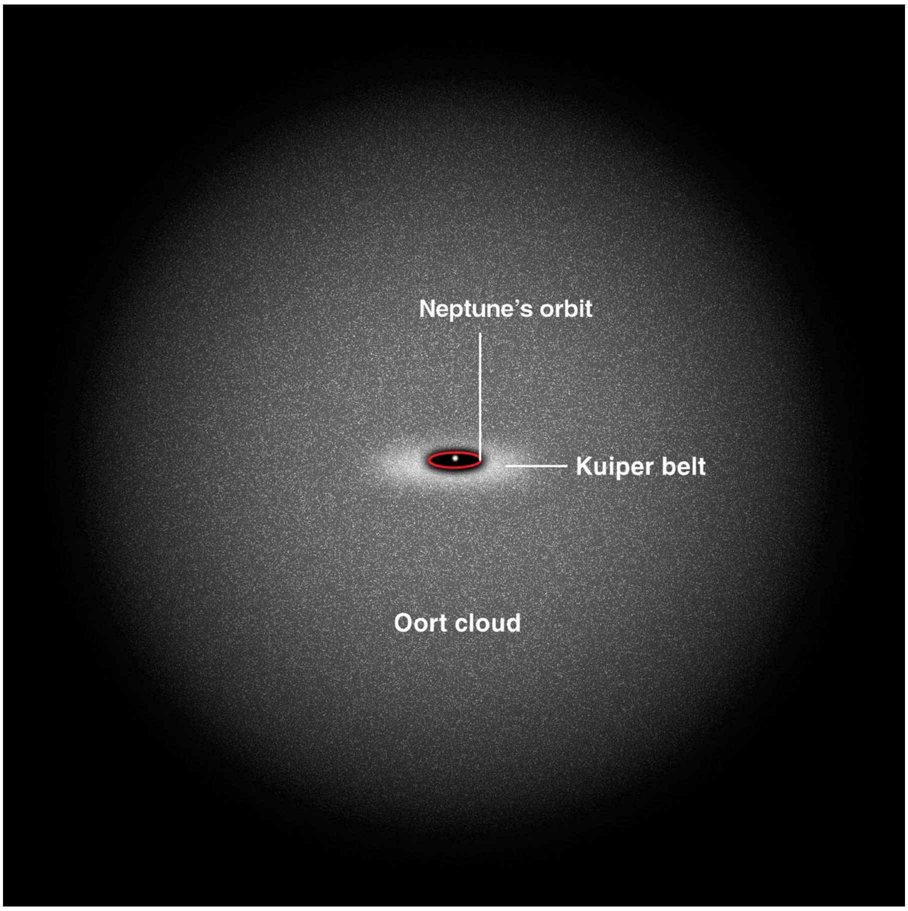


Diagram of the Oort cloud

Stocktrek Images, Inc. / Alamy Stock Photo

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

The Big Bang theory

There are a number of theories of how the Earth began. Two important theories are the:

- Steady state theory
- Big Bang theory

The main differences between the two theories are summarised below.

Big Bang theory	Steady-state theory
Universe exploded from a single point at some time about 13.7 billion years ago and is still expanding today	Universe has no beginning and no end
All the matter in the universe was concentrated into a single incredibly tiny point	The steady-state theory suggests that matter is constantly being created in empty space as the universe expands

The **Big Bang theory** is the more popular theory today. The following two pieces of evidence support this theory:

1. light from all the distant galaxies is **red-shifted** and the further away the galaxy the bigger the redshift;
2. microwave radiation comes evenly from all parts of the universe - **cosmic microwave background radiation** (CMBR).

Explanation of these observations

1. Redshift measurements mean:

    - all the galaxies are moving away from us;
    - the further away a galaxy is, the faster it is moving away.

    Both of these features are found in explosions - the fastest moving objects end up furthest away from the explosion. In other words, the evidence from redshift can be explained by the universe **expanding** from a single point source explosion.

2. **Cosmic microwave background radiation** (CMBR) comes evenly from all parts of the universe. CMBR is explained as radiation left over from an early stage in the development of the universe. The CMBR is a snapshot of the oldest light in our universe, imprinted on the sky when the universe was just 380 000 years old.

TEST YOURSELF

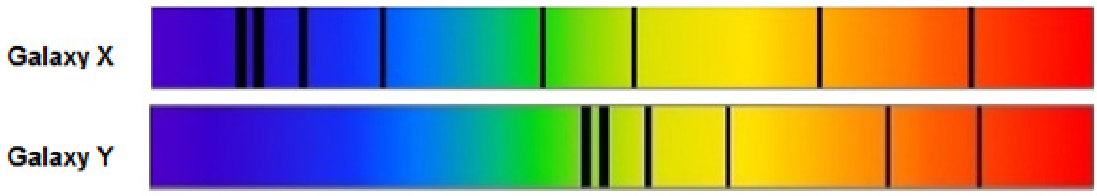
1. The name of the region from which it is believed that comets originate is the:

- **A** Oort cloud
- **B** Asteroid belt
- **C** Inner part of the Solar System

2. Select the correct statement about the orbits of planets and comets.

- **A** Planets have an elliptical orbit but comets have a spherical orbit
- **B** Both planets and comets have elliptical orbits
- **C** Both planets and comets both have circular orbits
- **D** Planets have a spherical orbit but comets have an elliptical orbit

3. State which of the following galaxies is furthest from the Sun.



- **A** Galaxy X is further away than galaxy Y
- **B** Galaxy Y is further away than galaxy X
- **C** Galaxy X and galaxy Y are about the same distance away

TEST YOURSELF

4. Match the following moons to the description on the right by drawing a line from the moon to the description. One has been done for you.

Name of moon	**Feature**
Io	only moon in the solar system with clouds and a thick atmosphere
Phobos	most volcanically active body in the solar system with hundreds of volcanoes
The Moon	the larger and innermost of the two natural satellites of Mars
Titan	it is about 1/6th the size of the planet it orbits

Our planet (Unit 2.1)

Our place in the universe (specification 2.1.1)

PRACTICE QUESTIONS

1. (a) The table gives some information about the planets in our solar system. Use the information in the table to answer the questions that follow.

Planet	Mean distance from sun (AU)	Diameter (1 000s km)	Time to spin once on axis (Earth days)	Time to orbit Sun (Earth years)	Average temperature (°C)	Known moons
Mercury	0.4	5	59	0.2	427	0
Venus	0.7	12	243	0.6	480	0
Earth	1.0	13	1	1	14	1
Mars	1.5	7	1	2	-63	2
Jupiter	5.2	143	0.4	12	-130	63
Saturn	9.5	120	0.4	29	-130	61
Uranus	19.2	51	0.7	84	-200	27
Neptune	30.0	50	0.7	165	-200	13

(i) Place a tick (✓) in the box next to the correct statements. [3]

Gas giant planets have more moons than rocky planets. ☐

The time taken by Earth to spin once on its axis is the same as the time taken to orbit the Sun once. ☐

The further a planet from the Sun the bigger it is. ☐

A day on Mars is the same duration as on Earth. ☐

There is no greenhouse effect on Mercury. ☐

Mars has the closest orbit to Earth. ☐

PRACTICE QUESTIONS

(ii) The dwarf planet Ceres is the largest object in the asteroid belt, which lies between the
orbits of Mars and Jupiter.
Estimate the temperature on Ceres. [1]

temperature = …………°C

(b) Complete the sentences below about the universe. [5]

(i) The universe began as the result of an ………………….. known as the Big Bang.
(ii) The universe continues to ……………………………… away from the Big Bang.
(iii) The universe is estimated to be 13.5 thousand ………………………… years old.

Space Health and Life (Unit 2)

Our planet (Unit 2.1)

World of life (specification 2.1.2)

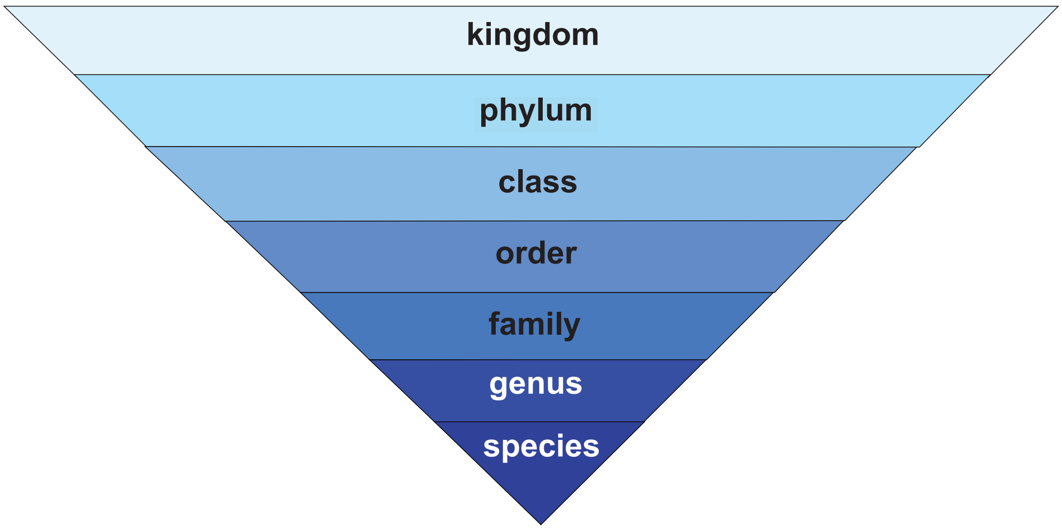
Classification of organisms

There are millions of different organisms on our planet. It is helpful to classify organisms into groups.

Classifying organisms helps us understand the relationship between organisms and it also helps us accurately identify and understand an unknown organism.

The binomial system

The modern system of classifying organisms was developed by Carolus Linnaeus and is called the binomial system.
In this system we separate organisms into smaller and smaller groups. The groups are:



Remember the order:

King Philip Came Over For Good Soup

Kingdoms are the broadest group and contain the most organisms. As you go down the list, each group gets smaller and contains fewer organisms.

Our planet (Unit 2.1)

World of life (specification 2.1.2)

Kingdoms

This is the broadest group. It is based upon what an organism looks like. These are called morphological features. The five kingdoms and some of their key features are described in the table below:

Kingdom	Feature
animal (all multicellular animals)	• multicellular • feeds on other organisms
plants (all green plants)	• cellulose cell wall • use light energy to produce food
fungi (moulds, mushrooms, yeast)	• cell wall • produce spores
bacteria	• no nucleus
single celled animals (e.g. amoeba, chlorella and plasmodium)	• one cell • some plant and animal characteristics

Classifying species

To classify a species we first put the organism into one of the kingdoms listed above.
We then use a logical system to place the organism into a 'narrower' group.
For example when we classify plants we can divide plants into:

- **non-flowering plants** such as ferns and mosses
- **flowering plants** which do produce flowers.

In the case of animals, we can either put them into the vertebrate phylum **or** one of the inveterate phyla. (Phyla are just the plural of phylum)

Vertebrates are animals with a backbone; **invertebrates** are animals that do not have a backbone.

Our planet (Unit 2.1)

World of life (specification 2.1.2)

Examples of vertebrates

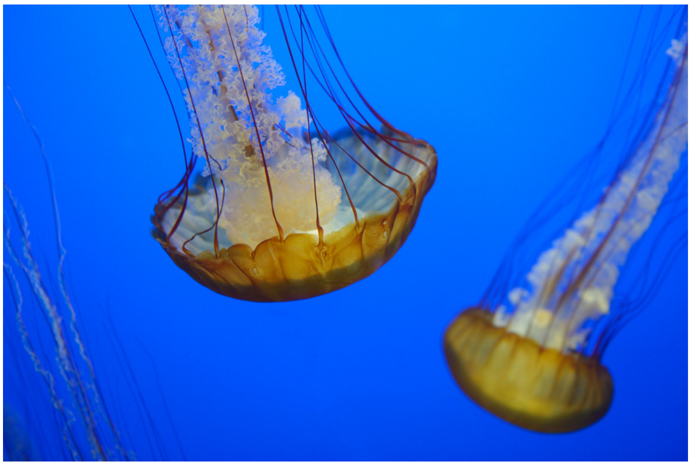
Squirrel
Rick & Nora Bowers / Alamy Stock Photo

Owl
David Fleetham / Alamy Stock Photo

Frog
WILDLIFE GmbH / Alamy Stock Photo

Examples of invertebrates

Crab spider
Sabena Jane Blackbird / Alamy Stock Photo



Jellyfish
Martin Shields / Alamy Stock Photo

Classifying organisms and scientific names

The table below shows how three well known animals are classified using this system. Notice that we use Latin words to classify the animals.

The **scientific name** of the organism is made of two parts, the **genus** and the **species**.

Group	House cat	Lion	Dog
kingdom	Animalia	Animalia	Animalia
phylum	Chordata	Chordata	Chordata
class	Mammalia	Mammalia	Mammalia
order	Carnivora	Carnivora	Carnivora
family	Felidae	Felidae	Canidae
genus	***Felis***	***Panthera***	***Canis***
species	***domesticus***	***leo***	***familiarus***
Name	***Felis domesticus***	***Panthera leo***	***Canis familiarus***

Some advantages of using a scientific name

The scientific name tells us about the classification of an organism and shows its relationship to other animals. It gives us more information than a common name and helps avoid confusion between organisms. It also gives us a naming system that scientists can use worldwide, again avoiding confusion between the names of organisms in different languages or even in different parts of the same country.

For example, the name ‘robin’ is used in the UK to describe quite a different bird to the one called robin in the USA.

UK robin (*Erithacus rubecula*)
David Cole / Alamy Stock Photo

American robin (*Turdus migratorius*)
Arterra Picture Library / Alamy Stock Photo

Other classification systems

Cladistics is another way to classify organisms. It can use data from DNA or RNA sequences, rather than just physical characteristics. It emphasises the evolutionary relationships between different species.

Our planet (Unit 2.1)

World of life (specification 2.1.2)

TEST YOURSELF

Answer the questions below based upon the table.

Group	Lion	Tiger	Grey wolf
kingdom	Animalia	Animalia	Animalia
phylum	Chordata	Chordata	Chordata
class	………………..	Mammalia	Mammalia
order	Carnivora	Carnivora	Carnivora
family	Felidae	Felidae	**W**
genus	*Panthera*	*Panthera*	**X**
species	*leo*	*tigris*	**Y**

1. The class that the lion belongs to is:
A Chordata
B Carnivora
C Mammalia

2. The scientific name for a lion is:
A Felidae Panthera
B *Panthera leo*
C leo

3. The scientific name of the grey wolf is *Canis lupus*. It belongs to the same order as the lion but to the Canidae family.

A W is Canidae, X is *Panthera*, Y is *lupus*
B W is Felidae, X is *Canis*, Y is *lupus*
C W is Canidae, X is *Canis*, Y is *lupus*

Our planet (Unit 2.1)

World of life (specification 2.1.2)

ADAPTATION TO THE ENVIRONMENT

In order to survive in an environment, organisms need to:

- be adapted to the environment
- survive alongside other living things.

To do this, organisms:

- may have special structural or behavioural adaptations
- obtain essential resources (food, water (and minerals for plants)) from the environment
- may need to compete with other organisms for essential resources
- compete for mates with other organisms of the same kind.

Adaptations to extreme conditions

Since there is constant competition for resources among organisms, those that are best suited to an environment are most likely to survive. Over many generations organisms have become suited to their environment. In other words, they have adapted to the environment.
Some habitats such as deserts or the Arctic are very difficult places to live in and organisms need to be well adapted to these environments if they are to survive. Animals that live in the Arctic also tend to be relatively large. This helps to decrease the surface area to volume ratio, minimising heat loss.

Penguins

Wings
Wings are not of any use to fly but act as flippers that power the penguin through water.

Blubber
Penguins have lots of blubber (fat) under their skin to insulate them.

Feet
The webbed feet are used as rudders in water.

Body shape
Streamlined body reduces drag when swimming.

Feathers
Tightly packed and waterproof outer plumage keeps penguins dry and warm.

More on the feet
Arteries in the penguins' legs are able to adjust the blood flow to the feet based on temperature.

Blood flow is restricted when it is colder, reducing heat loss through the feet.

Penguin
Andy Myatt / Alamy Stock Photo

Cacti

Spines

Cacti have spines instead of leaves to reduce surface area to minimise water loss.

They also protect the cacti from animals who may want to eat them.

Water storage

Stems of the cacti store water.

Root system

Cacti have wide-spread root systems to collect water from a large area.

Cacti
All Canada Photos / Alamy Stock Photo

SOMETHING TO WATCH

Watch a video describing how the Namaqua Chameleon is adapted to the Nambi desert.

https://youtu.be/AkzUuResd5Q

Behavioural adaptations

In addition to structural adaptations to fit an organism to an environment, organisms may adopt behavioural strategies such as hibernation or migration to deal with extreme environmental conditions.

Examples

Bird migration

- Birds (e.g. swans and geese) migrate from areas where food resources or nesting locations are low or decreasing, to areas of high or increasing resources.
- Birds that nest in the Northern Hemisphere tend to migrate northward in the spring to take advantage of increasing insect populations, budding plants and an abundance of nesting locations.
- As winter approaches and the availability of insects and other food drops, the birds move south again.

Hibernation

Some animals (e.g. hedgehogs, dormice and bats) hibernate as a means of dealing with extreme environmental conditions.

- The metabolism of a hibernating animal slows and its temperature plunges. Breathing slows and the heart rate falls.
- In order to survive hibernation, mammals feed heavily in summer and autumn, storing fat to see them through the winter.
- Hibernation is not without danger however. Animals may die during hibernation from lack of fat, severe weather or premature awakening.

Hibernating dormouse

FLPA / Alamy Stock Photo

SOMETHING TO WATCH

Watch a video describing the migration of some common British birds.

http://www.bbc.co.uk/guides/zqrggk7

Our planet (Unit 2.1)

World of life (specification 2.1.2)

BIODIVERSITY

Biodiversity is a term that describes the variety of living things on earth.
In short, it is described as a measure of variation of life. Biodiversity encompasses microorganisms, plants, animals and ecosystems such as coral reefs, forests, rainforests, deserts etc.
Biodiversity also refers to the number, or abundance of different species living within a particular region.

> **Biodiversity** describes the variety of living organisms in a particular habitat or in the world as a whole

There are many reasons for maintaining biodiversity. Biodiversity helps to:

- maintain the balance of the ecosystem. Losing an organism may:
  - affect other organisms in the food web;
  - have unexpected consequences such as erosion caused by deforestation.
- provide biological resources. Some organisms may provide a:
  - useful source of drugs;
  - food for human populations and animals
  - products for industry or homes
- social benefits. A wide biodiversity also helps human well-being.

Facts to think about

- 80% of the human food supply comes from 20 kinds of plants. But humans use 40 000 species for food, clothing and shelter. Biodiversity provides a variety of foods for the planet. It may be important for us to be able to draw on this genetic diversity to provide new food crops in the future.
- Biodiversity also plays an important role in drug discovery and medicinal resources. Medicines from nature account for usage by 80% of the world's population.
- Biological sources provide many industrial materials. These include fibre, oil, dyes, rubber, water, timber, paper and food.

Measuring biodiversity

It is often not possible to count all the organisms in a population. For example, the area to be monitored may be very large and not practical to measure the total population. In such a case it is necessary to **estimate** the total population size by **sampling**.

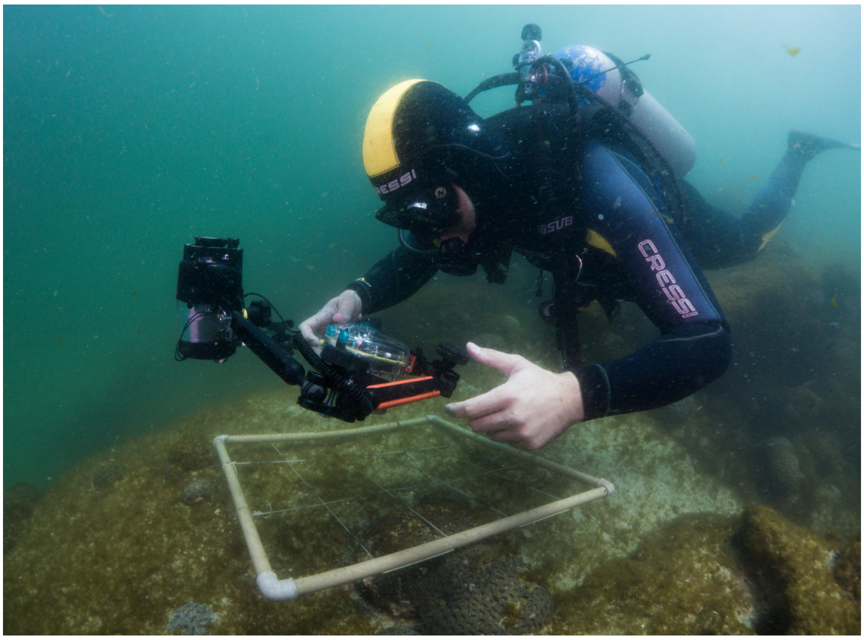
One method of sampling involves using a quadrat.

Using a quadrat

A quadrat is a square frame used to sample an area. They are placed **randomly** in the area to be studied.

Quadrats are useful for studying plants or slow moving animals such as snails.

They may be used in other contexts as well, e.g. monitoring a coral reef.



Scuba diver using photo quadrat
Leo Francini / Alamy Stock Photo

The individuals of each species in the quadrat are then identified and counted. This information may then be used to estimate population sizes.

Our planet (Unit 2.1)

World of life (specification 2.1.2)

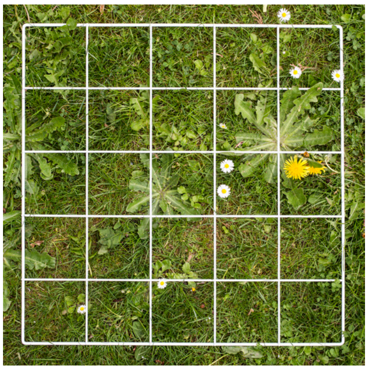
Worked example

Estimate the number of dandelions in a field.

Twenty 1 m^2 quadrats are randomly placed to sample a field 500 m^2 in area.

73 dandelions were counted in total.

Total sample area = 20 × 1 = 20 m^2



Quadrat
Science Photo Library

The estimated population size of dandelions in the field would be:

$$\frac{\text{total area } (m^2)}{\text{total sample area } (m^2)} \times \text{total number of dandelions in sample}$$

$$\text{estimated population of dandelions} = \frac{500}{20} \times 73 = 1\,823$$

Remember:

When using a quadrat:

- it should be placed randomly so that a representative sample is taken
- the validity and reproducibility of the results increases as the results from more quadrats are analysed

NATURAL SELECTION AND EVOLUTION

Natural selection

What is **Natural Selection**?

'The organisms best adapted to their environment tend to survive and transmit their genetic characteristics in increasing numbers to succeeding generations, while those less well adapted tend to be eliminated'.

In more detail:

- Individuals in a species show a wide range of variation due to differences in their genes.
- The individuals with characteristics most suited to the environment are the most likely to survive and reproduce.
- The genes that allowed the individuals to be successful are passed to the offspring in the next generation.
- Individuals that are poorly adapted to their environment are less likely to survive and reproduce. This means that their genes are less likely to be passed to the next generation.
- Over a long period of time the species will change.

"**Survival of the fittest**" is a way of describing the mechanism of natural selection. It means that organisms which have a slight advantage over others are more likely to survive **and breed**.

It is better remembered as "**survival of the fittest to breed**".

Evolution and natural selection

The basic idea behind the theory of evolution is that all the different species evolved from simple life forms. It is believed that simple life forms first developed more than three billion years ago and have gradually developed over a long period of time.

Charles Darwin first developed the idea of natural selection as the **driving force** behind evolution.

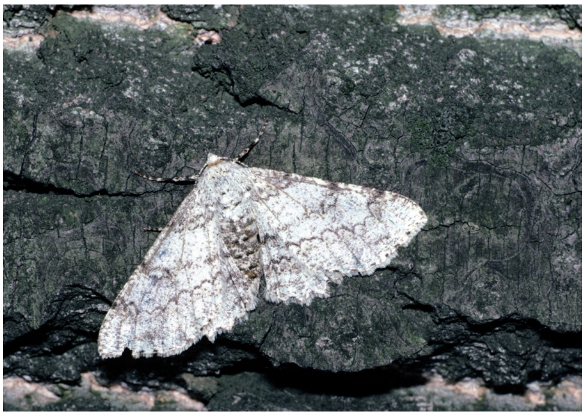
Pale peppered moth
Frank Hecker / Alamy Stock Photo

The peppered moth

Before the industrial revolution in Britain, most peppered moths were a pale variety. This meant that they were camouflaged against the pale birch trees that they rest on.

Black peppered moth against a light background
blickwinkel / Alamy Stock Photo

Moths with a black colouring were easily spotted and eaten by birds. This gave the pale variety an advantage, and they were more likely to survive to reproduce.



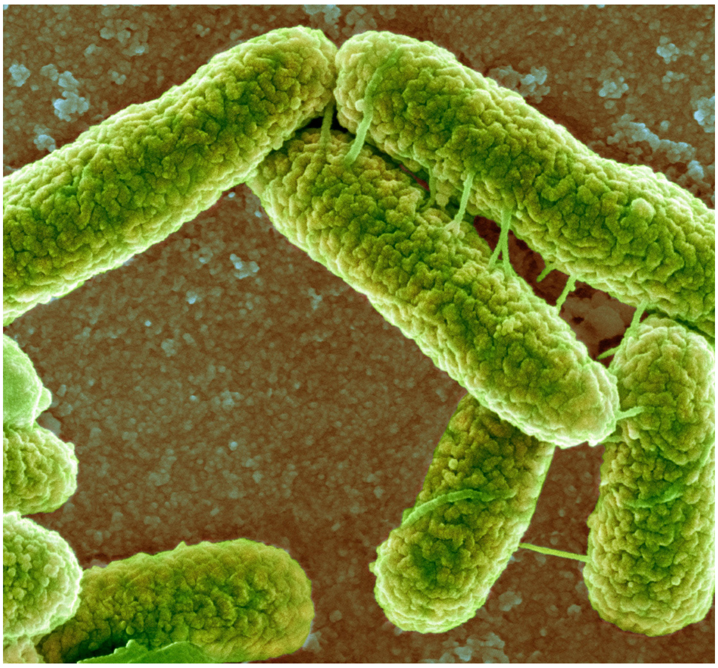
Pale moth against dark background
INTERFOTO / Alamy Stock Photo

When airborne pollution in industrial areas blackened the birch tree's bark with soot, the situation reversed. The black moths were now camouflaged, while the pale variety became more vulnerable to predators. This gave the black variety an advantage, and they were more likely to survive and reproduce.
Over time, the black peppered moths became far more numerous in urban areas than the pale variety.

Antibiotic resistance

E. coli is an example of a bacterium which, like other bacteria, reproduces very rapidly. This gives the potential for the bacteria to rapidly adapt to their environment.
During replication a mutation may occur (its DNA can be changed). Very often a mutation causes the death of the cell, but occasionally, it is beneficial for the bacteria. A mutation may, for example, allow the bacteria to become resistant to an antibiotic. When that antibiotic is present, the resistant bacteria have an advantage over the bacteria that are not resistant.

Antibiotic-resistant strains of bacteria are an increasing problem in hospitals.



Coloured electron micrograph of *E. coli* bacteria
Science Photo Library / Alamy Stock Photo

Warfarin resistant rats

Another example of Natural Selection is of rats becoming resistant to the rat poison Warfarin.

- Warfarin kills most rats but a few are resistant to Warfarin
- Warfarin is used by people to kill rats
- The resistant rats survive to breed and pass on their genes to the next generation
- The number of **resistant** rats increases with each generation.

Our planet (Unit 2.1)

World of life (specification 2.1.2)

TEST YOURSELF

1. Polar bears are able to survive in the extreme conditions of the Arctic more easily than smaller animals because:

A Polar bears lose heat more quickly than small animals
B They have a large surface area to volume ratio compared to smaller animals
C They have a small surface area to volume ratio compared to smaller animals

2. Lloyd is studying the population of snails in a field. The total area of the field was 200 m^2. He uses a quadrat to study the field.He uses a 1 m^2 quadrat to randomly take five samples of the field. The results from his sampling are shown below.

Quadrat number	Number of snails
1	4
2	6
3	1
4	0
5	2

(a) Use his results to estimate the population of snails in the field.
A 520
B 13
C 65

(b) He could improve his estimate of the snail population by:
A choosing where to place the quadrats
B taking more care when counting the snails
C taking 15 samples from the field instead of 5.

3. Which phrase best describes the term ‘survival of the fittest”?
A Survival of the fittest means that individuals which have a slight advantage over others are more likely to survive
B Survival of the fittest means that individuals who have a slight advantage over others are more likely to survive and breed.
C Survival of the fittest means that individuals who have a slight advantage over others are more likely to live longer.

PRACTICE QUESTIONS

1. Tour guides in Arizona USA are learning about the adaptation of snakes.

   (a) State what is meant by the term adaptation and explain why this occurs in nature. [2]

   ....

   ....

   ....

   ....

   (b) The guides learn to tell the difference between the non-venomous king snake and the venomous coral snake.

King snake
Robert Hamilton / Alamy Stock Photo

Coral snake
Rick & Nora Bowers / Alamy Stock Photo

Explain the advantages to king snakes of looking like a coral snake. [2]

....

....

....

Space Health and Life (Unit 2)

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

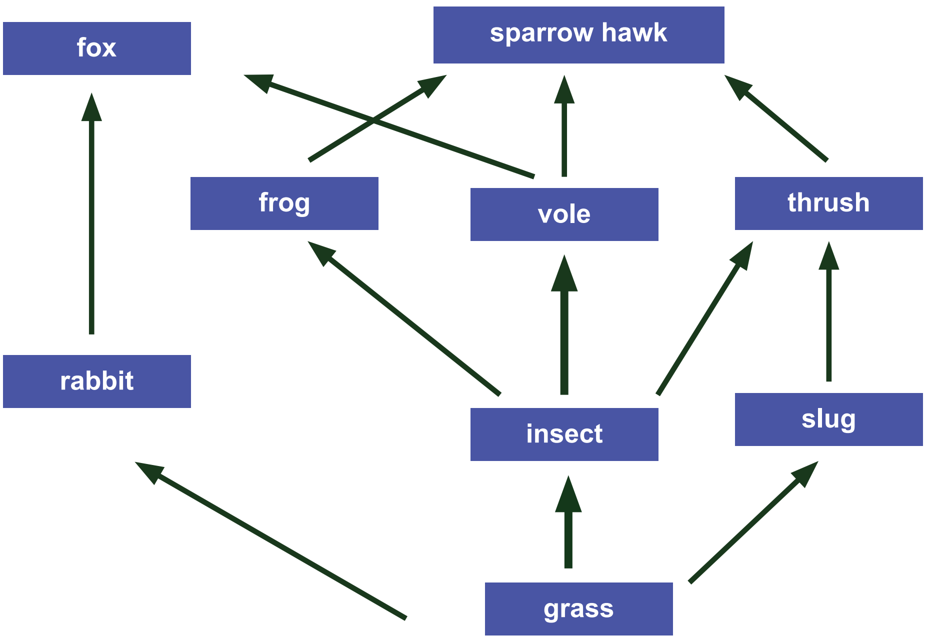
Chains, webs and pyramids

Food chains and food webs

A **food chain** shows a sequence of feeding relationships and the transfer of useful energy between organisms. It traces just one path through a food web.

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

Example of a food web



Two examples of food chains that form part of this food web are:

grass → insect → vole → sparrow hawk

grass → slug → thrush → sparrow hawk

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

Plants that **start** food chains by making food from carbon dioxide and water, using energy from the Sun, are known as **producers**.

In the food chains, grass is the producer.

A **primary consumer** is an organism that eats the producer. Since producers are plants, primary consumers are herbivores.

In each of the chains shown in the food web, rabbits, insects and slugs are primary consumers.

A **secondary consumer** is an organism that eats a primary consumer.

For example, a vole is a secondary consumer in the food chain

A **tertiary consumer** is an organism that obtains its energy by eating the secondary consumer.

The sparrow hawk eats the secondary consumer, the vole. The sparrow hawk is therefore a tertiary consumer.

It is possible that some animals in a food web can be in different levels. For example, the fox is a secondary consumer or tertiary consumer depending upon the food chain we examine:

grass → **insect** → **frog** → **fox**

grass → **rabbit** → **fox**

Trophic levels

The **trophic level** of an organism is the position it occupies in a food chain, food web or pyramid.

Food chains start at trophic **level 1** with producers such as plants. Primary consumers are at trophic level 2, and so on.

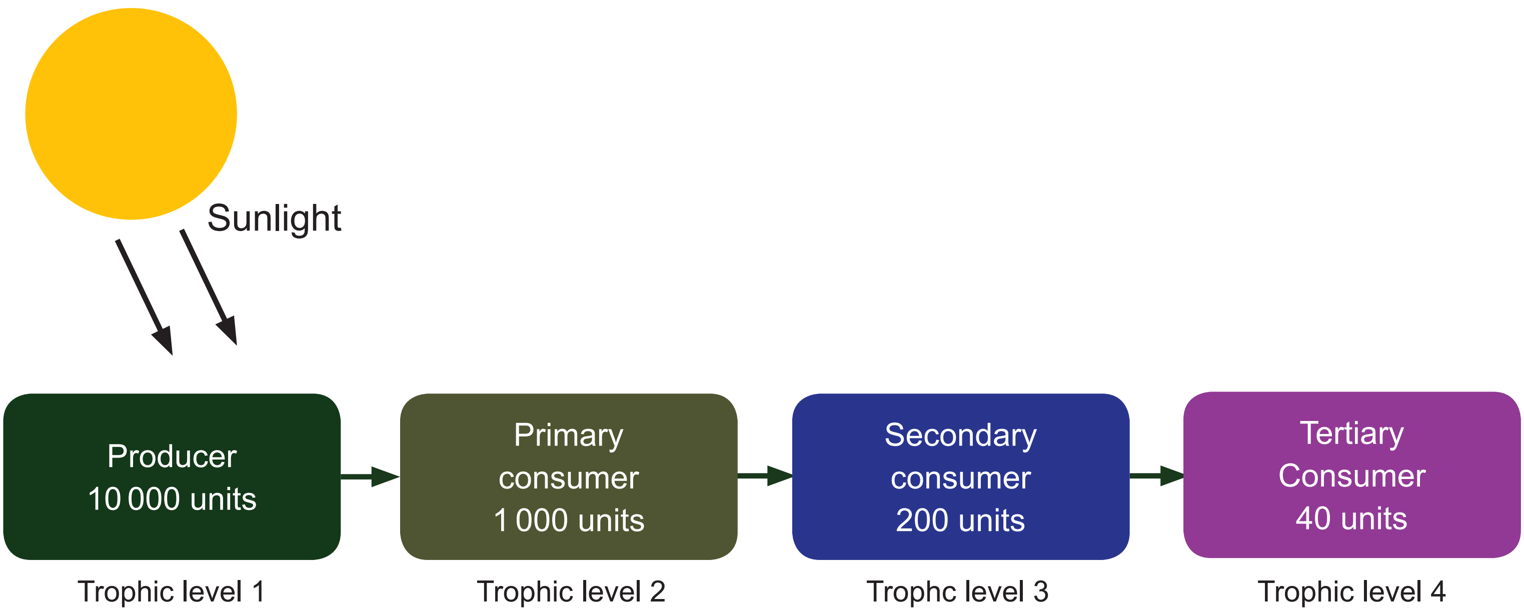
Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

Energy flow through the food chain

The sun’s radiation is the primary energy source for living things.

The diagram below shows the energy flow through a particular food chain



Green plants only use a small percentage of the solar energy that reaches them. Much of the energy is reflected. Plants capture this energy by using photosynthesis.

In the food chain above, only 1 000 of the 10 000 units of energy are transferred from the producer (trophic level 1) to the primary consumer (trophic level 2).

The **efficiency of energy transfer** from the producer to the primary consumer can be calculated using:

$$\text{efficiency of energy transfer} = \frac{\text{energy transferred}}{\text{total energy in}} \times 100\,\%$$

In this case:

$$\text{efficiency of energy transfer} = \frac{1\,000}{10\,000} \times 100\,\% = 10\,\%$$

The efficiency is low because it is difficult to digest plant food.

Between the second and third trophic level, the efficiency of energy transfer is:

$$\frac{200}{100} \times 100\,\% = 20\,\%$$

The **overall** percentage energy transfer from the **producer** to the **tertiary consumer** is:

$$\frac{40}{10\,000} \times 100 = 0.4\,\%$$

This low percentage explains why it is unusual to have more trophic levels in a food chain; too much energy is already lost for animals at higher tropic levels to find food.

Energy is lost in the food chain:

- as waste from organisms by excretion and egestion (undigested solid waste)
- as heat when organisms respire
- since animals use some energy to move about.

Pyramids of biomass and pyramids of number

Biomass is the dry mass of organisms in each step of a food chain.

A **pyramid of biomass** is a scaled diagram showing the mass of living matter at each stage in a food chain.

Secondary consumer

Primary consumer

Producer

Biomass always **decreases** from one trophic level to the next just like the amount of energy.

Do **not** confuse a pyramid of biomass with a pyramid of numbers. A pyramid of numbers shows the number of organisms at each trophic level in a food chain.

Example

Consider the food chain

oak tree → **aphid** → **ladybird**

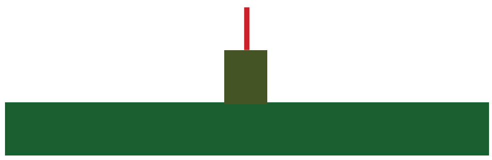
Answer the questions below based upon the table.

Organism	Number of organisms	Biomass
oak tree	1	500 000
aphids	10 000	1 000
ladybirds	200	50

We can represent the information as a pyramid of numbers and as a pyramid of biomass.

Pyramid of numbers

Pyramid of biomass



Making food production more efficient

The amount of material and energy decreases as we pass from one trophic level to the next. Food production is therefore more efficient if the food chain is short.

The efficiency of food production can also be improved by reducing the amount of energy lost by animals in the food chain.

Mammals and birds maintain a constant body temperature using energy released by respiration. As a result, their energy losses are high. If their surroundings are kept warm then this reduces energy losses.

Energy is also used up if animals move about. Restricting movement of the animal will mean less energy is lost. However, this raises serious animal welfare issues: Is it cruel to restrict animal movement? Does it reduce the quality of life of the animal concerned? A balance needs to be maintained to ensure animal welfare is maintained as well as efficient food production.

Battery-raised chickens. Restricted movement reduces energy loss.
studiodr / gettyimages

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

TEST YOURSELF

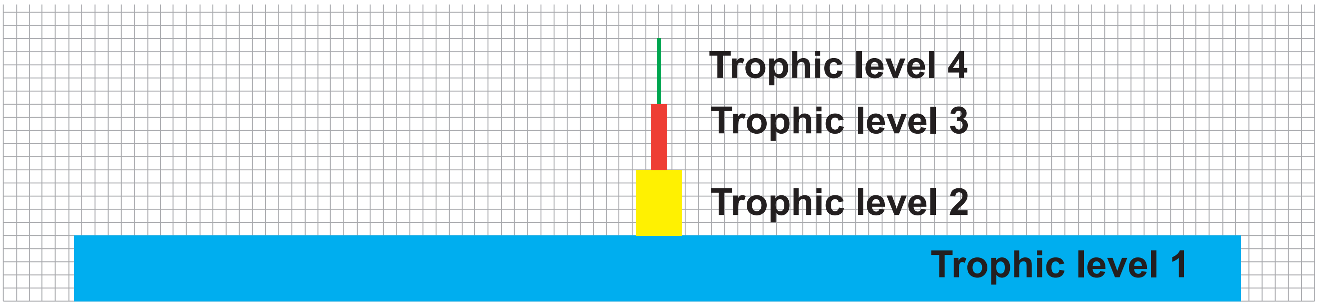
1. Select the correct word to complete the sentences below.

   Producers are (**small / animals / plants**). Producers are found at trophic (**level 1 / level 2**).

   Producers are eaten by (**secondary / primary)** consumers.

   Secondary consumers are found trophic level (**1 / 2 / 3**).

2. Select the set of data that was used to construct the pyramid of biomass shown below.



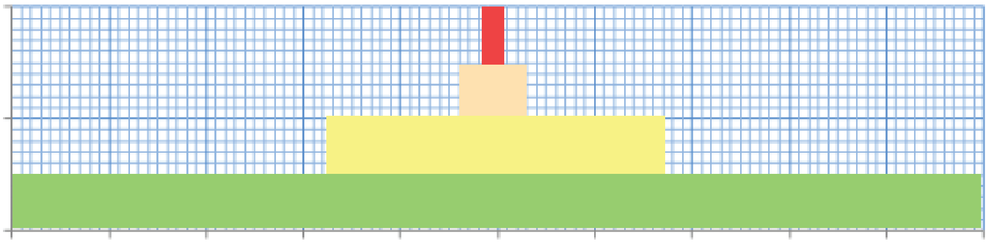
Organism	Biomass		
	DATA **A**	DATA **B**	DATA **C**
producer	809	1.5	1
primary consumer	37	11	809
secondary consumer	11	37	11
tertiary consumer	1.5	809	1.5

A Data **A**
B Data **B**
C Data **C**

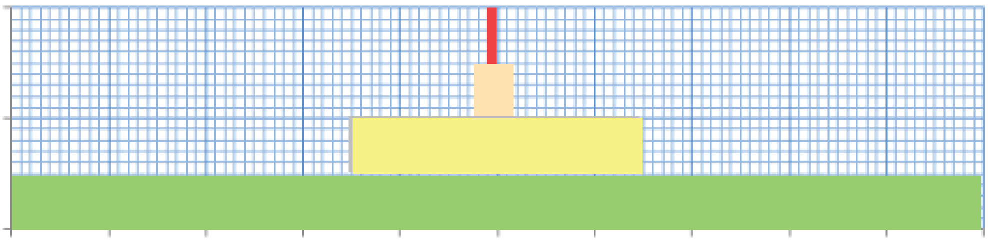
3. Select the pyramid of number (**A, B, C, D**) that correctly displays the information in the table for the following food chain, clover → snails → frogs → thrush

Organism	Number
clover	100
snails	30
frog	4
thrush	1

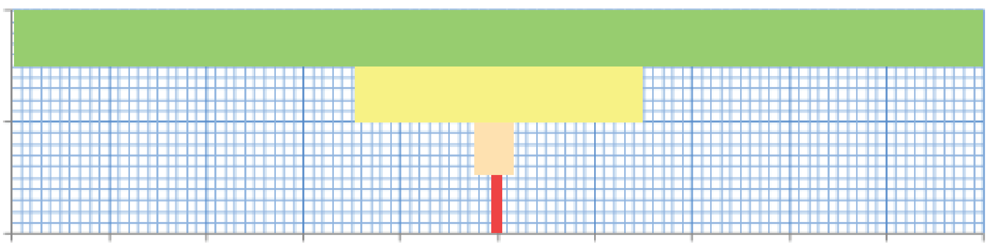
A



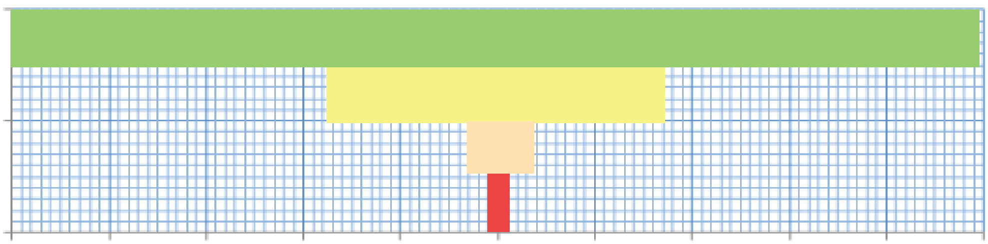
B



C



D



Interdependency of organisms

All living things within an ecosystem depend upon each other. Thus if there is a change in the size of one population, the population of other organisms within the ecosystem will be affected in some way.

Plant – animal interdependence

In ecosystems, animals and plants depend on each other in many different ways.

- Plants carry out photosynthesis and help regulate the levels of oxygen and carbon dioxide in the atmosphere.
- Plants also provide food for animals.
- Some animals depend on plants to provide them with a home or provide shelter from the environment.

Animals can also provide important services for plants.

- Animals, such as bees, can act as pollinators for flowering plants.
  Without pollinators, pollination would not take place, seeds would not be produced and flowering plants would fail to reproduce.
- Animals can also assist plants in seed dispersal. They can do this by eating fruit and then dropping the seed or by excreting it later. Some seeds can attach to the coats of animals and so be transported to a new place where they may grow.

Bees pollinating pink flowers
Tapsiful / gettyimages

Lesser Burdock - can become attached to coats of animals
John Glover / Alamy Stock Photo

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

Factors that affect populations

Populations of organisms in a habitat are affected by factors such as:

- competition
- predation
- disease

These factors are known as **environmental selection** pressures and they determine which individuals will live or die; i.e. which will do best at surviving and reproducing?

Competition

Where there are many different organisms living together in a habitat, they will often need to compete for the same resources.

Animals will compete for:	Plants will compete for:
• food • water • territory	• light • water • nutrients • space

The more organisms there are in a habitat, the more competition there is. The competition may be:

- between members of the same species (intraspecific competition);
- between different species (interspecific competition).

Competition between species

Interspecific competition occurs when members of different species compete for a shared resource.

Competition between members of the same species

Intraspecific competition occurs when members of the **same** species compete for limited resources. Members of the same species have very similar resource requirements. Resources not only include food, water and space **but may also include mates**.

If every member of the species has sufficient resources then individuals will not need to compete and the population will grow rapidly.

Intraspecific competition can be more important than interspecific competition. For example, competition between grey squirrels is likely to have a bigger impact on the population of grey squirrels than competition with red squirrels.

Red deer stag fighting for mates: An example of intraspecific competition
Naturfoto-Online / Alamy Stock Photo

The relationship between predator and prey populations

Predation is where a predator feeds on its prey. The interdependency of organisms within an ecosystem is clearly shown by the relationship between **predator** and **prey populations**.

There is a continuous struggle between predators and their prey for survival. Predators need to be adapted for efficient hunting if they are to catch enough food to survive. Prey species must be well adapted to escape their predators if enough are to survive for the species to continue.

The relationship between the two populations can be shown on a **predator-prey graph**.
A typical of the predator-prey relationship is that of the lynx and the snowshoe hare.

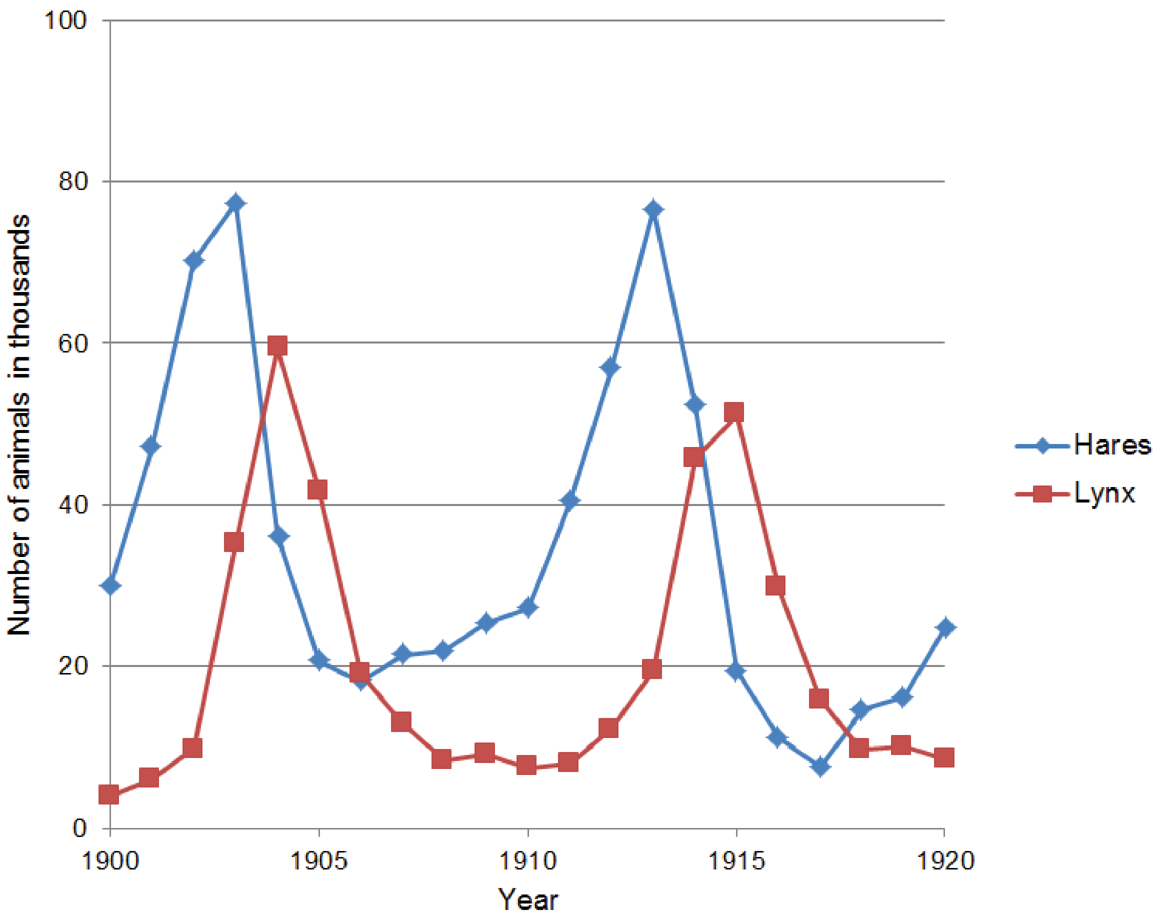
Snowshoe hare
Naturfoto-Online/Alamy Stock Photo

Lynx
imageBROKER/Alamy Stock Photo

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

The graph below shows the relationship between the lynx (predator) and snowshoe hare (prey) between 1900 and 1920.



Notice that on the graph predator numbers peak slightly after the numbers of prey numbers peak. This is typical of **predator-prey cycles**.

Explanation

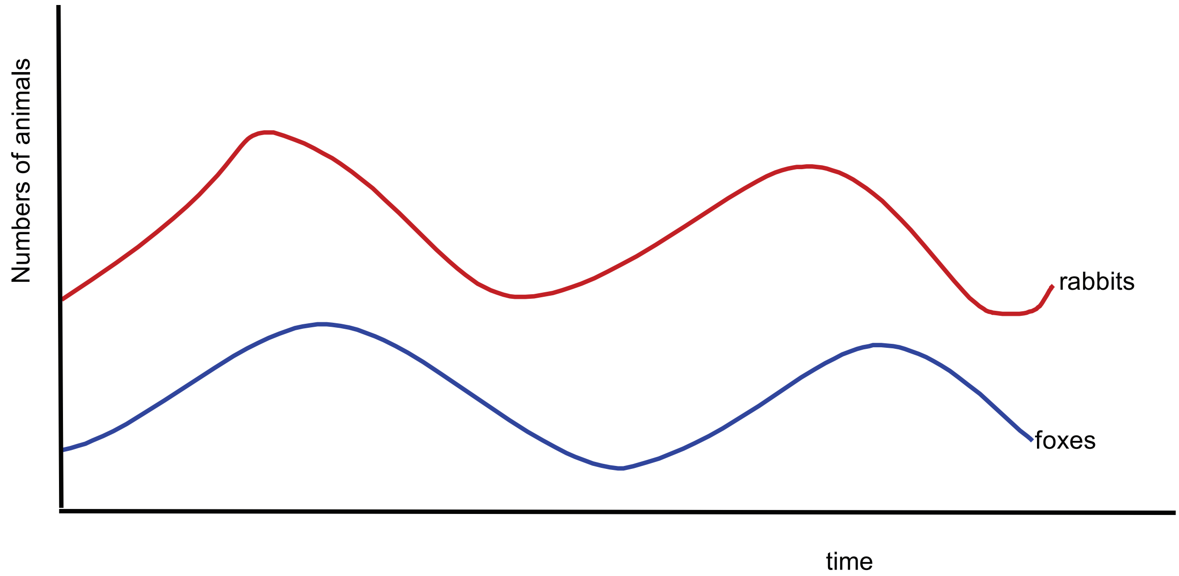
- When the hare (prey) population increased, the lynx (predator) population responded to the increased food source by increasing.
- As the lynx numbers increased, the higher numbers eventually reduced the hare numbers to the point where the lynx population could no longer be sustained, and so the lynx population fell.
- As the predator numbers decreased more hares were able to survive and the numbers of hares started to increase. The whole cycle started once again.

TEST YOURSELF

1. A population will grow rapidly if:

A predator numbers increase
B individual members of the species are forced to complete for resources
C individual members of the species have sufficient resources

2. Explain the changes of the fox and rabbit populations below by selecting the correct words from the brackets.



- When the rabbit population increases, the fox population which is the (prey predator), increases because there is an (decreased / increased) food source.
- As the (prey / predator) numbers increase, the higher numbers eventually reduce the rabbit numbers to the point where the fox population can no longer be sustained, and so the fox population starts to fall.
- As the (prey / predator) numbers decrease, more rabbits are able to survive and the number of rabbits starts to increase. The whole cycle begins again.

Our planet (Unit 2.1)

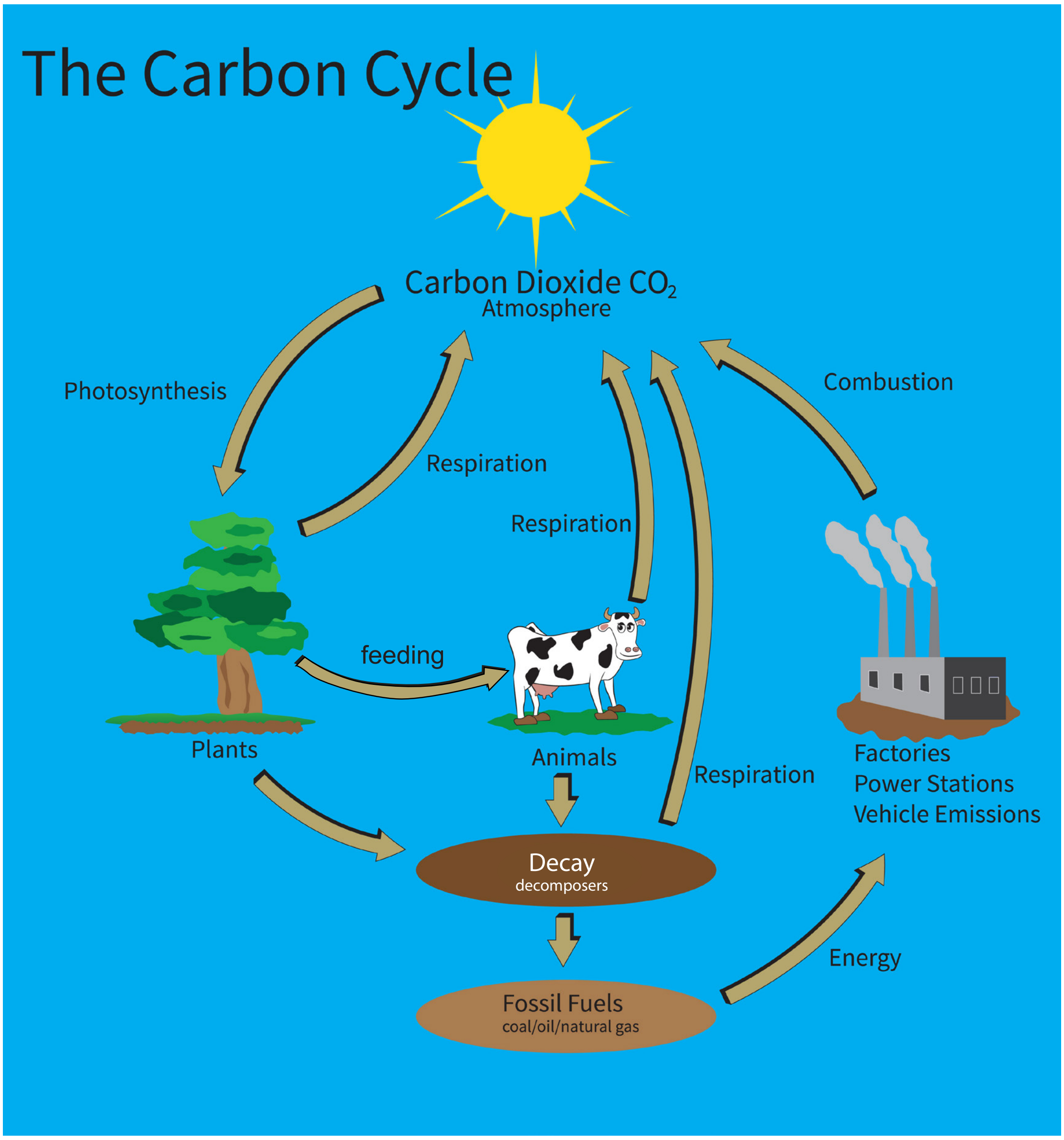
Transfer and recycling of nutrients (specification 2.1.3)

THE CARBON CYCLE

Carbon is absolutely essential to life on Earth. All organisms contain carbon since they all contain proteins, fats and carbohydrates.

The movement of carbon, in its many forms, between the atmosphere, oceans, biosphere, and geosphere is described by the **carbon cycle**.

The diagram below shows some of the important processes responsible for the movement of carbon.



Carbon cycle
Photiconix / Alamy Stock Photo

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

Processes involved in the carbon cycle

Removing carbon dioxide from the atmosphere

Green plants **remove** **carbon dioxide** from the atmosphere by **photosynthesis**.

The carbon becomes part of complex molecules such as proteins, fats and carbohydrates in the plants.

Returning carbon dioxide to the atmosphere

Organisms **return** **carbon dioxide** to the atmosphere by **respiration.**

Remember: Plants and microorganisms respire as well as animals.

Passing carbon from one organism to the next

Carbon is passed from one organism to the next through food chains.

1. When an animal feeds on plants, it takes carbon from the plants into its body. The carbon becomes part of the fats, carbohydrates and proteins in the animal.
2. Microorganisms, some animals and fungi feed on waste materials, and the remains of dead animals and plants.

Worm
Arterra Picture Library / Alamy Stock Photo

The carbon then becomes part of these microorganisms and these feeders.
e.g. An earthworm feeds on rotting plant leaves and other organic material.

Fungus
William Arthur / Alamy Stock Photo

Bacteria and fungi are also examples of decomposers. They play an important part in the recycling of organic material by digesting dead plant material. They release enzymes onto the dead material, breaking down the large molecules into soluble chemicals which are then used in respiration and for raw materials.

3. In certain conditions, when decay is prevented, animal and plant remains may eventually form fossil fuels (i.e. coal, oil and gas). Fossil fuels act as stores of carbon and energy.

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

Human activity and the carbon cycle

The **two** main human impacts on the carbon cycle are:

- Deforestation
- Burning of fossil fuels

1. **Deforestation**

Deforestation on the Brazilian border
luoman / gettyimages

Large amounts of carbon are stored in living plants. Therefore deforestation influences the carbon cycle in two ways:

- the removal of vegetation - Plants are no longer capturing carbon from the atmosphere through photosynthesis
- dense forests are replaced by crops or pasture land - Less carbon is stored in small plants than large trees

2. **Burning of fossil fuels**

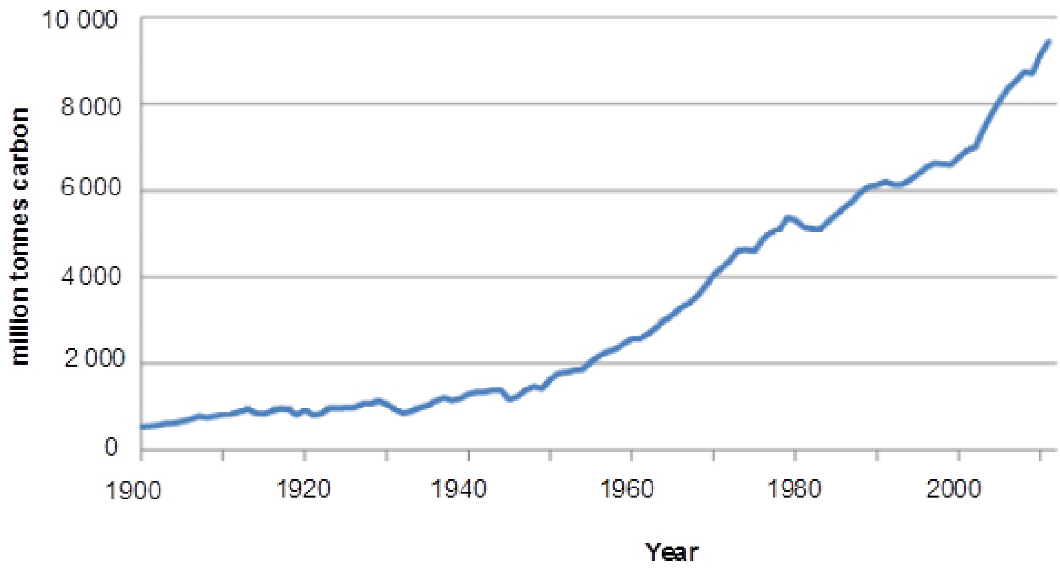
Coal-fired power station
Paul Glendell / Alamy Stock Photo

Burning fossil fuels such as coal, oil and natural gas results in carbon from the fossil fuels being released into the atmosphere as CO_2.

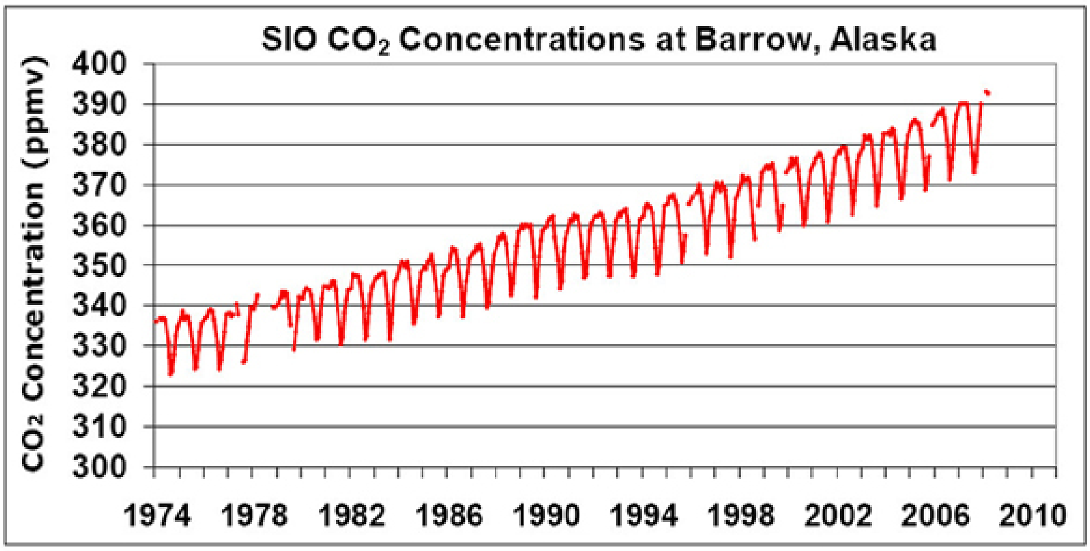
This is the most significant man-made contributor to global carbon dioxide emissions.

Global carbon emissions from fossil fuels have significantly increased since 1900. Since 1970, CO_2 emissions have increased by about 90%.

The graph on the following page shows the annual emissions of carbon dioxide into the atmosphere as a result of burning fossil fuels.



As a result of man's activity, the carbon dioxide concentration in the atmosphere is increasing. The graph below is based upon readings taken at Barlow, Alaska. Notice there are seasonal variations in carbon dioxide levels.



Does this matter?

There is a general consensus between most scientists that increased carbon dioxide levels in the atmosphere are responsible for global warming and climate change.

To understand this we need to consider the greenhouse effect.

The greenhouse effect

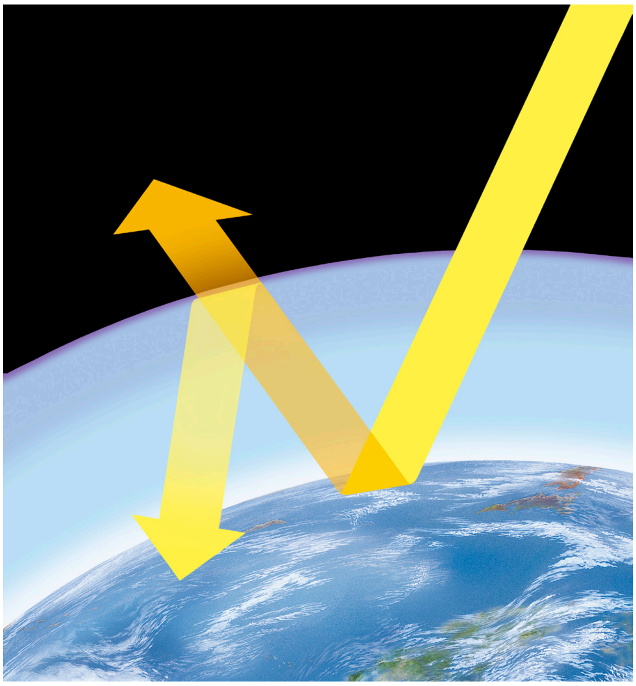
The **greenhouse effect** is a **natural** process by which the atmosphere traps some of the Sun's energy, warming the Earth enough to support life.

Without the greenhouse effect, the Earth would be a very much colder place (about 30°C cooler). The greenhouse effect allows for liquid water on the Earth's surface and helps stabilise conditions for life.

The Earth's atmosphere behaves as a greenhouse. Certain gases (e.g. water vapour, methane and carbon dioxide) stop heat radiating into space from the Earth and thereby keep the Earth warmer than it otherwise would be. This is called the greenhouse effect.

The greenhouse effect is explained below:

1. Most electromagnetic radiation from the Sun passes through the Earth's atmosphere but some is reflected.
2. The Earth's surface absorbs electromagnetic radiation with short wavelengths and so warms up.
3. Heat is radiated away from the Earth's surface as longer wavelength infrared radiation.
4. Some of this infrared radiation is absorbed by greenhouse gases in the atmosphere and re-emitted in all directions. Some of the re-emitted radiation is trapped in the Earth's atmosphere and some escapes into space.



Greenhouse effect
Gary Hincks / Science Photo Library

SOMETHING TO WATCH

Watch a video explaining the greenhouse effect.

https://www.youtube.com/watch?v=ZzCA60WnoMk

Global warming and climate change

Global warming is the term used to describe the gradual increase in the mean temperature of the Earth's atmosphere and its oceans, a change that is believed to be permanently changing the Earth's climate.

Carbon dioxide levels in the atmosphere are increasing. Many scientists believe that the increased **carbon dioxide concentration** is responsible for global warming.

They believe that the extra carbon dioxide is trapping even more heat in the Earth's atmosphere and is strengthening the greenhouse effect.

Changes in the climate, as a result of **global warming** may:

- make it impossible to grow certain food crops in some regions
- cause melting of polar ice caps which may lead to rising sea levels and the flooding of low-lying land
- make extreme weather events more likely since there is more energy in the hotter atmosphere

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

The graphs below show that the **mean** annual global temperature has increased as the carbon dioxide concentration has increased.

The increase in temperature from long term averages is known as the **global temperature anomaly.** It is probable that the increase in global temperature is a result of carbon dioxide increases.

Computer models appear to back this up; climate predictions from these models show similar changes to what actually occurs when the amount of carbon dioxide is altered in the models.

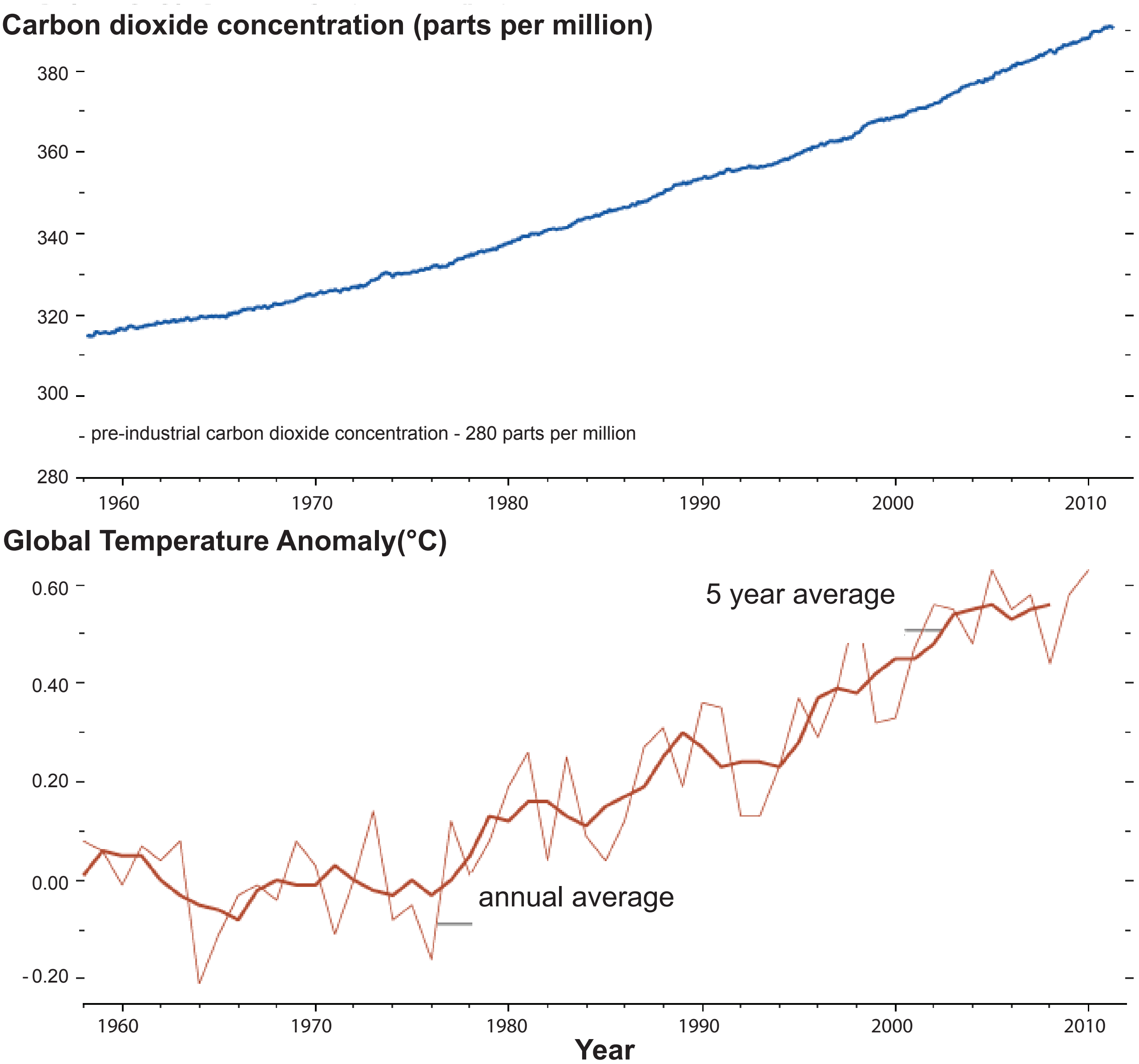


Diagram from http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php

Other factors affecting global warming

There are a small number of scientists who agree that global warming is taking place, but do not agree that carbon dioxide levels are to blame.
A factor that may affect the mean temperature of the atmosphere is the amount of energy given out by the Sun. Although the solar output from the Sun is extremely stable it is possible that even very small changes may have an effect on the Earth's climate. Apart from the 11 year sunspot cycle, there appear to be longer cycles in solar output (200 years, 2 400 years) which may affect the Earth.
At present, solar variations remain a controversial mechanism of climate change.

Solutions to global warming

What can we do?

- Decrease our fossil fuel use.
- Switch to low carbon energy sources, for example, nuclear, wind, solar, tidal power.
- Use carbon capture technologies:

  Carbon capture means that carbon dioxide emissions are trapped and stored before they get into the atmosphere.

Puzzle piece
SilverV / gettyimages

  Thus if we burn methane to generate electricity, we capture and store the carbon dioxide instead of releasing it into the atmosphere.

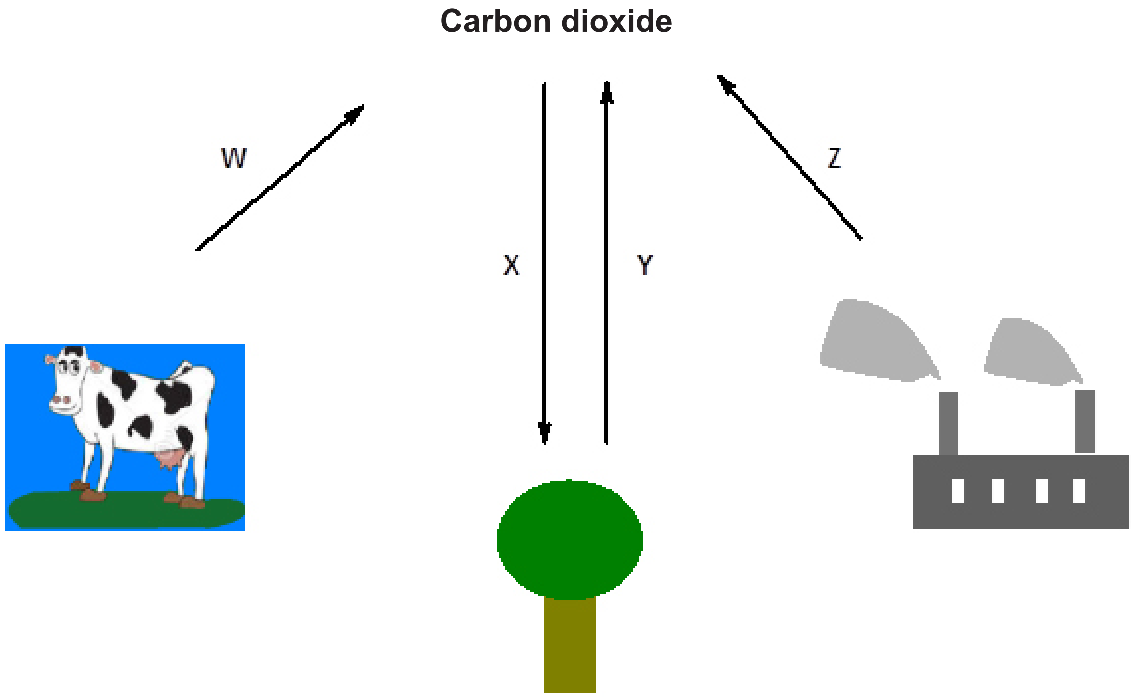
- Recycle

  Recycling generally involves using less energy than obtaining new resources.

- Use cars less and public transport more

TEST YOURSELF

1. Select the correct labels for the processes W, X, Y and Z that remove or add carbon dioxide to the atmosphere.



(a) **Label W**: **A** respiration **B** photosynthesis **C** combustion
(b) **Label X:** **A** respiration **B** photosynthesis **C** combustion
(c) **Label Y:** **A** respiration **B** photosynthesis **C** combustion
(d) **Label Z:** **A** respiration **B** photosynthesis **C** combustion

2. **Two** gases that cause the greenhouse effect are:

A carbon dioxide and methane
B carbon dioxide and nitrogen
C water and nitrogen

3. Changes to the Earth's climate may:

A increase the number of tsunamis and earthquakes
B cause sea levels to rise
C damage the ozone layer

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

NUTRIENT CYCLES

Nutrient cycles can be thought of as nature's recycling system.

Ecosystems are interconnected systems where matter and energy flows and is exchanged as organisms feed, digest, and move about. As we have seen, the carbon cycle describes how carbon is extracted from the atmosphere and flows through the food chain until it is returned to the atmosphere as carbon dioxide.

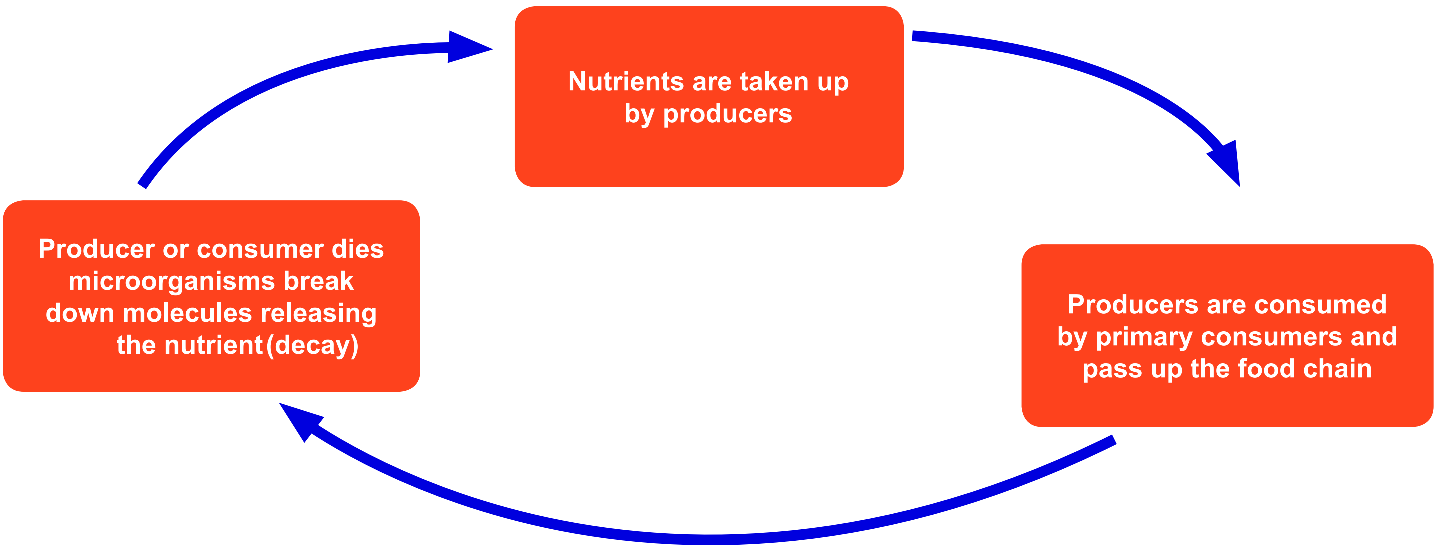
The carbon cycle is an example of nutrient cycling. As we have seen, the carbon cycle describes the extraction of carbon from the atmosphere by plants using photosynthesis, its movement through the food chain and its return to the atmosphere.

Similar mineral cycles can be described for valuable minerals such as nitrogen, phosphorus and oxygen. All these are necessary for life. In fact, nutrient cycling is one of the most important processes that occur in an ecosystem.

Recycling
Science Photo Library /
Alamy Stock Photo

Nutrient cycles describe the use, movement, and recycling of nutrients in the environment.

The basic elements of a nutrient cycle can be summed up in a simple diagram.



In a stable ecosystem, the processes which remove materials are balanced by processes which return materials.

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

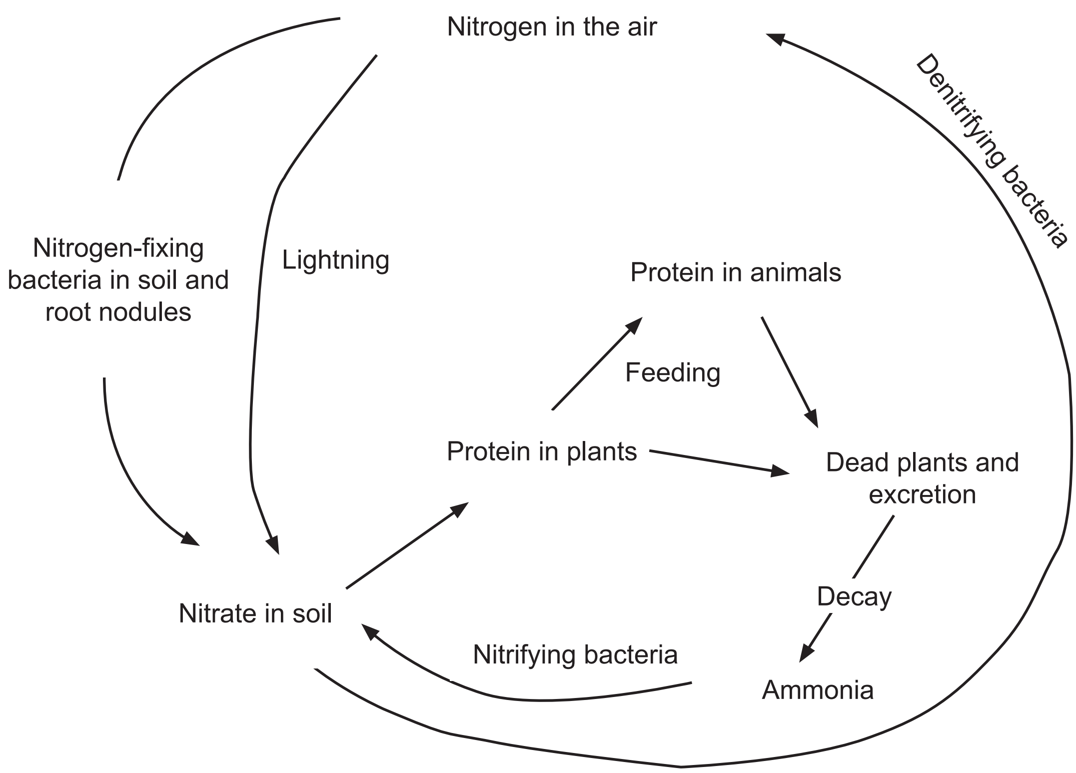
Nitrogen cycle

Brief overview

An example of a nutrient that is recycled is nitrogen. Plants and animals need nitrogen for proteins to enable growth. This element is released as ammonia when organisms die and decay as a result of the action of microorganisms. Ammonia is converted into nitrate and released into the soil which can then be used by other organisms e.g. plants.

Foundation tier: You do NOT need to know about the details of the nitrogen cycle that follow (the cycle or key points).

In more detail



The key points

- Nitrogen gas **cannot** be used directly by plants or animals
- Nitrogen-fixing bacteria living in root nodules of **legume** plants **or** the soil fix nitrogen gas into nitrates. The action of lightning can also convert some atmospheric nitrogen into nitrates.
- Decomposers (bacteria and fungi) break down dead animals and plants converting the proteins and urea into ammonia
- **Nitrifying bacteria** convert this ammonia to nitrates
- Plants absorb nitrates from the soil
- Primary consumers eat producers and digest the plant proteins for their own use (to form new proteins)
- Nitrogen is passed up the food chain from one trophic level to the next
- **Denitrifying bacteria** covert nitrates to nitrogen gas. Denitrifying bacteria prefer to live in waterlogged or unploughed soil.

Water-logged fields lose nitrogen by leaching and due to the action of denitrifying bacteria.

Flooded field
watcherfox / gettyimages

Factors affecting decomposition processes

The table below summarises a number of factors that affect the action of microorganisms in decomposition reactions (e.g. compositing and land fill sites).

Factor	Comment
temperature	• high temperatures prevent decay action of enzymes as the proteins are denatured • decomposers killed • low temperatures slow decay • rate of growth and reproduction of decomposers reduced
oxygen	• oxygen is needed for respiration by decomposers
water	water is needed: • for transport • to support reactions inside decomposers
pH	• compost microorganisms operate best within a pH range of 5.5 - 8
Heavy metals	• heavy metals may slow decomposition rates due to toxicity of these elements towards microorganisms

Compost heap
Organics image library / Alamy Stock Photo

Compost heaps need a good supply of oxygen for microorganisms to respire.
Decomposition is fastest in the temperature range of 40-60°C.
Most species of microorganisms cannot survive at temperatures above 60-65°C and so decomposition is prevented at higher temperatures.

PRACTICE QUESTIONS

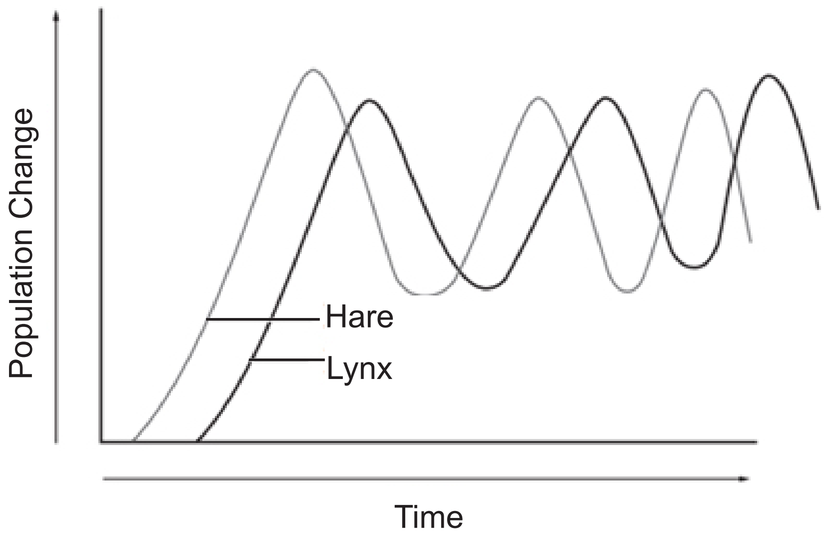
1. In the natural habitat, the lynx is a predator of the snowshoe hare.

(a) State one way in which the hare is adapted to its environment. [1]

....

....

(b) The population of lynx and hares changes in the pattern shown in the graph.



Explain why the population change of lynx lags behind that of the hare. [3]

....

....

....

....

....

PRACTICE QUESTIONS

2. The table shows the energy budget for a cow grazing on grass.

Input energy (food) (kJ)	Losses (kJ)		Retained energy (kJ)
	heat	undigested food waste	
2 500	850	1 520	…………….

(a) Calculate the retained energy for the cow. **Write your answer in the table**.

[1]

(b) The energy conversion efficiency (ECE) is the percentage (%) of input energy retained within the cow.

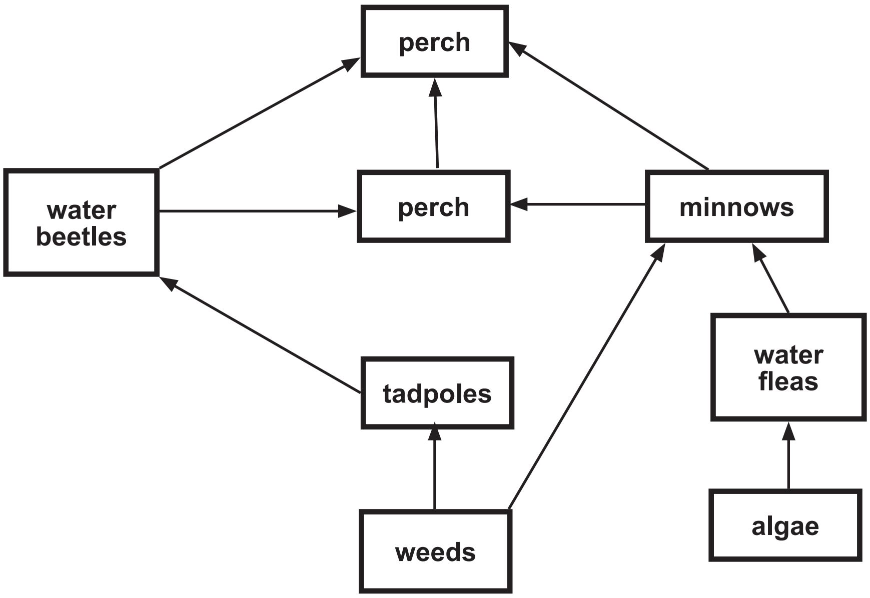
Calculate the ECE for the cow. [2]

ECE = ……………%

PRACTICE QUESTIONS

3. (a) (i) Name the source of energy for a food web. [1]

....



(ii) Name one secondary consumer from the food web above. [1]

(iii) Draw one food chain from the web that includes four living things and ending with the perch. [2]

(b) A warden regularly removes lilies from the surface of the pond. Explain why this is necessary. [2]

....

....

(c) The warden notices the water fleas are disappearing from the pond. Explain how this will affect the food web. [3]

....

....

....

PRACTICE QUESTIONS

4. Denitrifying bacteria prefer to live in waterlogged ground. Denitrification leads to the gaseous loss of nitrous oxide (N_2O) into the atmosphere, which is a major greenhouse gas.

Flooded field
driftlessstudio / gettyimages

Using this information, answer the following questions.

(a) Give one environmental advantage of improving drainage of waterlogged ground. [1]

....

....

(b) Explain one economic benefit and one environmental advantage of improving drainage of waterlogged ground. [2]

....

....

....

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

TEST YOURSELF - ANSWERS FOR UNIT 2.1

Using electromagnetic radiation to explore the universe

1. **A** increasing wavelength **B** microwaves **C** infrared **D** X-rays

   E gamma waves **F** increasing frequency

2. B
3. B
4. A
5. C
6. B

Our Solar System

1. A
2. D
3. B
4. Io – most volcanically active body in the solar system with hundreds of volcanoes
   Phobos - the larger and innermost of the two natural satellites of Mars
   Titan - only moon in the solar system with clouds and a thick atmosphere

Classification of organisms

1. C
2. B
3. C

Adaptation to the environment

1. C
2. a) A b) C
3. B

Our planet (Unit 2.1)

Transfer and recycling of nutrients (specification 2.1.3)

TEST YOURSELF - ANSWERS FOR UNIT 2.1

Chains, webs and pyramids

1. plants, level 1, primary, 3
2. A
3. B

Interdependency of organisms

1. C
2. predator, increased, predator

The carbon cycle

1. (a) A (b) B (c) A (d) C
2. A
3. B

Space Health and Life (Unit 2)

Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

ENVIRONMENT UNDER THREAT

The environment and biodiversity is changing due to the impact of human activity on the environment. Human activity includes building homes, factories, shops or roads, mining resources from the ground or disposing of the waste, growing food, using energy resources and much more. All these activities affect the environment around us. This leaves us with questions to answer.

How do our unwanted products affect the world around us? How can we live more sustainably? How can we treat our waste products to improve safety? What methods can be used to maintain biodiversity?
Science can help us answer these important questions.

Habitat

One of the great threats to biodiversity is loss of habitat. We first need to remind ourselves of what is meant by the term habitat.

A **habitat** is a place where an organism or a community of organisms live.

Examples of habitats:

- a grove of trees
- grasslands
- hedgerows
- rainforest
- a pond
- a bog
- rivers and streams
- a host organism inhabited by parasites

If we destroy a habitat, animals that are adapted to that habitat will struggle to survive or become extinct. This results in a loss of biodiversity.
Habitat loss is probably the main reason why species become extinct.

Giraffe in Savanna
Anna Omelchenko / Alamy Stock Photo

The following would be examples of habitat destruction:

- clearing forests for farmland
- filling in wetlands to build houses
- mining or quarrying
- poisoning land with pollutants from mine waste (e.g. Parys Mountain where copper mining in the 18th century destroyed the original natural habitat).

Parys Mountain copper mine
Jeff Morgan 16 / Alamy Stock Photo

Protecting habitat

If we can protect the natural habitat, then the organisms that live in that habitat have an opportunity to survive. This can be achieved by creating National Parks, nature reserves or making Sites of Special Scientific Interest.

One issue related to habitat loss is fragmentation of habitat. This happens when a habitat that was once continuous is split up into smaller pieces. This has big impacts on animals that can't move between patches of suitable habitat.

Fragmented habitats make it harder for animals to find food, and harder to find a mate because they get isolated from each other. This reduces the chances of survival.

One way of overcoming this problem is to create **land corridors** connecting the smaller reserves together. This allows organisms to move between habitats and improves their chance of survival. It also helps preserve the genetic diversity of the organisms.

Conservation and sustainability

Conservation

Protecting the habitat is one way of preserving biodiversity. It shows us the need to act in a responsible way towards the environment. Protecting habitat is part of conservation.

Conservation is the protection, preservation, management, or restoration of wildlife and of natural resources such as forests, soil, and water.

Examples of different methods of conservation are summarised below:

- protecting habitats by creating Sites of Special Scientific Interest or National Parks
- making laws to protect endangered species and control international trade
- captive breeding programmes
- The goal of most captive breeding programs for endangered species is to establish captive populations that are large enough to be stable and genetically healthy.
- creating a genetic bank (a seed bank or sperm bank)

The purpose of a **genetic bank** is to store genetic material for the future.

For example, a **seed bank** stores seeds to preserve genetic diversity.

A **sperm bank** is a similar concept applied to preserving genetic diversity in animals.

The mountain gorilla is an example of an animal that is critically endangered and needs protection.

Mountain gorillas
imageBROKER / Alamy Stock Photo

Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

Sustainability

We also need to act in a responsible way towards the environment when we use natural resources. We have a duty to act in a thoughtful way so that future generations will also be able to enjoy the rich diversity of life on Earth as well as having sufficient resources to live. This means we need to live sustainably. This is particularly important as the world's population is growing and there is a greater demand on resources.

Sustainability means that we provide for our needs **without** using up the resources and damaging the environment.

To act sustainably we need to think carefully about the consequences of:

1. using natural resources.
   This may require us to change the way we do things. For example,
   - quotas are placed on fishing so that fish stocks are not completely used up
   - trees may be replanted if some woodland is removed
   - recycling schemes are put in place so reducing our need to find new raw materials.

2. changing the way we use land.
   This requires us to take into account the impact of, for example, housing developments or road building on the environment.

   - In England and Wales all new development work requires environmental scientists to complete an **Environmental Impact Assessment.**

     This involves scientists collecting data on the environment where the proposed development is to take place and assessing how the environment, including endangered species in that environment, will be affected. The assessment is used to decide whether the work should go ahead, be refused or modified to reduce the effect on wildlife.

Housing development
Image Source / Alamy Stock Photo

Pollution

Pollution involves the addition of substances to the environment that have a harmful effect on living organisms.

Sometimes we use compounds for a positive purpose but if they get into the wider environment there can be **unintended** consequences.

Adding fertiliser to a field can cause unintended problems
Julian Eales / Alamy Stock Photo

Examples:

Pollutant	Comment
heavy metals	These may get into the environment as a result of mining or incorrectly disposing of waste containing heavy metals. Many heavy metals are toxic and **accumulate** in the food chain (read later about the bioaccumulation of mercury).
fertilisers	Fertilisers are spread on fields to improve crop growth. It is possible that fertilisers may be washed off fields into waterways where they may cause **eutrophication.**
pesticides	Pesticides are used in agriculture to kill pests that otherwise destroy crops. These may remain in the soil for a long time or be washed off into waterways. Some pesticides have been linked with environmental damage (read later about the bioaccumulation of DDT).
sewage	If sewage gets into waterways it may also cause **eutrophication**.
waste - plastics	Most plastics are not biodegradable. This means they can persist in the environment for a very long time. Even our oceans contain large quantities of plastics. This may cause animals to choke if they mistake it for food. The government in Wales introduced charges on carrier bags to help try to **reduce** our use of plastic bags. The use of **bio**degradable plastics also helps **reduce** the long term impact of the plastics on the environment.
waste - household items	Many household items contain toxic chemicals. e.g. • low energy lamps contain mercury; • batteries and mobile phones contain toxic chemicals. These should not be put in general household waste to be buried in a landfill site.

Sustainability, conservation and waste disposal

Sewage treatment

How do we prevent sewage damaging the environment? This is the role of sewage works.

In sewage treatment works, the **main process** is the breakdown of the waste by the action of **microorganisms** into products which are harmless to the environment.
A wide range of different bacteria are needed to breakdown the different types of material found in sewage.

In sewage treatment works, lots of oxygen is provided by stirring the waste. Oxygen is needed by the bacteria for aerobic respiration. **Aerobic respiration** means that the waste is completely broken down.

Anaerobic respiration would only give a partial breakdown of the waste.
The treatment of sewage means that the water, after treatment, is safe to be discharged back into rivers.

The solid waste left after treatment is completed can be used as a fertiliser for fields.

Sewage treatment - aeration
LOOK Die Bildagentur der Fotografen GmbH / Alamy Stock Photo

Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

Household waste disposal

The European Union defines waste as 'any substance or object that the holder discards, intends to discard or is required to discard'. We probably just call it rubbish. Whatever the name, it is a problem. Placing rubbish in landfill sites is not sustainable.

Landfill site UK
Paul Glendell / Alamy Stock Photo

What should we do with our waste? The options are:

- bury it in a landfill site or incinerate
- reuse
- recycle

Burial or incineration is really a last resort. There is a limit to how much material can be put into a landfill site. This is also wasteful since the resources that were used to make the product in the first place are no longer available to future generations.

Reuse

Reuse is often confused with recycling and considered to be the same. However, they actually concern entirely different processes.

Reusing refers to using an object as it is without treatment.
This reduces pollution and waste, thus making it a more sustainable process.

Reuse is preferable to recycling since it generally consumes less energy.

Recycle

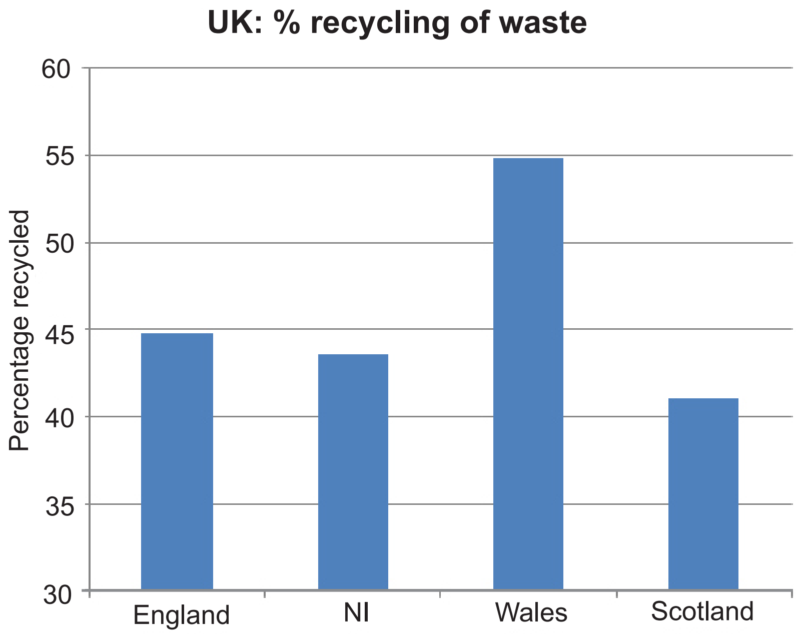
Recycling means turning an item back into raw materials which can be used again, usually to make a completely new product.

Negatively, recycling is an energy consuming procedure.
Positively, recycling:

- means that we bury less material in landfill sites
- reduces our need to extract new raw materials from the Earth
- helps improve sustainability and also reduces damage to the environment when we obtain the material.

All Welsh councils have been set the target to recycle 58% of waste by 2016 and the target will eventually rise to 100% by 2050.

In 2015, households in Wales generated 1.3 million tonnes of household waste of which 54.8% was recycled. This was the highest recycling figure in the UK.



Finally what should we as citizens do to be more sustainable?
It can be summed up in three words:

reduce	reuse	recycle

Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

What happens if pollutants get into the environment?

If pollutants get into the environment they can cause serious harm. We will look at just two problems caused by different pollutants in more detail. Obviously, other pollutants can have other environmental effects (e.g. carbon dioxide has been linked with global warming).

Bioaccumulation of toxic compounds

Bioaccumulation is the gradual build up over time of a chemical in a living organism.

These chemicals are then passed up the food chain from one trophic level to the next and often become more concentrated as they do so.

This means animals at the top of the food chain are affected more severely.

This is what happens:

- Small amounts of toxic substances are taken up by producers (plants)
- These plants are eaten by primary consumers
- Primary consumers are eaten by secondary consumers which in turn are eaten by higher level consumers
- At each trophic level of the food chain, the toxins remain in the tissues of the organisms and so the toxin concentration is highest in animals at the top of the food chain.

Example: Minamata disease

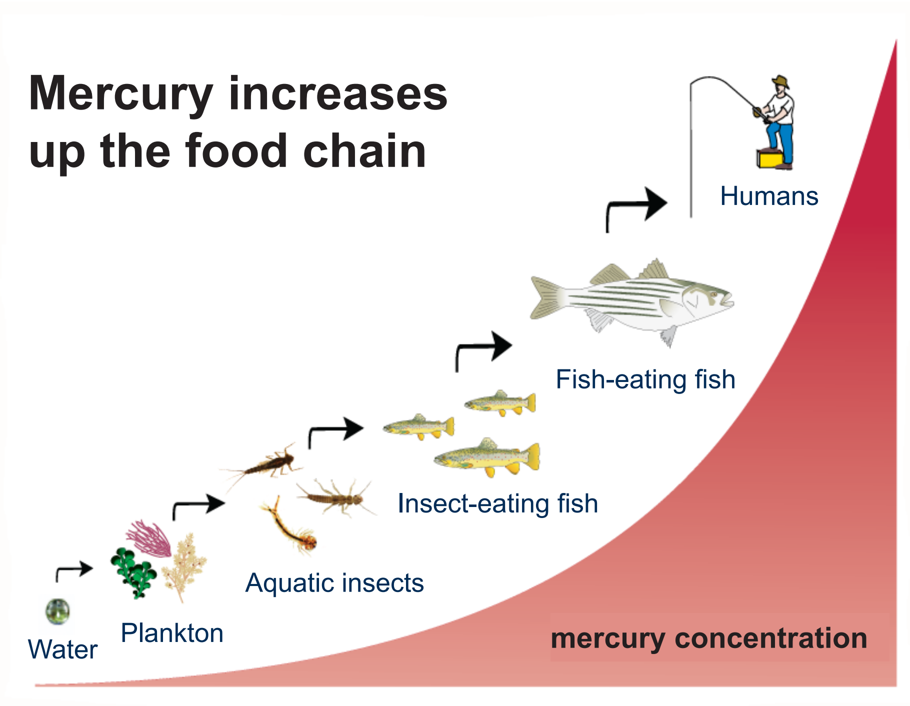
A disease was first noticed in Minamata, Japan in communities which ate shellfish and fish as part of their diet which came to be known as Minamata disease.

Those suffering from it experienced numbness, loss of vision, damage to hearing and speech and muscle weakness. Animals in the community were also affected. The animal effects were severe enough in cats that they came to be named as having “dancing cat fever”.

The cause of the disease was found to be mercury poisoning. Mercury is a heavy metal which accumulates in the food chain.

It was caused by the release of a toxic mercury compound into the sea from a chemical factory. The mercury was taken up by plankton where it accumulated.

Zooplankton consumed the contaminated plankton. The mercury was passed higher up the food chain to higher level consumers, such as shellfish and fish where it concentrated further.



Humans, as the final consumers, ended up consuming fish and shellfish with high mercury concentrations.

Example: DDT

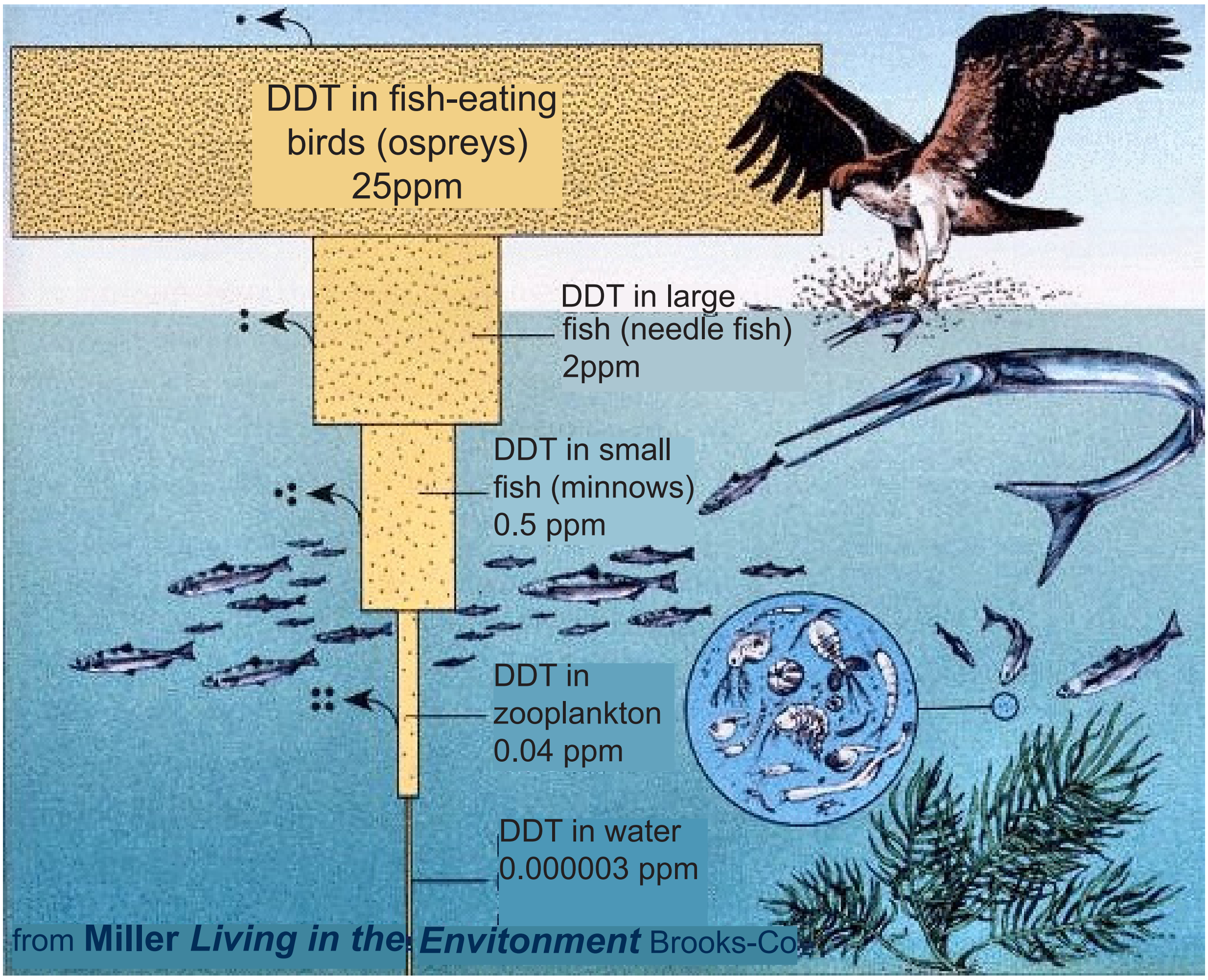
Another example of bioaccumulation is from the use of DDT as an insecticide in the 1950s and 1960s.

DDT is an insecticide that can pass up the food chain from producers to zooplankton to small fish to larger fish and finally to birds of prey, such as the osprey.

It accumulates in the birds of prey, giving them a large concentration of DDT. High concentrations of DDT in birds cause weakness in their eggs so reducing their population.

DDT was used to kill fleas and mosquitos
Everett Collection Historical / Alamy Stock Photo

The diagram below shows how the concentrations of DDT magnify through each level of the food chain.



http://www.mhhe.com/biosci/genbio/enger/student/olc/art_quizzes/genbiomedia/0414.jpg

Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

Eutrophication of rivers and lakes

Fertilisers contain high levels of nitrates and phosphates to encourage plant growth. If fertilisers are washed into streams or lakes they can cause serious environmental harm in a process known as **eutrophication.**

1. High levels of nitrates and phosphates from fertilisers encourage the growth of photosynthesisers such as plants and algae which forms a bloom over the surface (algal bloom).
2. Plants under the algal bloom die because of a lack of sunlight.
3. When the plants and algae die, they decompose by the action of microorganisms.
4. The microorganisms use oxygen from the water for respiration, so reducing the concentration of dissolved oxygen in the water.
5. The oxygen levels fall so low that fish can no longer live.

Sewage has the **same** effect as fertilisers and can also cause eutrophication.

Fish death due to eutrophication
blickwinkel / Alamy Stock Photo

Monitoring our environment

Living Indicators

Pollution levels can be measured directly. The presence or absence of certain living organisms can also act as an indicator of the amount of pollution.

An indicator species is a species whose abundance gives us a measure of the health of the ecosystem.

Examples

1. Lichens

Lichens grow in exposed places such as rocks or tree bark. They need to be very good at absorbing water and nutrients to grow there. Rainwater contains just enough nutrients to keep them alive.

Air pollutants dissolved in rainwater, especially sulfur dioxide, can damage lichens and prevent them from growing.

This makes lichens natural indicators of air pollution.

Different lichens can tolerate different levels of pollution. For example,

- bushy lichens need clean air
- leafy lichens can survive a small amount of air pollution
- crusty lichens can survive in more polluted air

A variety of lichens growing on a tree in Scotland
MichaelGrant / Alamy Stock Photo

If no lichens grow in an area then that is a sign that the place is heavily polluted.

2. Invertebrate animals can be used to monitor water pollution

Many aquatic invertebrate animals cannot survive in polluted water, so their presence or absence indicates the extent to which a body of water is polluted.

Examples of indicator species for levels of water pollution are given in the table below.

Factor	Indicator species
very high	sludgeworm, rat-tailed maggot
high	water louse
low	freshwater shrimp
clean	mayfly larva

The mayfly lava is only found in clean water
blickwinkel / Alamy Stock Photo

Non-living Indicators

Non-living indicators are physical measurements (e.g. oxygen concentration) which tell us something about the health of an ecosystem.

Examples of non-living indictors are:

- temperature
- pH
- oxygen concentration

All these physical parameters tell us something about the health of an environment. In most cases these parameters are most easily measured using a digital probe.

Measuring oxygen using digital oxygen probe
Martin Shields / Alamy Stock Photo

Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

TEST YOURSELF

1. Select the correct word (or words) in the brackets that is/are correct:
High levels of fertiliser in a river can lead to (**eutrophication / bioaccumulation**).
This process is described below.

1. High levels of (**pesticides / nitrates / acids**) encourage the growth of photosynthesisers such as plants and algae.
2. Plants that are under the algal bloom die because of a lack of sunlight.
3. When the plants and algae die, they decompose by the action of microorganisms which use (**carbon dioxide / nitrogen / oxygen**) when they (**photosynthesise / respire)**.
4. The fish can no longer live because (**carbon dioxide / nitrogen / oxygen**) levels are too low.

2. Two examples of living indicators are:

A lichens and oxygen concentration
B pH and invertebrates
C lichens and invertebrates
D pH and oxygen concentration

3. Two examples of non-living indicators are:

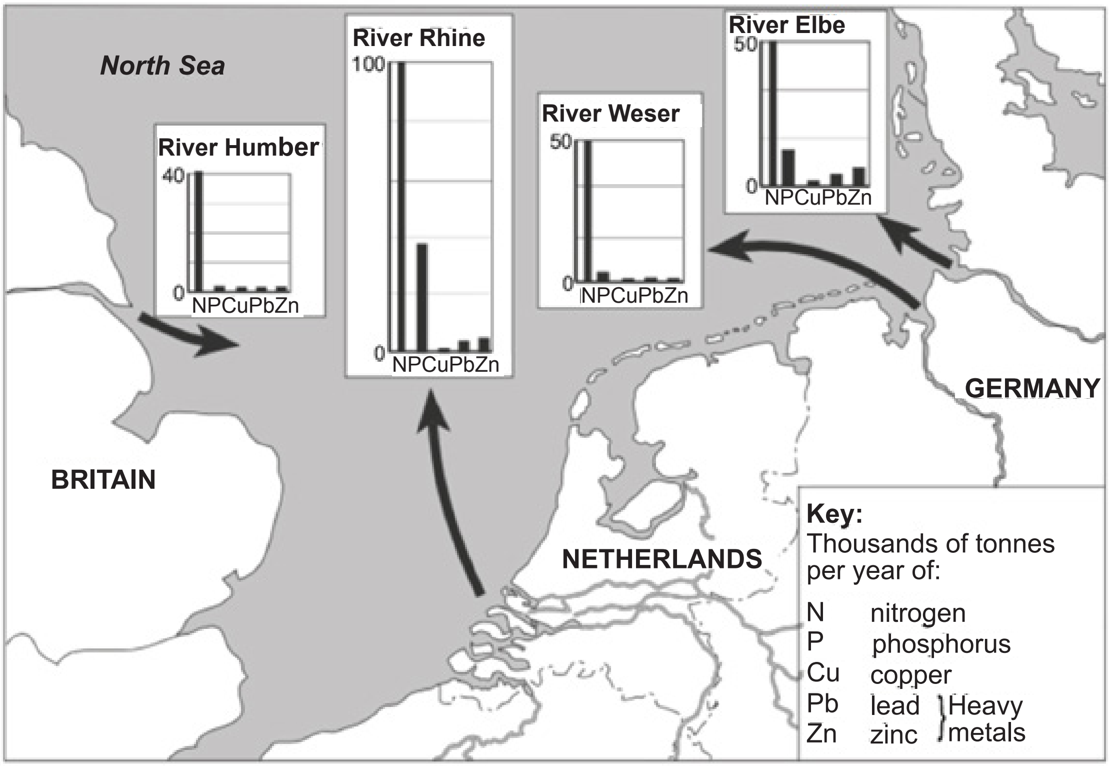
A lichens and oxygen concentration
B pH and invertebrates
C lichens and invertebrates
D pH and oxygen concentration

4. It is important that we use resources sustainably. Select the correct statement from below.

A Recycling is considered sustainable even though it requires the use of energy
B Recycling is sustainable because it does not require the use of energy
C Recycling waste refers to using an object without treatment

PRACTICE QUESTIONS

1. Over 80% of sea pollution comes from land-based activities. Rivers are one common path of entry of pollution into the sea. The map shows the main pollution levels in some rivers that enter the North Sea.



(a) Use the information above to answer this question.

(i) State one way farming adds to water pollution. [1]

……………………………………………………………………………………

(ii) State one way industry adds to water pollution. [1]

……………………………………………………………………………………

(b) Explain why the lowest concentration of oxygen is found at the mouth of the river Rhine. Use the information above to give one reason why. [2]

……………………………………………………………………………………

……………………………………………………………………………………

PRACTICE QUESTIONS

(c) It is observed that many fish-eating birds have been found dead near the mouth of the rivers Elbe and Rhine.

(i) Use the information above to give one reason why. [1]

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(ii) Explain why dead birds are found rather than dead fish. [2]

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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Protecting our environment (Unit 2.2)

Protecting our environment (specification 2.2)

TEST YOURSELF - ANSWERS FOR UNIT 2.2

Environment under threat

1. eutrophication, nitrates, oxygen, respire, oxygen
2. C
3. D
4. A

Space Health and Life (Unit 2)

Health, fitness and sport (Unit 2.3)

Factors affecting human health (specification 2.3.1)

Health, fitness and sport (Unit 2.3)

Factors affecting human health (specification 2.3.1)

Genes, inheritance and health

Some characteristics of living organisms are caused by the environment while others are inherited. This is true for humans as for all other organisms. Inheritance is governed by our chromosomes and the genes we carry.

Chromosomes, DNA and genes

Each body cell in the human body contains **23 pairs** of **chromosomes.**

One chromosome from each pair is inherited, one from the mother and the other from the father.

Chromosomes are long sections of DNA (deoxyribonucleic acid) found in the nucleus of body cells.
DNA is a large, complex molecule which carries the genetic code that determines the characteristics of living things.

A single strand of DNA is made from chemicals called bases. There are four different types of bases, A, T, C and G. The pattern of these bases forms the code which holds information in the gene.

In DNA, two strands coil together to form a structure known as double helix (see the diagram). You can think of DNA as a ladder-type structure with the weak bonds between bases forming the rungs of the ladder.

The bases A, T, C and G are **NOT** the same as bases we met in acid base theory. Don't confuse the two!

The two strands are held together by weak bonds between complementary base pairs. The weak bonds holding these strands together will only be formed between certain base pairs (called complementary pairs).
The complementary pairs between which bonds can form are:

- A and T
- C and G

DNA
John Schwegel / Alamy Stock Photo

Chromosomes contain the genes that are inherited from both parents.

Factors affecting human health (specification 2.3.1)

Genes are short sections of DNA.
Each gene carries information which codes for a specific protein.

Since we inherit a chromosome from each parent, we will also have two copies of each gene; one from the father, the other from the mother.

Alleles, phenotypes and genotypes

Some genes may have different forms. These different forms are called alleles.

An **allele** is a variant form of a gene.

Some characteristics, such as eye colour, are controlled by a single gene. There is one allele (form of the gene) for blue eye colour and a different allele for brown eye colour.
For every characteristic we have two forms of one gene, one from the father and one from the mother. For some individuals the two genes are the same, for others they are different.
In other words, we either inherit **two** copies of the **same allele** or **two different alleles.**

The **genotype** describes the alleles present in an individual for a particular characteristic.
Individuals who are:

- **homozygous** for a certain gene carry two copies of the same allele
- **heterozygous** for a certain gene carry two different alleles

Alleles are either dominant or recessive.

This means that:
- the characteristic controlled by the **dominant allele** will develop if the allele is present on one **or** both chromosomes in the pair.
- the characteristic controlled by the **recessive allele will** develop only if the allele is present on **both** chromosomes in the pair.

Another important word which can be confused with genotype is phenotype.

Phenotype is the physical characteristic resulting from the inherited information.

Example

In the case of eye colour, one allele codes for blue eyes and one another codes for brown eyes. If someone has blue eyes we say they have the phenotype for blue eyes.

What happens if you inherit an allele for blue eyes and an allele that codes for brown eyes? The allele for brown eyes is dominant but the allele for blue eyes is recessive. You will have:

- brown eyes if you inherit either one or both alleles for brown eyes
- blue eyes only if you inherit two copies of the allele for blue eyes.

We represent the dominant allele with a capital letter.

The recessive allele is represented by the corresponding lower case letter.

We can represent the dominant allele for brown eyes with B. Since blue is a recessive genotype we will use a lower case letter to represent it, b.

The table below shows the possible genotypes and phenotypes that can arise from the combination of these two alleles.

Genotype	Phenotype
bb	blue eyes
Bb	brown eyes
BB	brown eyes

Genetic mutations

A genetic mutation occurs when DNA changes, altering the genetic instructions.

This may result in a genetic disorder or a change in characteristics. Mutations can happen spontaneously but they can also be caused by environmental factors such as radiation and certain chemicals (e.g. in cigarette smoke).

Health, fitness and sport (Unit 2.3)

Factors affecting human health (specification 2.3.1)

Mutations may be harmless or occasionally beneficial. Generally mutations are harmful.
Some inherited medical conditions, such as cystic fibrosis or Huntington's disease, are directly caused by a mutation in a single gene.

Inherited disorders

An example of an inherited condition is Huntington's disease. The symptoms associated with Huntington's disease usually develop in middle age. They include tremors, clumsiness, mood changes and memory loss. Huntington's is caused by the presence of the **dominant** allele, **H**. A person who has the heterozygous genotype, **Hh**, will therefore suffer from the disease.

Not all genetic diseases are caused by a dominant allele.

In some cases, such as **cystic fibrosis,** the allele for the disease, **n**, is recessive. In this case, a person who has the heterozygous genotype, **Nn**, will **not** develop the disease themselves but since they have the recessive allele associated with the disease they are a carrier.

If they have children with another person who is a carrier there is a chance that some of their children will inherit both recessive genotypes and therefore suffer from the disease.

Inheritance is best explained using Punnett squares.

Punnett squares

Genetic diagrams, called Punnett Squares, are used to show the possible outcomes of inheriting different alleles. In these diagrams a dominant allele is shown by a capital letter and a recessive allele by a lower case letter.

Example problem - Huntington's disease

Huntington' is caused by the presence of the **dominant** allele, H. A father is a **heterozygous** carrier of Huntington's. The mother is **not** a Huntington's sufferer. What is the chance (probability) that one of their children will inherit the disorder?

Answer

The father is a **heterozygous** carrier. This means he carries both the dominant and recessive alleles. His genotype is **Hh**.

The mother is **not** a sufferer so she cannot carry the dominant allele. Her genotype must be **hh**.

		father	
		H	h
mother	h	Hh	hh
	h	Hh	hh

Whenever the dominant allele is present, the child will inherit the disease.
In this case the dominant allele is found in two of the four possible offspring.
This means the chance of a child suffering from the disease is 1 in 2 or 50%.

Example problem - cystic fibrosis

The allele for cystic fibrosis is recessive. A person will therefore only experience the symptoms associated with the disease if they have inherited the recessive allele from both parents.
A mother and father are both **heterozygous** carriers of cystic fibrosis. What is the chance (probability) that one of their children will suffer with the disorder?

Answer

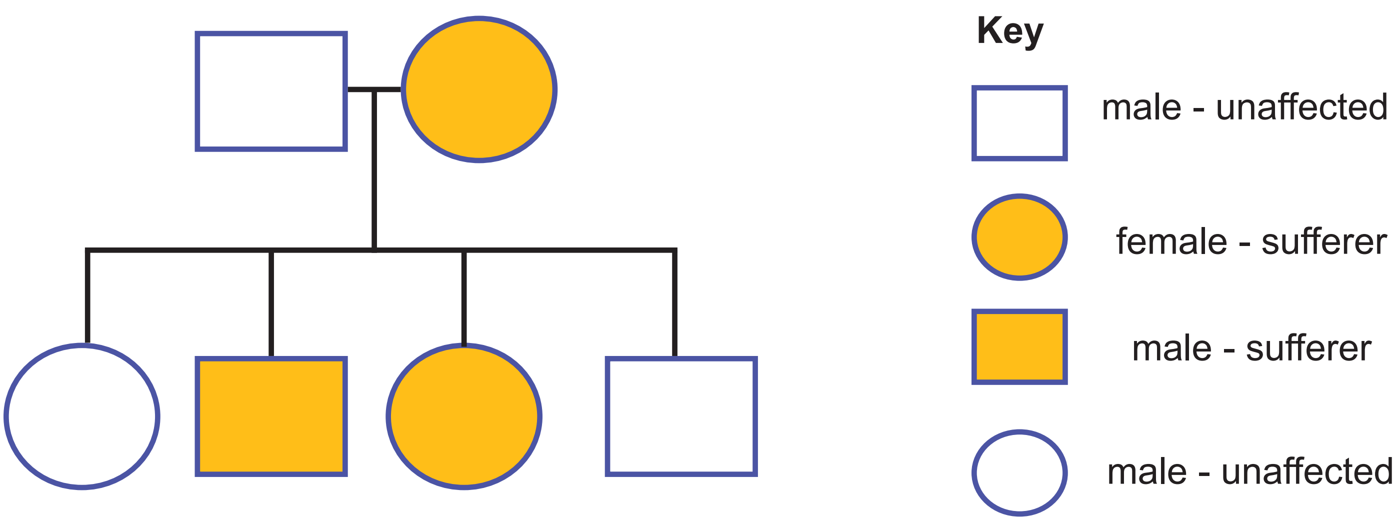
We will represent **recessive** allele by **n**. The parents are both **heterozygous**. This means they carry both the dominant and recessive alleles. Their genotype is **Nn**.

		father	
		N	n
mother	N	NN	Nn
	n	Nn	nn

In only one case does the child inherit both recessive alleles from their parents (genotype nn). This means the chance of a child suffering from the disease is 1 in 4 or 25%.

Example – Family information and Huntington's

Huntington's disease is caused by the dominant allele, H.



Examine the family tree shown in the diagram and state the genotype of:

(i) an unaffected child

(ii) the mother

Answer

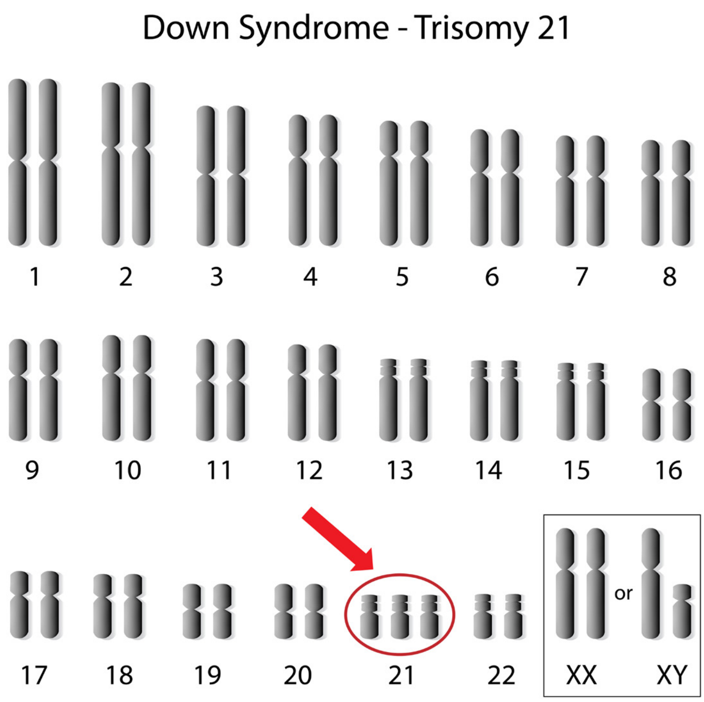
(i) An unaffected child can**not** carry the dominant allele at all.
The unaffected child must be hh.

(ii) Since some of the children are unaffected, the mother must carry the recessive allele as well as the dominant allele. (If she was a homozygous sufferer, all her children would carry the allele and so all would be sufferers).

Her genotype must be Hh.

Down’s syndrome

Down’s syndrome is caused by the presence of three copies of chromosome 21, rather than just the usual two copies. It happens when a sperm cell or egg cell forms abnormally.
The chromosomes below are found in pairs as expected except for chromosome 21 where there are three copies of the chromosone (and therefore the genes).



Down’s syndrome
Alila Medical Images / Alamy Stock Photo

Health, fitness and sport (Unit 2.3)

Factors affecting human health (specification 2.3.1)

TEST YOURSELF

1. Each body cell in the human body contains 23 pairs of:

A genes **B** DNA **C** chromosomes

2. This question is about cystic fibrosis. We will represent recessive allele for cystic fibrosis by **n**.

(a) A heterozygous carrier of the disease has the genotype:

A NN **B** Nn **C** nn

(b) A sufferer from cystic fibrosis has the genotype:

A NN **B** Nn **C** nn

3. Use the following Punnett square to determine the probability (chance) that a child will be a carrier for cystic fibrosis.

		father	
		N	n
	N	NN	Nn
mother	n	Nn	nn

A 0%
B 25%
C 50%
D 100%

Health, fitness and sport (Unit 2.3)

Factors affecting human health (specification 2.3.1)

Lifestyle plays a big role in human health. Factors which are all known to have a big impact on our health and life expectancy are:

- alcohol intake
- whether an individual smokes
- diet
- amount of exercise.

It can be difficult however to link health to specific lifestyle choices in certain cases. Only over time after a large amount of data is collected and analysed in an appropriate way can it be safe to draw conclusions about health and lifestyle choices.

Obesity

Figures for 2015 show around a quarter of adults in the UK were classed as obese and a further 40 % were overweight. The situation in Wales was worse with over half the population of Wales being overweight. Wales is facing an obesity crisis and the NHS struggles under increased demand. The NHS nationally already spends an estimated **£5.1billion a year** treating obesity. This is money that could otherwise have been spent on other problems.

Some experts believe obesity is responsible for more ill health than smoking. Being significantly overweight is linked to a wide range of health problems, including:

- diabetes
- heart disease
- high blood pressure
- some cancers (e.g. breast and prostate cancers)
- stress, anxiety, and depression.

Obesity
Ian Shaw / Alamy Stock Photo

When is a person said to be obese?

A person is considered **obese** if they are very overweight with a high degree of body fat.

The most common way to assess if a person is obese is to check their body mass index, BMI. A person is said to be obese if their BMI value is in the range 30 – 40 and very obese if it is over 40.

Body mass index

One way that is often used to assess our health is to measure our body mass index (BMI). BMI is an attempt to measure the amount of tissue mass (muscle, fat, and bone) in an individual, and then categorize that person as underweight, normal weight, overweight, or obese based on that value.

$$\text{BMI} = \frac{\text{mass}}{\text{height}^2}$$

mass is measured in **kilograms** and height is measured in **metres**

BMI value	Significance
less than 18.5	underweight
18.5 – 24.9	ideal weight
25-29.9	over weight
30-39.9	obese
over 40	very obese

$$\text{BMI} = \frac{\text{mass}}{\text{height}^2}$$

e.g. for a person who has a mass of 64 kg and a height of 1.82 m:

$$\text{BMI} = \frac{64}{1.82^2} = 19.8$$

The individual has an ideal weight for their height.

The BMI provides an easy way of measuring whether we are overweight, however it may not be particularly accurate.

Limitations of BMI

BMI has limitations, particularly when applied to:

- athletes – BMI does not distinguish between fat and muscle, which tends to be heavier and can tip more toned individuals such as athletes into overweight status, even if their fat levels are low.
- children - children are growing and may show significant variations in height, muscle tone etc. at different ages. BMI charts designed for adults should not be used for children.

Important contributors to obesity include poor diet and a lack of exercise.

Eating too little

Eating too little of one type of food substance can lead to deficiency diseases.
There are also times when some people do not eat enough food although food is available. This may be because of poor diet or poor self-image or a wrong view of themselves as fat when they are not. It may lead to illnesses such anorexia.

Diet

Reference intake (RI) and Guideline Daily Amount (GDA)

Energy and different types of nutrients in food have been given daily intake guideline values called reference intake (RIs). The **reference intake** is the amount regarded as suitable to maintain a healthy body.

An older term you may see is **guideline daily amounts** (GDAs). It means the same thing.
The new reference intake values (RIs) are values which have been set out in European law.

An individual's nutritional requirements can vary with gender, weight, activity and age.

This means that some people may need to eat more and others less. RIs (or GDAs, if you prefer) are guidelines for an average person of a healthy weight and level of activity.

The table below shows some typical reference intake values.

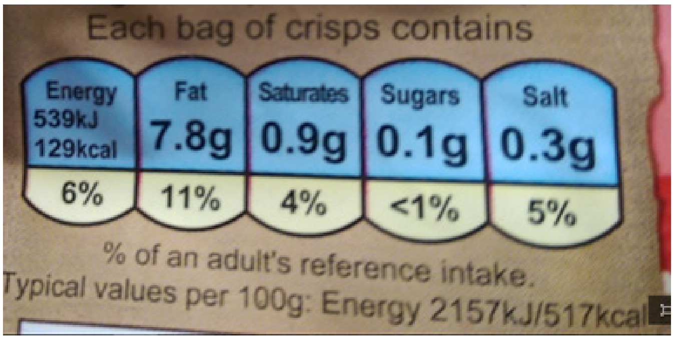
Typical values	Women	Men	Children (5-10 years)
energy (calories)	2 000	2 500	1 800
protein (g)	45	55	24
carbohydrate (g)	230	300	220
sugars (g)	90	120	85
fat (g)	70	95	70
saturated fat (g)	20	30	20
fibre (g)	24	24	15
salt (g)	6	6	4

A typical nutrition panel given on food packs usually gives information on the content of a product **per 100g** for calories and nutrients (protein, carbohydrate, sugars, fat, saturated fat, fibre and salt).

The RIs quoted on food packets are based on the requirements for an **average female**.

If the values for males and children were also quoted on a packet the information would appear confusing so just quoting the values for women makes it is easier to follow.

An example of the information shown on a crisp packet is shown below.



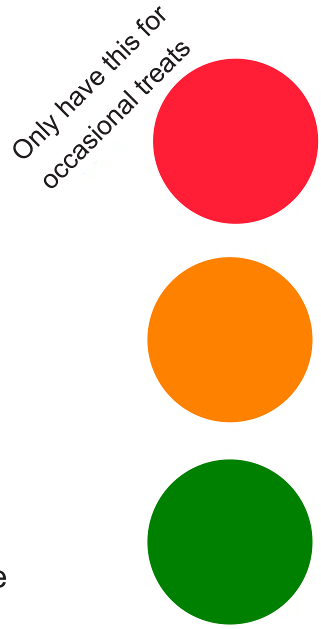
Traffic light system

The Food Standards Agency has developed a traffic light label that gives independent expert advice to help individuals make healthier choices quickly and easily.

The green, amber or red coloured labels on the front of the pack give a quick indication of the balance of nutrients in the food.

These show you at a glance if the food you are thinking about buying has low, medium or high amounts of fat, saturated fat, sugars and salt, helping you get a better balance.

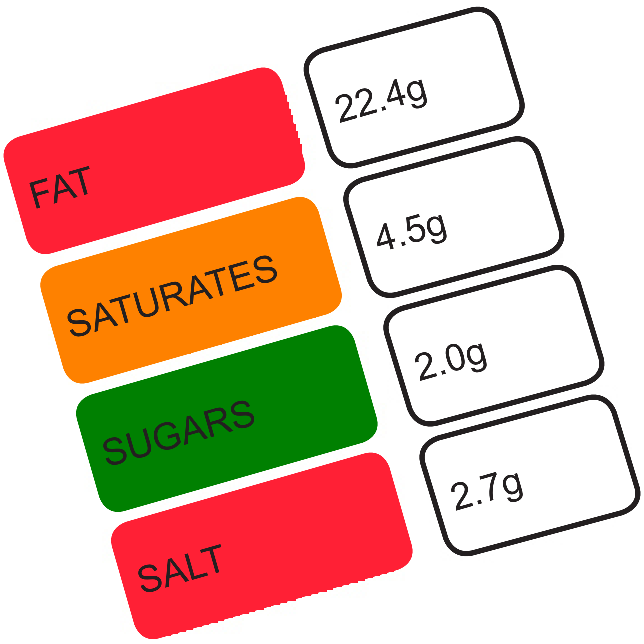
Question: What if the traffic light panel has all three colours?
Answer: For a healthier choice, try to pick the products with more greens and ambers and fewer reds.



means *high*
inicating the food is high in fats, sugars or salt

means *medium*
making it an ok choice

means *low*
making it the healthier choice



Salt

Salt (sodium chloride) is found naturally in many kinds of food, but it is also added by food manufacturers. Processed foods often have a high proportion of salt. Salt is a necessary nutrient for correct functioning of our bodies. **Too little salt** is associated with:

- muscle cramps
- dizziness
- electrolyte disturbance

However **too much salt** in the diet can be harmful and can lead to:

- high blood pressure leading to an increased risk of heart disease and strokes

It is thought that a daily intake of 6 g of salt should be about right for the average adult. Obviously, if you are doing physical work or taking part in prolonged exercise then you may need to have a higher salt intake to balance the losses from sweating.

Alcohol and health

Alcoholic drinks such as wine, beer or spirits contain an alcohol called ethanol. Alcohol has a number of effects on the body, some of which are well known.

Short-term effects include	Long-term effects include damage to the:
• depressant • sleepiness • reduced reaction times and impaired judgment • impaired balance and muscle control (causing slurred speech and blurred vision) • reddening of the skin caused by increased flow of blood to the skin • poor sleep • a very high intake can also cause death	• damage to the liver • circulatory and heart diseases • damage to the brain

Health, fitness and sport (Unit 2.3)

Factors affecting human health (specification 2.3.1)

Action of alcohol

Alcohol interferes with chemical processes in the body and the signals between the nerves and brain. For this reason, reaction times are slowed down and judgement is impaired.
People, who regularly drink alcohol, become tolerant of it and need to drink more in order to experience the same effect. If they carry on drinking they can become addicted to alcohol.

Smoking

Cigarette smoke contains an addictive substance called nicotine which is responsible for smokers becoming dependant. It reaches the brain in about 10-20 seconds after being inhaled.

Cigarette smoke contains over 4 000 **chemicals**, including 43 known cancer-causing (carcinogenic) compounds and 400 other toxins. These include nicotine, tar, and carbon monoxide.

Harmful effects from cigarette smoke include:

Cigarette packet
Science Photo Library / Alamy Stock Photo

1. An increased risk of heart disease and strokes. Carbon monoxide reduces the ability of the blood to carry oxygen. This puts extra strain on the circulatory system which can lead to strokes and heart disease.
2. An increased risk of miscarriage and premature birth if mothers smoke while pregnant. This is caused by a reduction of the amount of oxygen being received by the growing foetus.
3. Emphysema which is a long-term, progressive disease of the lungs, that primarily causes shortness of breath. Cigarette smoke destroys lung tissue reducing the ability of the lungs to exchange gases.
4. An increase in the risk of lung cancer, mouth cancer and throat cancer. Tar in cigarette smoke contains many carcinogens.

Stopping people smoking

In order to encourage people to give up smoking the government has tried a number of different strategies including:

- stopping advertising
- making it illegal to sell cigarettes to people under 18
- placing high taxes on cigarettes
- printing warning messages on the front of cigarette packets
- banning smoking in public spaces.

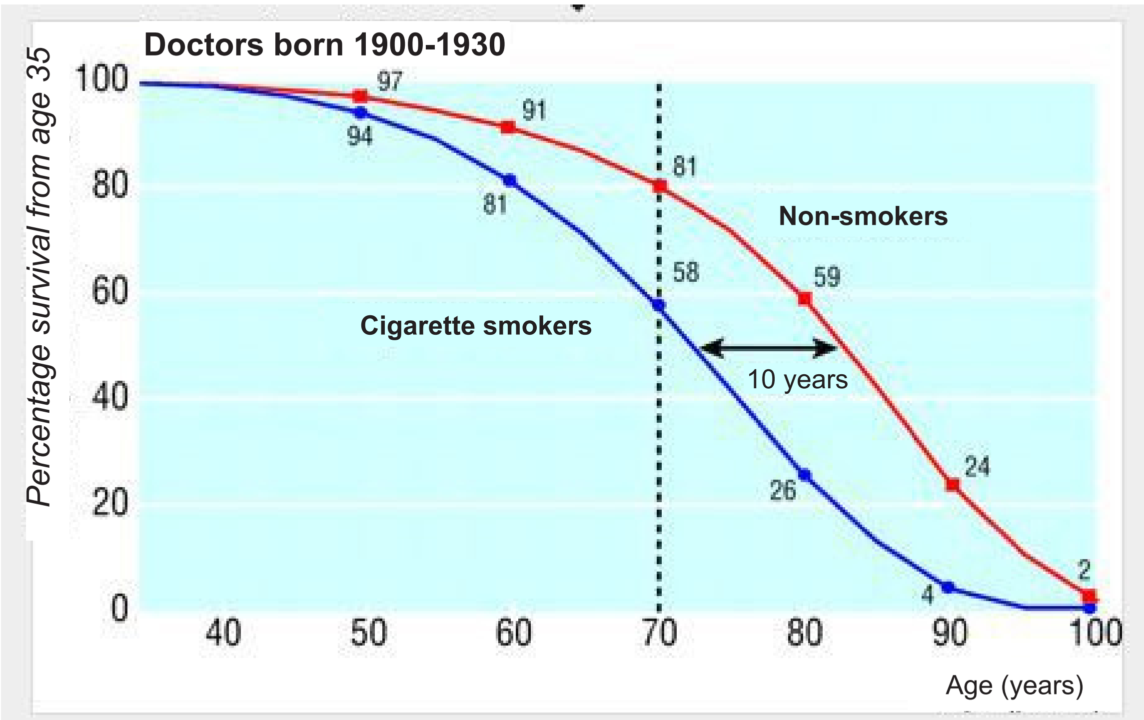
Epidemiological studies

Epidemiology is the study of factors that affect the health of populations.

Doctors and scientists carry out epidemiological studies to try to determine the lifestyle factors that could increase the chances of getting heart disease and other illnesses.

In a typical study, researchers examine two groups of people: for example those who smoke and those who do not smoke.

An example is of a study of doctors born between 1900 and 1930 that shows a difference in survival rates of those who were smokers and those who were non-smokers.



Reproduced from 'Mortality in relation to smoking: 50 years' observations on male British doctors', Richard Doll, Richard Peto, Jillian Boreham, Isabelle Sutherland, 328, 2004 with permission from BMJ Publishing Group Ltd

It is the work of the researcher to ensure that data from such studies is carefully analysed and checked to ensure that appropriate conclusions are drawn.

E-cigarettes

Are e-cigarettes safer than tobacco? Or are they a high-tech way to hook a new generation on a bad nicotine habit? The honest answer is nobody knows yet.

E-cigarettes contain addictive nicotine like tobacco cigarettes. This means if you stop using them, you can get withdrawal symptoms. This may include feeling irritable, depressed, and anxious. It can be dangerous for people with heart problems.

So far, evidence suggests that e-cigarettes may be safer than regular cigarettes. The biggest danger from tobacco is the smoke, and e-cigarettes don't burn tobacco. Tests show the levels of dangerous chemicals they give off are a fraction of what you'd get from cigarette smoke. However we really don't know the long term risks posed by e-cigarettes yet.

TEST YOURSELF

1. The formula for body mass index (BMI) is:

A $\frac{\text{mass}}{\text{height}}$

B $\frac{\text{mass}}{\text{height}^2}$

C $\frac{\text{mass}^2}{\text{height}}$

2. Dave has a mass of 80 kg and height of 1.8 m. His BMI is:

A 24.7 **B** 44.4 **C** 24.4

3. Too little salt in the diet is associated with:

A muscle cramps
B high blood pressure
C heart disease

4. A packet of crisps has an energy content of 548 kJ. Joshua, aged 10, eats a packet of crisps every day. Calculate the percentage of his reference intake (guideline daily amount) to the nearest whole number that this represents.

Energy: Daily reference intake for a child aged 5-10 = 7 530 kJ

A 8% **B** 6% **C** 7%

Controlling blood glucose (sugar) levels.

Homeostasis and the regulation of blood glucose levels

Conditions, such as temperature and the level of glucose in the blood, need to be controlled so that a constant internal environment in the body can be maintained.

This is called **homeostasis**.

Homeostasis control mechanisms in the body work by **negative feedback.** A negative feedback system is one in which the output is used to reduce the input.

Blood glucose levels will vary according to the amount of exercise we do and when (and what) we have eaten. It is important that the body maintains glucose levels over a narrow range. If blood glucose levels become:

- too low the cells will not have sufficient glucose for metabolism
- too high then glucose may start to be lost in urine.

Ultimately, if blood glucose levels become too high or too low then a person may go into a coma (loss of consciousness).

Blood glucose levels are controlled by the release or storage of glucose.

The body controls this by the **hormones** **insulin** and **glucagon.**

The **pancreas** produces both of these hormones.

1. If the glucose levels in the blood **are high,** insulin is released by the pancreas. The insulin acts on the liver, causing it to convert excess glucose into glycogen for storage.

   As blood glucose levels drop so less insulin is released by the pancreas.

2. If blood glucose levels **are too low** (e.g. after exercise) then the hormone glucagon is released by the pancreas which has the opposite effect to insulin on the liver, i.e. glycogen is converted back to glucose.

- Glucagon has the ability to raise blood glucose levels
- Insulin is capable of lowering blood glucose levels

SOMETHING TO WATCH

A short video explaining how blood glucose levels are controlled can be found at:

https://www.youtube.com/watch?v=e-3N7w2sWps

Diabetes

People who cannot control their blood glucose levels have a condition called **diabetes.**

If the blood glucose levels are not regulated then a person suffering with diabetes can go into a coma. When they go into a coma, they will need urgent medical attention.

There are two different types of diabetes.

Type 1 diabetes – The body does not produce sufficient insulin

Type 2 diabetes – Body cells do not correctly respond to the insulin that is produced

Type 1 diabetes

This accounts for about 5 to 10 out of every 100 people who have diabetes.
Without insulin, cells cannot absorb glucose, which they need to produce energy.

- **Treatment:** This can be treated by controlling the amount of sugar and carbohydrate in the diet **and regular insulin injections**. A pancreas transplant will also provide a new source of insulin.

Diabetes
Bill Cheyrou / Alamy Stock Photo

Type 2 diabetes

Type 2 diabetes accounts for the vast majority of people who have diabetes - 90 to 95 out of every 100 people. It generally occurs in more mature people who are often overweight, but type 2 diabetes is rising in children.

- **Treatment:** This is treated by controlling the amount of sugar and carbohydrate in the diet and taking medication which makes the liver respond to the insulin.

Diagnosing diabetes

A common symptom of diabetes is the presence of glucose in urine. We can test for blood glucose using Benedict's solution.

Benedict's solution is a blue solution that turns red when heated if glucose is present.

Pollutants and health

Our environment and the things we come in contact with can have a serious impact on our health.

Heavy metals

We have already shown that mercury caused Minamata disease in Japan after people ate sea food contaminated with high levels of mercury. Other heavy metals have also been associated with disease. One other well-known metal associated with poisoning is lead.
Lead poisoning is a serious and sometimes fatal condition. It occurs when lead builds up in the body over a period of time, perhaps many years. Lead is a highly toxic metal and a very strong poison. It is found in lead-based paints, including paint on the walls of old houses and toys. Water pipes were also once made of lead but these have now been largely removed.
Repeated exposure to lead can lead to

- aggressive behaviour
- loss of developmental skills in children
- loss of appetite
- memory loss
- anaemia

….. and many other problems.

Air pollution and health

A variety of air pollutants have known or suspected harmful effects on human health. These pollutants are often the products of combustion of fossil fuels, e.g. by motor vehicles. The level of these air pollutants can also depend upon weather conditions.

Pollutant	Health risk
nitrogen dioxide, sulfur dioxide, ozone	These gases irritate the airways of the lungs. They can increase the symptoms of those who suffer from asthma and lung disease.
particles	Very small particles can be carried deep into the lungs where they can cause inflammation and a worsening of asthma, heart and lung diseases. Diesel engines are linked to this type of pollution.
carbon monoxide	This gas prevents the uptake of oxygen by the blood. This can lead to a reduction in the supply of oxygen to the heart, particularly in people suffering from heart disease.

Health, fitness and sport (Unit 2.3)

Factors affecting human health (specification 2.3.1)

TEST YOURSELF

1. Homeostatic control mechanisms work in the body by a:

- **A** positive feedback mechanism
- **B** reversed loop – positive feedback mechanism
- **C** negative feedback mechanism

2. Insulin and glucagon are made in the:

- **A** liver
- **B** gall bladder
- **C** pancreas

3. Match the correct hormone to the statement that follows.

glucagon	**A** causes the liver to convert glucose to glycogen
insulin	**B** causes the liver to convert glycogen to glucose

4. Which type of diabetes cannot be treated by regular insulin injections?

- **A** type 3 diabetes
- **B** type 2 diabetes
- **C** type 1 diabetes

5. Glucose in urine can be tested for using:

- **A** Starch solution
- **B** pH paper
- **C** Benedict's solution

6. Repeated exposure to lead can cause:

- **A** aggressive behaviour
- **B** heart disease
- **C** a stroke

PRACTICE QUESTIONS

1. Food energy is measured in kilojoules (kJ) and kilocalories (kcal). These units of measurement allow us to talk about how much energy a food contains and how much energy is used during exercise.

The energy value **per gram** of various food components includes:

- fat – 37 kJ
- carbohydrates – 16 kJ
- protein – 17 kJ
- dietary fibre – 13 kJ
- water – 0 kJ

When we regularly eat more energy than our body needs, the excess is stored inside fat cells.

(i) State one reason why foods high in fat should be eaten in moderation. [1]

....

....

(ii) State two medical problems linked to obesity. [2]

....

....

(iii) Calculate the energy content of 1 kg of fat. [1]

energy content = …………… kJ

(iv) An overweight person hopes to lose 1 kg of body fat in 30 days.
Calculate by how much they need to reduce their calorie intake each day. [2]

The conversion factors for joules and calories are:

1 kJ = 0.24 kcal

answer = ………… kcal /day

PRACTICE QUESTIONS

2. In a recent report by the National Obesity Forum high obesity rates were recorded in certain parts of the UK. The table below shows some of the 'best' and 'worst' areas of the country.

Best areas	Percentage registered with GP as obese (%)	Worst areas	Percentage registered with GP as obese (%)
Camden (London)	3.9	Merthyr Tydfil (Wales)	10.6
Westminster (London)	4.8	Barnsley (North England)	10.8
Lambeth (London)	5.6	Rhondda (Wales)	11.1
Dagenham (Kent)	9.3	Shetland (Scotland)	15.5

(a) All the 'best areas' are in the 'South of England'. Suggest why the 'South of England' may have less of an obesity problem than other parts of the UK.

[2]

....

....

(b) There are approximately 22 000 people living in Shetland (Scotland).

(i) Use the equation below to calculate the actual number of people living in Shetland who are registered with their GP's as obese. [2]

$$\text{Number of obese people} = \frac{\text{\% of registered obese patients x population of Shetland}}{100}$$

Total number of people in Shetland who are registered obese = ...

(ii) State one assumption that has been made in your calculation of the number of obese people in Shetland. [1]

....

....

(iii) Suggest one method by which more accurate data for the number of obese people in the different regions could be obtained. [1]

....

Space Health and Life (Unit 2)

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

INTRODUCTION

Medical scientists have developed and continue to develop methods to diagnose and treat disease. For example, scientists have found that some ionising radiations can be put to useful medical applications.

This topic explores some methods that medical scientists use to diagnose and treat diseases. We will start by explaining some important terms and concepts that medical scientists use.

Ionising radiation

Radiation is a broad term. It can be used to refer to:

- waves from the electromagnetic spectrum (e.g. radio waves, microwaves, gamma rays)
- particles emitted from a radioactive source (e.g. alpha or beta particles)

Ionising radiation is radiation that can cause electrons to be removed from atoms or molecules.

Examples of ionising radiation include:

- high energy electromagnetic radiation (UV, X-rays and gamma rays)
- alpha and beta particles emitted from radioisotopes

Radioisotopes and half-life

The nuclei of radioactive atoms are unstable. They break down and change into a completely different type of atom. This is called radioactive decay. An example of an unstable nucleus is iodine-131 which emits beta particles. Over a period of time the number of radioactive nuclei fall. Half-life is used to make predictions about how quickly the radioactivity takes to fall.

The **half-life** is the time taken for the number of radioactive nuclei (or the mass of radioactive nuclei) to reduce to half its initial value.

Another way of defining half-life

The half-life is the time taken for the activity (count rate of the sample) to reduce to half of the initial value.

Health, fitness and sport (Unit 2.3)

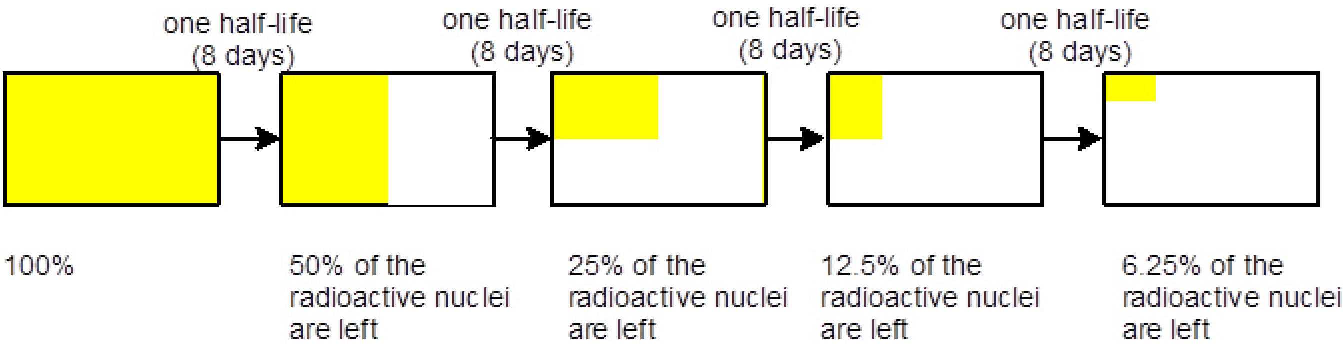
Diagnosis and treatment (specification 2.3.2)

Each radioactive isotope has its own half-life. Half-lives can be very different.

Examples

Radioactive isotope used in medicine	half-life
iodine-131	8 days
cobalt-60	5.2 years
caesium-137	30.2 years

In the diagram below, the number of radioactive **iodine-131** nuclei in a sample is represented by the yellow shaded area.



Notice that the number of radioactive nuclei halves over 8 days no matter how much iodine-131 you start with.

The time to go from:

- 100 to 50 % is one half-life (8 days)
- 50 to 25 % is one half-life (8 days)
- 25 to 12.5 % is one half-life (8 days)
- 2.5 to 6.25 % is one half-life (8 days)

After another 8 days 6.25 % of the radioactive nuclei will halve to 3.125 %

Question

How long does it take for the iodine-131 to go from 100 % to 25 %?

Answer

The total time to go from 100 % to 25 %

= 2 × half-life = 2 × 8 = 16 days

Question

How long does it take for the iodine-131 to go from 100 % to 12.5 %?

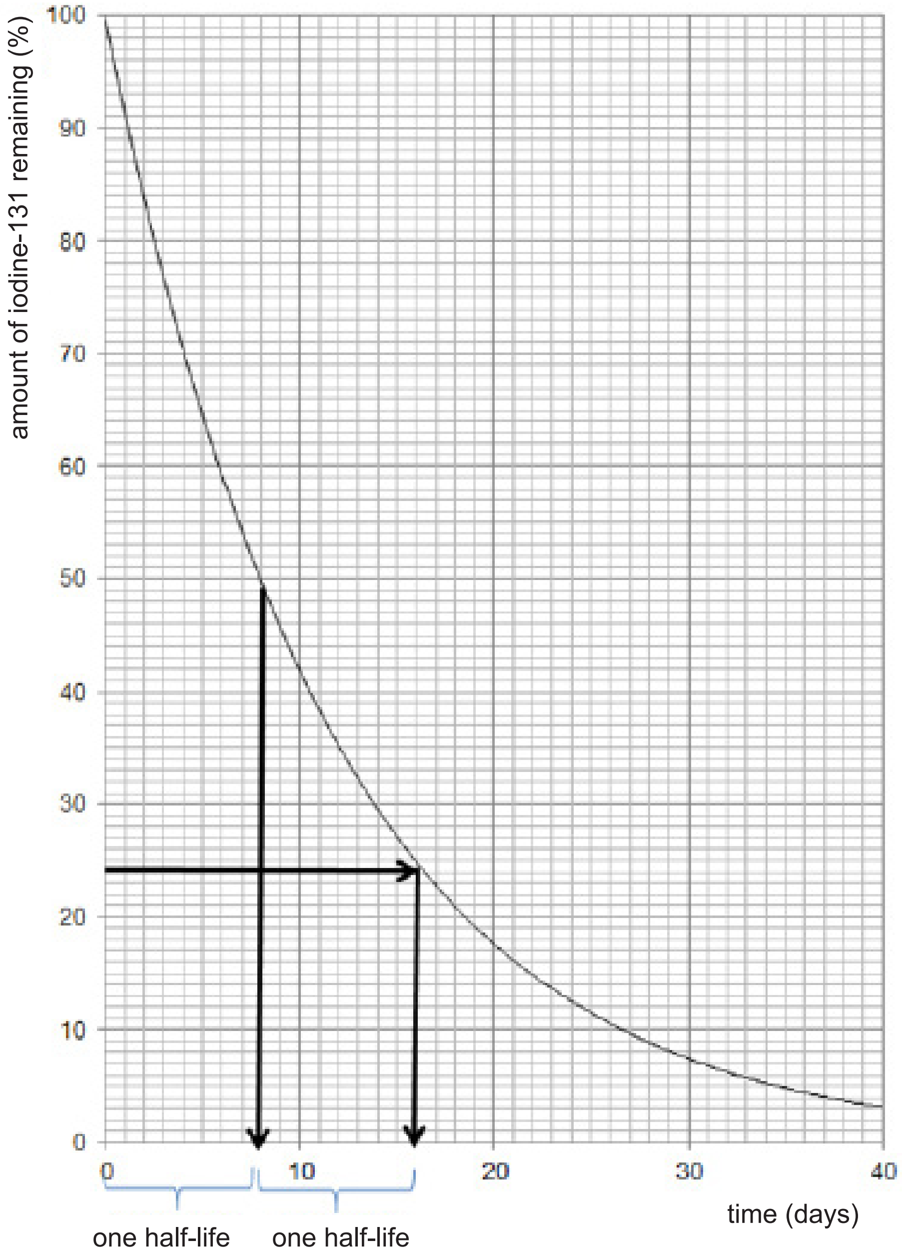
Answer

The time to go down from 100 % to 12.5 %

= 3 × half-life = 3 × 8 = 24 days

The graph below shows the same information.

Notice it will always take 8 days to half the amount of iodine remaining. It does not matter where you start!



Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

Alpha, beta and gamma radiation

Alpha radiation

Alpha radiation consists of alpha particles.

An **alpha particle** is the same as the **nucleus** of a helium atom

i.e. two protons and two neutrons

It is a common **mistake** to say an alpha particle is the same as a helium **atom** or helium **ion**.

It is not! There are **no** electrons in an alpha particle.

It is the same as a helium **nucleus**.

Beta radiation

A beta particle is a **high** velocity electron which comes out of the **nucleus** of an atom.

These electrons do **not** come from the electron shells around the nucleus.
They form when a neutron splits into a proton and an electron. The electron then shoots out of the nucleus at high speed.

Gamma radiation

Gamma radiation is high energy (high frequency) electromagnetic radiation.

Penetrating properties of radiation

Radiation can be absorbed by substances in its path. Different types of radiation have different penetrating power.

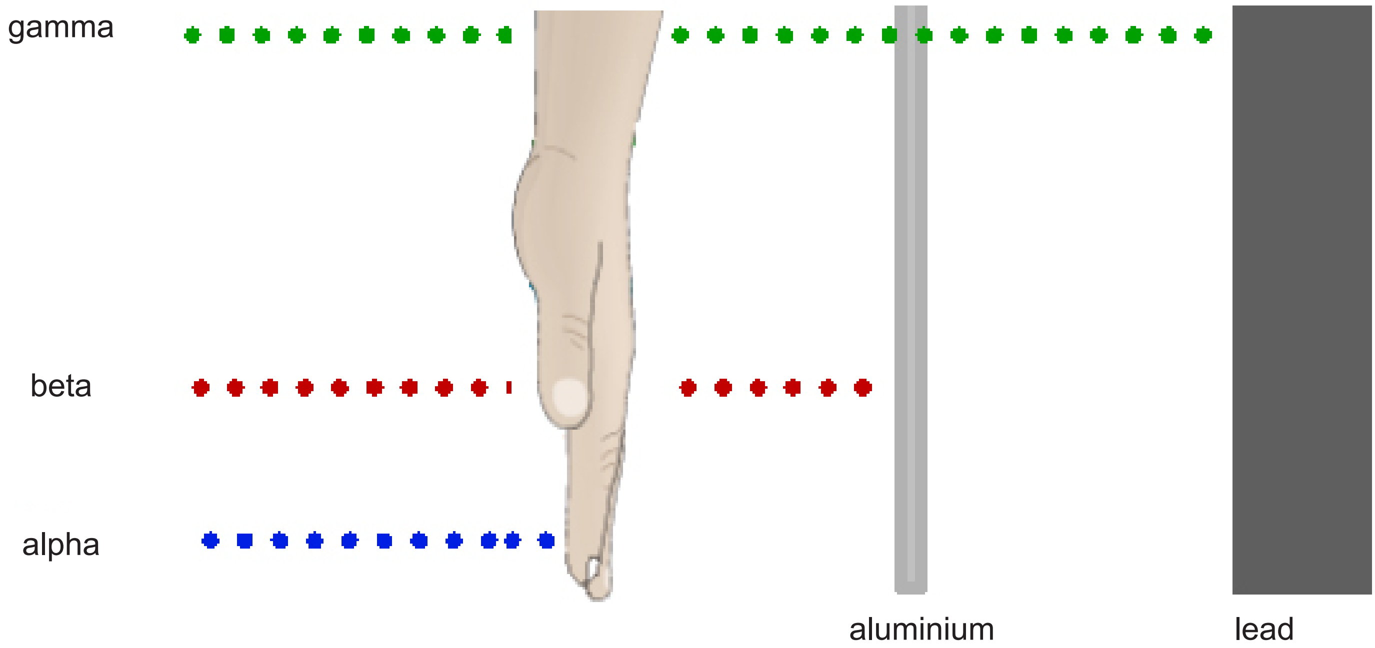


Table showing relative penetrating powers of alpha, beta and gamma radiation

Type of radiation	Penetrating power	Stopped by	Comment
alpha particles	least penetrating	sheet of paper	absorbed by the thickness of the skin
beta particles		thin sheet of aluminium	absorbed by a few centimetres of body tissue
gamma radiation	most penetrating	thick sheet of metal, such as lead, or concrete	can easily penetrate right through body tissue

Ionising power and tissue

The penetrating power of nuclear radiation depends upon the ionising power of the radiation. The radiation continues to penetrate matter until it has lost all of its energy.

One alpha particle can ionise 10 000 atoms. The fact that they are strongly ionising makes them very dangerous to life. Because they are so strongly ionising they are quickly absorbed.
The charge on beta particles is half of that of alpha particles. For this reason, they are **less** ionising and penetrate further into the body.

Gamma radiation has the lowest ionising power of the three so that they penetrate **very deeply** into matter before most of the energy has been used up.

Summary: Alpha - greatest ionising power
Gamma - least ionising power

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

TEST YOURSELF

1. Examples of ionising radiation are:

A alpha particles, beta particles and radio waves
B radio waves, X-rays and gamma rays
C alpha particles, beta particles, gamma rays

2. An alpha particle is:

A a high velocity electron
B a helium atom
C two protons and two neutrons

3. The half-life of iodine-131 is 8 days. How long will it take for the number of radioactive nuclei to fall to 25% of the original value?

A 24 days
B 16 days
C 8 days

4. The order of penetration from least to most penetrating is:

A	alpha	beta	gamma
B	beta	alpha	gamma
C	gamma	beta	alpha

5. The half-life of cobalt-60 is 5.2 years. After 15.6 years the activity of a cobalt-60 sample will fall to:

A 33% of the original activity
B 25% of the original activity
C 12.5% of the original activity

Medical imaging

Medical imaging involves creating images of the body to reveal and diagnose or examine disease or injury.

Medical imaging can make use of electromagnetic radiation or sound waves.

Imaging using X-rays

X-rays are able to pass through the body.
As they pass through the body, the energy from X-rays is absorbed at different rates by different parts of the body.

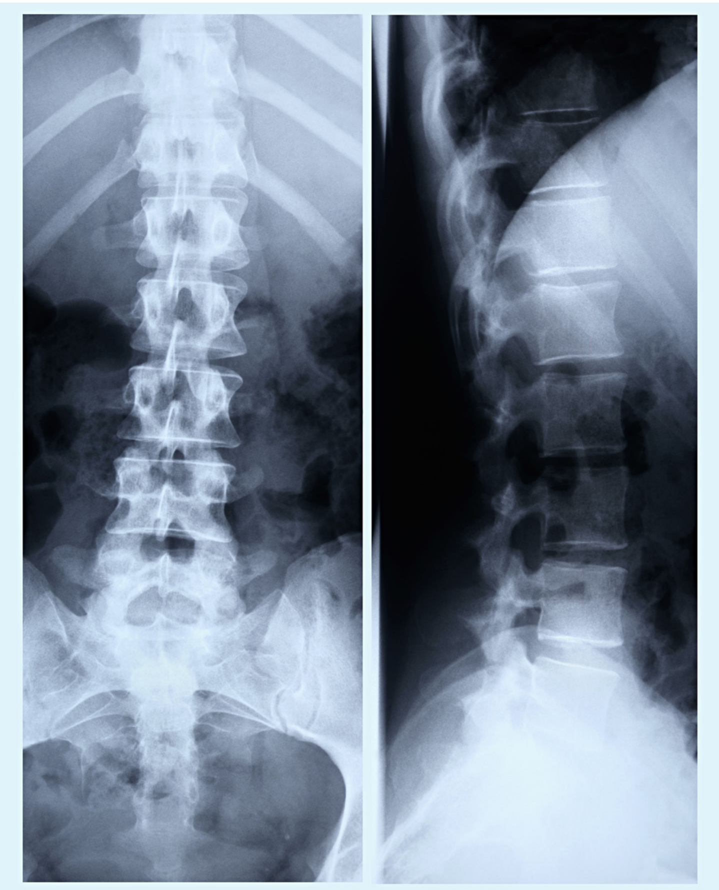
A detector on the other side of the body picks up the X-rays after they've passed through and turns them into an image.

Dense parts of the body that X-rays find it more difficult to pass through, such as bone, show up as **white areas** on the image.

Softer parts that X-rays can pass through more easily, such as your heart and lungs, show up as **darker areas**.

X-rays involve taking one image.
What is formed is a **two-dimensional image.**

X-rays are useful in applications such as medical imaging of bone fractures and dental problems.



X-ray image of the spine
Image Source Plus / Alamy Stock Photo

X-rays and CAT scans

X-rays are also used in CAT scans (sometimes called CT scans).

CAT scans can produce detailed images of many structures inside the body, e.g. internal organs, blood vessels and bones.

Patient having a CAT scan
Hero Images Inc. / Alamy Stock Photo

CAT scans are formed by processing together a large number of X-ray images taken around an axis. Once again, the more dense objects (e.g. bones) absorb some X-rays while they pass through the softer tissues.

The many two dimensional images are then combined to form a **three dimensional** image of the body.

3D CAT scan
Cultura RM / Alamy Stock Photo

What CAT scans are used for

CAT scans can produce detailed images of many structures inside the body, including the internal organs, blood vessels and bones. They can be used to:

- diagnose conditions - e.g. damage to bones, injuries to internal organs, strokes and cancer
- guide further tests or treatments - e.g. CAT scans can help to determine the location, size and shape of a tumour before having radiotherapy
- monitor conditions - e.g. checking the size of tumours before and after cancer treatment.

Are X-rays and CAT scans safe?

X-rays are ionising radiation and therefore are able to damage body cells.

As a precaution, only the part of the body being examined is exposed to a low level of radiation. Generally, the amount of radiation a person is exposed to during an X-ray is the equivalent to between a few days and a few years of exposure to natural radiation from the environment.

Being exposed to X-rays does carry a very small risk of causing cancer many years or decades later.

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

MRI scans

Magnetic resonance imaging (MRI) is a type of scan that uses strong magnetic fields and radio waves to produce detailed three dimensional images of inside the body.

An MRI scanner is a large tube that contains powerful magnets. A person lies inside the tube during the scan.

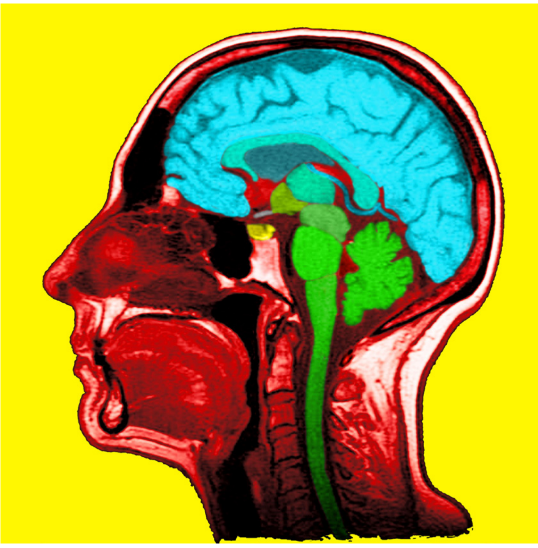
A magnetic field is set up that varies through the body.

A pulse of radio waves is sent through the body which interacts with protons in the body.

After the pulse ends the protons in the body emit radio waves which tell us about their position.

All the information from the radio waves is used to produce an image.

MRI scan
Glow Wellness / Alamy Stock Photo



MRI scan of head
BSIP SA / Alamy Stock Photo

An MRI scan can be used to examine almost any part of the body, including the:

- brain and spinal cord
- bones and joints
- breasts
- heart and blood vessels
- internal organs, such as the liver

The results of an MRI scan can be used to help diagnose conditions; plan treatments and assess how effective previous treatment has been.

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

Ultrasound

Ultrasound is the name given to sound waves with high frequencies.
These frequencies cannot be heard by humans.

Ultrasound has many applications in medicine. These include:

- safe monitoring of a foetus during pregnancy
- diagnosis of diseases

Ultrasound image
Robert Dant / Alamy Stock Photo

Medical images from ultrasound

The ultrasound is sent into the patient's body. Where there is a change in density of two structures in the body (e.g. at a boundary between different tissues or organs) some of the ultrasound is reflected.

The depth of each layer is calculated using the time taken for each reflected wave to return. The reflected waves are usually processed to produce a picture of the inside of the body on a screen.

Pregnant lady having an ultrasound image taken
Tetra Images / Alamy Stock Photo

Unlike X-rays, ultrasound waves are **not** ionising. This means they are safe to use when performing a foetal scan.

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

Gamma camera

The gamma camera is an imaging technique which can be used in diagnosing cancer. It involves using a gamma detector (camera) together with a radioactive isotope which is attached to special drugs, called tracers, which are designed to carry the radioisotope to the organ being investigated.

Radioisotopes with **short half-lives** are chosen to make sure that the tracer does not stay radioactive in the body for long periods.

Woman undergoing a gamma camera scan
Mark A. Johnson / Alamy Stock Photo

For most examinations, the radioisotope is injected into a vein, but sometimes it may be inhaled. The tracer then carries the radioisotope to the part of your body under investigation. The radioisotope gives off gamma rays, which are detected by a gamma camera.

Image from gamma camera
BSIP SA / Alamy Stock Photo

The information is passed to a computer which produces an image.

A gamma camera scan will show how well an organ or part of your body is working, as well as what it looks like.

Are there risks?

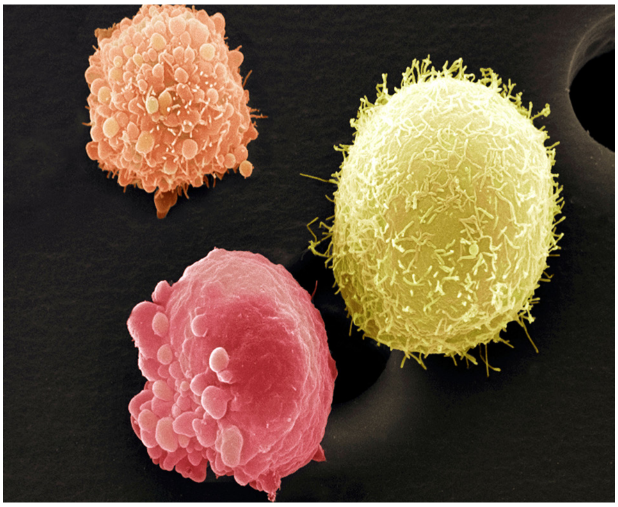
Gamma camera scanning involves the use of radioisotopes which emit gamma radiation which is ionising radiation. This means there is a small risk that the radioisotope may damage body cells.

For most tests, the extra radiation is equivalent to the background radiation (radiation from our environment) a person would receive over a period ranging from a few months up to 3 years.

Treatment of cancer

Radiotherapy

Radiotherapy is a treatment involving the use of ionising radiation. It is commonly used to treat cancer.



Skin cancer cells
Science Photo Library / Alamy Stock Photo

How it works

The **ionising radiation** used during radiotherapy damages the DNA of cancer cells.

Cancer cells are more likely to be damaged by ionising radiation than healthy cells.

As a result the cancer cells die or reproduce more slowly.

Nearby healthy tissues may also suffer cell damage from radiation, due to mutations in the cell DNA, but generally these cells are not so badly affected.

There are two types of radiotherapy:

- internal radiotherapy
- external radiotherapy.

External radiotherapy

External radiotherapy usually involves using a machine which focuses an external source of X-rays which are targeted at the tumour.

External beam radiotherapy usually involves a series of daily treatments over a number of days or weeks.

Internal radiotherapy

Internal radiotherapy involves using a radioactive isotope such as iodine-131 that is taken as a drink or injected into a vein.

The radioisotopes used in internal radiotherapy have short half-lives and so although they constantly emit radiation these emissions quickly get less.

After treatment

Patients who have internal radiotherapy may still be emitting radiation for a few days after each dose and limited contact with other people is advised. In the case of external radiation therapy, the patient does NOT emit radiation after treatment.

Selecting a radioisotope

There are nearly one hundred different radioisotopes whose radiation is used in medicine. It is important to select the correct radioisotope for an application.

- **External radiotherapy** uses radioisotopes which emit X-rays (or sometimes gamma radiation). The radiation is targeted at the tumour and so needs to penetrate through the body to get to the tumour. Ideally the radiation source (the radioisotope) used will have a long half-life so it does not need to be changed very often.
- **Internal radiotherapy** uses radioisotopes which are beta emitters. Since these do not need to penetrate through the body to the target organ, shorter range beta emitters are more suitable. Isotopes used in internal radiotherapy need to have a relatively short half-life so they are not active in the body any longer than necessary to treat the cancer. e.g. Iodine-131 with a half-life of 8 days is used in the treatment of thyroid cancer.

Chemotherapy

Chemotherapy is a type of cancer treatment, which uses drugs to kill cancer cells. It kills the cancer cells by damaging them, so they can't reproduce and spread. Most chemotherapy drugs are carried in the blood. This means that they can reach cancer cells anywhere in the body. But chemotherapy can be given in different ways. This depends on the type of cancer being treated and the chemotherapy drugs being used. Chemotherapy drugs also affect some healthy cells. These healthy cells can usually recover from damage caused by chemotherapy but cancer cells can't and eventually die. Chemotherapy and radiotherapy are often used together in cancer treatments.

SOMETHING TO WATCH

A short video giving a brief overview of chemotherapy by a Macmillan nurse:
https://youtu.be/fB13YmdLdvw

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

TEST YOURSELF

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1. X-ray images are:

- **A** one dimensional images
- **B** two dimensional images
- **C** three dimensional images

2. CAT scans combine images which were taken with:

- **A** gamma rays
- **B** X-rays
- **C** radio waves

3. Ultrasound:

- **A** can cause mutations to DNA in cells
- **B** can be used in internal radiography
- **C** is safe to use because it does not involve ionising radiation

4. Ultrasound scans use:

- **A** long wavelength sound waves
- **B** low frequency sound waves
- **C** high frequency sound waves

5. Internal radiotherapy usually involves:

- **A** using a machine which focuses an external source of X-rays which is targeted at the tumour
- **B** using a radioactive isotope such as iodine-131 that is taken as a drink or injected into a vein
- **C** using a machine which focuses an external source of alpha particles which are targeted at the tumour

6. Chemotherapy is a type of cancer treatment, which:

- **A** uses drugs to kill cancer cells
- **B** uses ionising radiation to kill cancer cells
- **C** uses iodine-131 to locate cancer cells in the body

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

Drugs

The development of new drugs

Drugs are substances that change chemical reactions in the body. Medical drugs relieve disease and illness, and are extensively tested before being used.

The development of new drugs is a costly and long process.

- It takes an average of 12 years for a drug to go from the research lab to the patient.
- Only about 1 in every 5 000 drugs that start the development process actually makes it to the market.

Bottles of prescription medicine
Tetra Images / Alamy Stock Photo

Drug testing

1. Initial research
   Compounds may be identified as possible new drugs as a result of new understanding of a disease. These compounds are tested using computer models and laboratory tests using human cells.

   Many substances fail at this stage because they damage cells or do not seem to work.

2. Animal testing
   Drugs that pass the first stage are tested on animals.
   These tests involve giving a known amount of the drug to animals and monitoring them for any side-effects.

3. Clinical trials
   If a drug passes animal testing then it is tested on healthy volunteers in clinical trials to make sure they are safe. Only very low doses of the drug are given to begin with.
   The substances are then tested on people who suffer from the illness that the drug is intended to treat to ensure that they work. If there are no problems, further clinical trials are done to find the best dose of the drug.

Clinical trials

In order to be confident that the results of clinical trials are trustworthy and give meaningful information, it is important to build checks into the testing. Clinical testing includes ‘blind’ and ‘double-blind’ trials.

In blind and double-blind trials the volunteers are split into two groups:

- a test group which receives the new drug
- a control group which receives the existing drug for that illness or a placebo

A placebo is a fake drug that has no effect on the body.

The researchers examine the evidence to see if there are any differences between the test group and the control group.

Blind trials

In a blind trial, the volunteers do not know which group they are in, but the researchers do. However, it is possible that the researchers may unintentionally give away clues to the volunteers about which group they are in.

This is called observer bias and may make the results unreliable.

Double-blind trials

In a double-blind trial, the volunteers do not know which group they are in, and neither do the researchers, until the end of the trial.

This removes the chance of ‘observer bias’ and makes the results more reliable.

It should be remembered that medical drug trials are not without risk. Sometimes very severe and unexpected side-effects appear.

Animal testing and ethics

There are two different positions on the ethics of testing new drugs on animals. These are summarised below.

In favour - experimenting on animals is acceptable if:

- suffering is kept to a minimum
- there are human benefits which cannot be gained by other methods

Against - experimenting on animals is wrong because:

- it causes suffering to animals
- the benefits to human beings are not proven
- any benefits to human beings that animal testing does provide could be produced in other ways

Drugs and treatment

There are many different drugs that can be used in the treatment of disease. New drugs are constantly being developed.

There are many types of medication. Some examples include:

- medicines that destroy infectious organisms e.g. antibiotics
- medicines that relieve disease but do not destroy pathogens e.g. aspirin and paracetamol
- medicines that fight cancer

Medication is given for a specific reason because of the positive effects it has. Unfortunately there may also be side-effects associated with the medication.
With new drugs it may not always be apparent what the side-effects are until a lot of people have used them.

Aspirin

Aspirin is used to relieve pain, fever, and inflammation in various conditions such as:

- lower back and neck pain
- the 'flu' and colds
- headache
- rheumatoid arthritis
- nerve pain, toothache
- muscle pain

It also has anticlotting properties and may be used to prevent a:

- heart attack
- stroke.

Unfortunately, aspirin like many other drugs has side effects associated with its use.
In the case of aspirin, prolonged use can cause bleeding in a patient's stomach and stomach ulcers.

Aspirin
Lee Brown / Alamy Stock Photo

TEST YOURSELF

1. A placebo is a:

A new drug that is released for clinical trials
B tested drug whose effect on patients is well known
C fake drug

2. Aspirin and paracetamol:

A can be used to destroy bacterial infections
B do not destroy bacteria but relieve the symptoms of a disease
C destroy bacteria and relieve the symptoms of a disease

3 Clinical testing can made more reliable by stopping the observer making biased observations.

This is done by using:

A blind trials
B double-blind trials
C animal testing

Health, fitness and sport (Unit 2.3)

Diagnosis and treatment (specification 2.3.2)

PRACTICE QUESTIONS

1. Radiotherapy is a branch of medicine used for the treatment of cancerous tumours.

External radiotherapy uses a powerful gamma emitter which is heavily shielded. The gamma-ray beam is aimed at the tumour for short periods of time from different directions. The tumour cells are killed by absorbing large amounts of heat from the energy of the radiation.

Scan
Thegift777_gettyimages

Internal radiotherapy is carried out by inserting a small radioactive source, which has a short half-life, directly into the tumour. They give a very high dose of radiation to the area of the cancer cells. The radiation emitted by the source destroys the tumour from the inside. Internal radiotherapy is generally more effective than external radiotherapy.

(a) (i) State one reason why the therapist may shield parts of the patient's body. [1]

....

(ii) State one reason why the gamma-ray beam in external radiotherapy is directed at the tumour for short periods of time from different directions. [1]

....

(iii) State two reasons why internal radiotherapy is considered to be more effective than external radiotherapy. [2]

....

....

PRACTICE QUESTIONS

(b) A patient receives an implant of 200 units of iodine-125 directly into a prostate gland tumour. The patient was injected with the implant on 1 Jan 2015. On 2 March 2015 only 100 units remain.

(i) Calculate how many units of the implant remain on 1 May 2015. [2]

January

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

February

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

March

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

April

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

May

SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

June

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Number of units = …………….

Space Health and Life (Unit 2)

Health, fitness and sport (Unit 2.3)

Fighting disease (specification 2.3.3)

Health, fitness and sport (Unit 2.3)

Fighting disease (specification 2.3.3)

MICROORGANISMS AND THE BODY'S DEFENCES

Treatment of infection and disease is extremely important. Once, a small cut to the hand could have been life threatening but now modern medicine means we do not need to worry if we hurt ourselves. However as drug resistant diseases arise, it is important that new treatments are developed otherwise we may find ourselves unprotected from diseases we can currently treat.

Microorganisms

There are **three** main types of **microorganisms:**

- bacteria
- viruses
- fungi

It is important to realise that not all microorganisms are harmful; some are harmless and perform vital functions and assist in maintaining processes necessary for a healthy body.
It has been estimated that an average man (1.7 m tall, 70 kilograms, 20–30 years old) contains on **average** about 30 trillion human cells and about 39 trillion bacteria.

Some microorganisms are harmful.

Pathogens are microorganisms that cause **infectious** disease.

Bacteria and viruses are the main pathogens.
Bacteria are living cells which are able to multiply extremely rapidly in the right conditions. Once inside the body, they release poisons or toxins that make us feel ill.
Diseases caused by bacteria include:

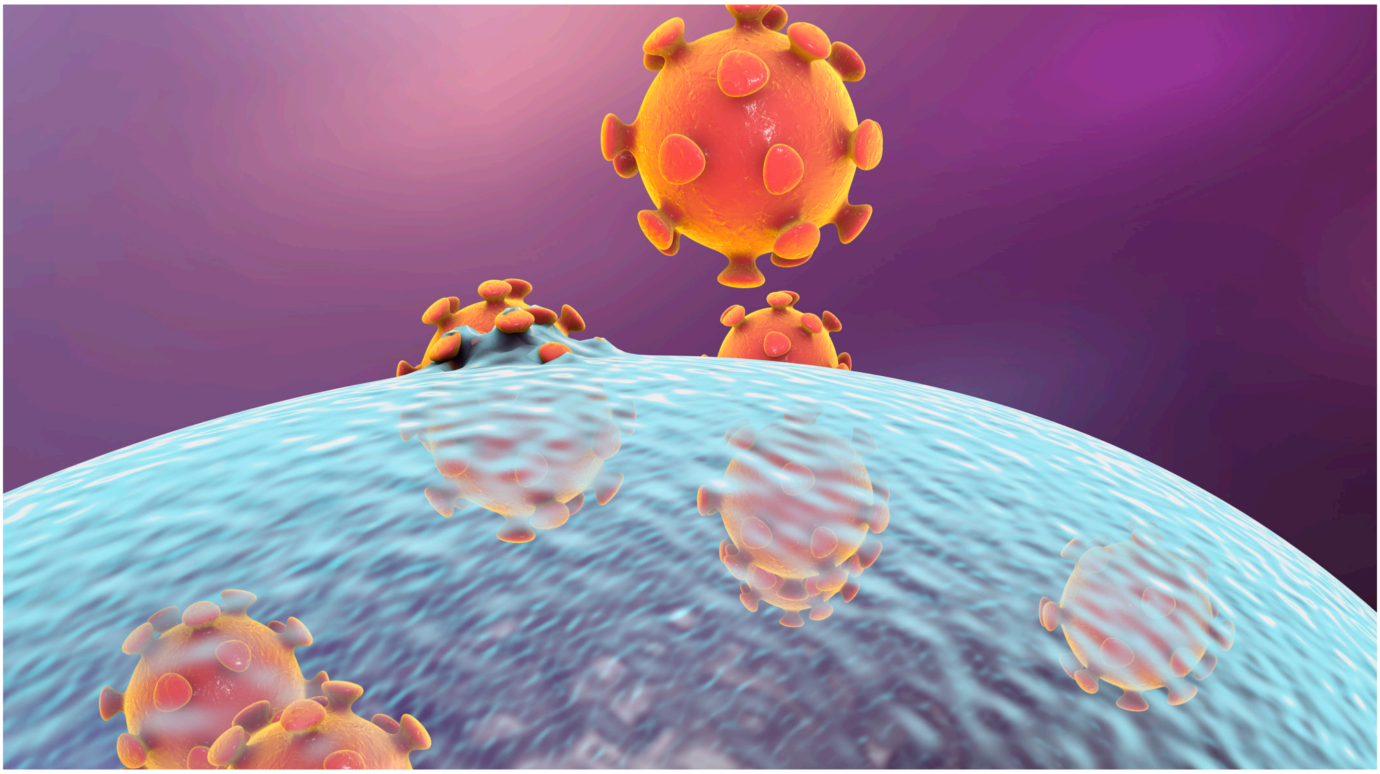
- food poisoning
- tuberculosis (TB)
- cholera

Rod-shaped bacteria
Science Photo Library / Alamy Stock Photo

Health, fitness and sport (Unit 2.3)

Fighting disease (specification 2.3.3)

Viruses are many times smaller than bacteria. Viruses damage cells by taking over the cell and reproducing inside them.



Viral replication in a human
KATERYNA KON/SCIENCE PHOTO LIBRARY

Diseases caused by viruses include:

- flu (influenza)
- colds
- measles

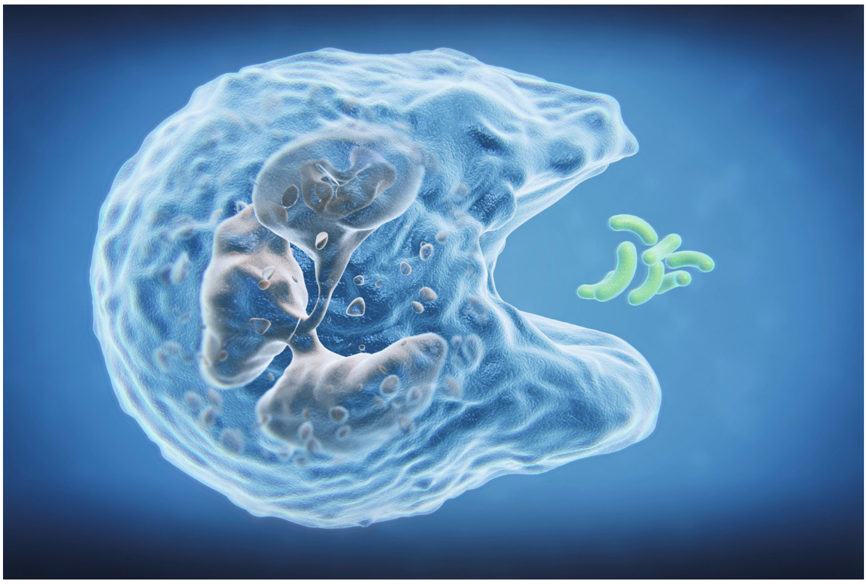
The body's defences

First line of defence: skin

The skin is the largest organ of the body. It acts as a barrier from pathogens.
Skin is a waterproof and mechanical barrier which prevents microorganisms living on the skin from getting through unless it becomes broken.

Communities of microorganisms also live on the surface of our skin, called the skin flora, which makes it difficult for pathogens to become established.

If the skin becomes damaged then blood clots seal the wound to prevent entry of microorganisms.



White blood cell engulfing bacteria
The Science Picture Company / Alamy Stock Photo

Health, fitness and sport (Unit 2.3)

Fighting disease (specification 2.3.3)

Second line of defence: immune system

If a pathogen manages to get into the body, the second line of defence takes over.
White blood cells play an important role in this.

White blood cells can:

- ingest pathogens and destroy them
- produce antibodies which inactivate particular pathogens
- produce antitoxins which counteract the toxins released by pathogens.

Some more detail: antigens, lymphocytes and antibodies

Antigens are proteins that are found on the surface of pathogens.

Antigens can be regarded as a 'signature' for a particular pathogen. The whooping cough bacterium, for example, will have different antigens on its surface from the TB bacterium.

When an antigen enters the body, the immune system produces antibodies against it. Antigens are recognised by a special type of white blood cell called a lymphocyte.

One type of white blood cell is called a **lymphocyte.** These are the cells responsible for producing antibodies.

When a lymphocyte recognises an antigen as being foreign, it multiplies quickly to form clones of cells. These produce antibodies that are specific to the antigen that is present.

Antibodies neutralise the pathogen bearing the foreign antigen.

They do this in a number of ways:

- they bind to pathogens and damage or destroy them
- they coat pathogens, clumping them together so that they are easily ingested by other white blood cells (called phagocytes)
- they bind to the pathogens and release chemical signals to attract more white blood cells (phagocytes)

Memory cells

The body's response to infection is relatively slow when it meets an antigen for the first time. However if the body encounters the same antigen a second time it is able to respond much faster, producing antibodies quickly and in large numbers. This is due to the presence of memory cells that are produced after the first infection.

After the body has been infected, lymphocytes also produce **memory cells** that stay in the body.

These cells can rapidly trigger the production of antibodies if re-infection occurs.

Vaccination

What is a vaccine?

When our body meets a pathogen, lymphocytes recognise the antigens on the surface of the pathogen and produce antibodies.

A vaccine contains an inactive form of the pathogen, antigens or parts of antigens which are derived from pathogens. This stimulates the body to produce antibodies specific to the pathogen.

Vaccines
Dina2001RF / Alamy Stock Photo

Memory cells are also produced which will enable the body to recognise the antigens in the future. This leads to a rapid immune response.

To vaccinate or not to vaccinate

Vaccines have been called 'one of the greatest success stories in public health'.

Through the use of vaccines, smallpox has been eradicated and the polio virus nearly eliminated. Other diseases such as measles and rubella have also been significantly reduced.

However there remains some controversy about the use of vaccines.

Recently controversy was caused by a flawed study published in a medical journal that claimed the MMR vaccine was responsible for autism. Unfortunately the media ran uncritical stories once the report was published which caused a loss of confidence in the vaccine. This report has been completely **discredited** but unfortunately there is still reluctance for some parents to vaccinate their children with the MMR vaccine.

The **low** level of vaccination in the general population led to an outbreak of measles in Swansea 2013 with 1 219 measles notifications. 88 people were hospitalised and one fatality recorded. The cost of the outbreak exceeded £470 000.

The NHS website gives three good reasons to have your child vaccinated:

- vaccinations are quick, safe and effective
- once your child has been vaccinated against a disease, their body can fight it off better
- if a child isn't vaccinated, they're at higher risk of catching the disease and becoming very ill.

It is possible that there are some risks from vaccines but these seem to be quite small when weighed against the risks of catching the disease.

Health, fitness and sport (Unit 2.3)

Fighting disease (specification 2.3.3)

Why can we have repeated infections?

The immune system's production of memory cells after infection means that we do not normally suffer from an infection with the same pathogen.

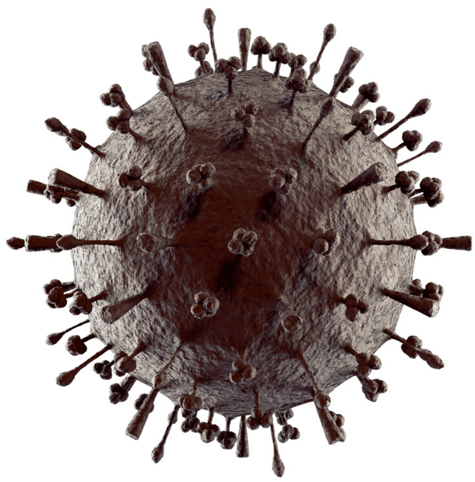
However some viral infections can occur repeatedly.

This can be explained by **natural selection**.

When viruses replicate, a **mutation** may occur which results in a strain of the virus which is resistant to the antibodies. This virus will be able to replicate and infect an individual who is immune to the original virus.

It appears that some viruses are better at doing this than others, for example, the flu virus. The ability of flu to mutate relatively frequently also makes it difficult to produce an effective vaccine.

In contrast, the polio virus and measles virus do not have a high mutation rate. As a result these vaccines have not been changed significantly since they were first developed. Induced immunity for these two viruses lasts a lifetime.



Flu virus H1N1 H5N1 influenza
Oleksiy Maksymenko Photography / Alamy Stock Photo

Antibiotics were originally medicines produced by living organisms such as fungi.

Antibiotics

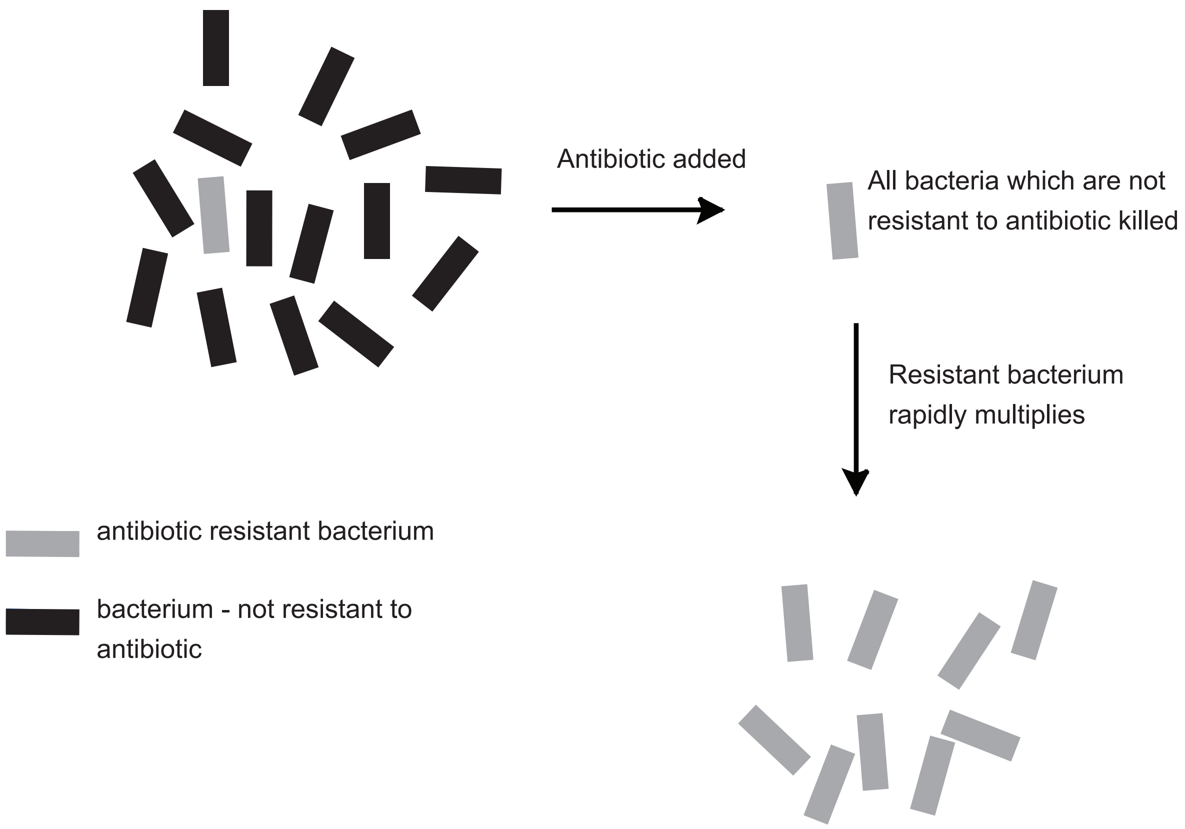
Antibiotics are substances that either kill bacteria or stop them from growing.
Antibiotics do **not** work on viruses.

The first antibiotic to be widely used was penicillin but there are a number of other antibiotics available. The introduction of antibiotics has saved millions of lives from disease that would have been once considered killers.

Resistance

Unfortunately there is a problem. More and more strains of bacteria are becoming resistant to antibiotics.

A mutation results in resistance to the antibiotic. While all other bacteria are killed, the resistant bacteria are able to survive and multiply.



This process has occurred in many different types of bacteria e.g.

- MRSA (methicillin-resistant *Staphylococcus aureus*) is very dangerous because it is resistant to most antibiotics
- multidrug resistant TB
- drug resistant gonorrhoea (a sexually transmitted disease)

Preventing MRSA

MRSA has become a problem for some hospitals and has been responsible for the deaths of some patients. In order to reduce the number of MRSA outbreaks control measures are put in place. These include:

- screening of patients before they enter a ward to see if they carry MRSA on their skin
- washing hands frequently – especially after using the toilet, and before and after eating
- following correct procedures with wound care which may otherwise lead to infection
- keeping hospital wards clean
- using hand wipes or hand gel

Effective management means that the number of death certificates mentioning MRSA as a cause of death fell by 20 % from 364 in 2011 to 292 in 2012.

SOMETHING TO WATCH

Watch these BBC news clips about:

- the danger of antibiotic resistance
  http://www.bbc.co.uk/news/health-35153795
- the source of new antibiotics
  http://www.bbc.co.uk/news/health-32722413

Health, fitness and sport (Unit 2.3)

Fighting disease (specification 2.3.3)

TEST YOURSELF

1. A pathogen is:

A microorganism that produces antibodies
B a disease, such as flu or measles
C a microorganism that causes infectious disease

2. Diseases caused by bacteria include:

A food poisoning, TB and cholera
B food poisoning, TB and flu
C food poisoning, measles and flu

3. Antigens are:

A released by white blood cells called lymphocytes
B proteins that are found on the surface of the pathogen
C proteins that neutralise the pathogen carrying the foreign antibody

4. Antibiotics can be used to treat infections caused by:

A bacteria
B viruses
C most pathogens

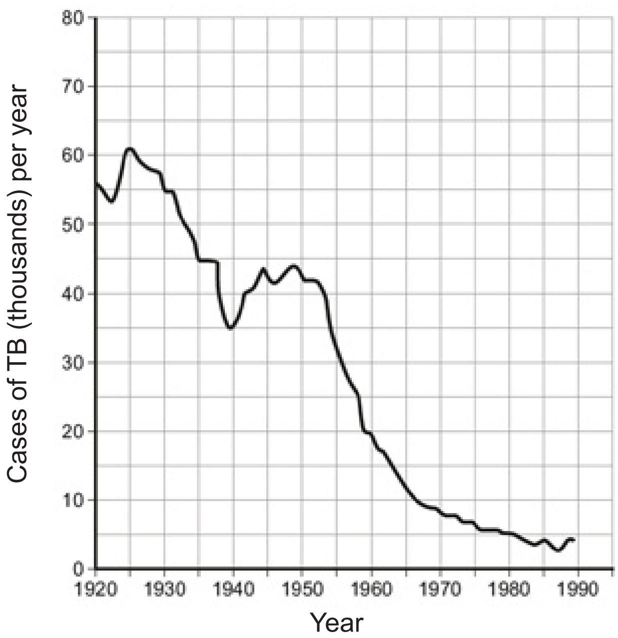
Health, fitness and sport (Unit 2.3)

Fighting disease (specification 2.3.3)

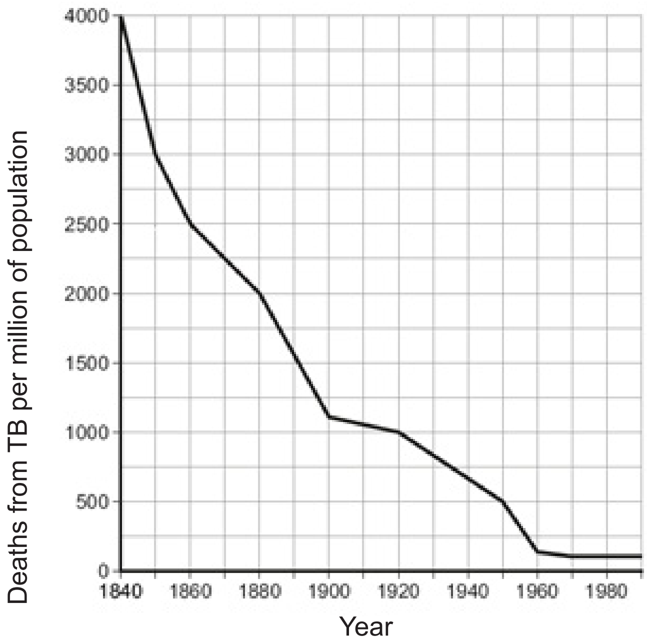
PRACTICE QUESTIONS

1. Tuberculosis (TB) is a disease caused by the bacterium *Mycobacterium tuberculosis*. The graphs below show information about TB in the UK. Antibiotics were first used to treat TB in the 1940s. Vaccination became available in the 1960s.

Graph **1**



Graph **2**



From this information

(a) (i) I Calculate the reduction in the death rate from tuberculosis between 1860 and 1900.

[2]

deaths per million population = ...

II Suggest why the death rate fell during this time.

[1]

....

PRACTICE QUESTIONS

(ii) From the graphs, what evidence is there that antibiotics were effective in reducing the death rate from TB between 1940 and 1950?

[1]

....

....

(iii) From graph 1, what evidence is there to support the idea that the vaccination against TB has been effective?

[1]

....

(b) in 2012 an investigation by the World Health Organisation (WHO) revealed a problem. 20% of cases of TB occurring in the world were caused by a strain to *Mycobacterium tuberculosis* called DRTB which had become resistant to antibiotics. Suggest how doctors and hospitals may have contributed to the problem.

[1]

....

....

....

....

Space Health and Life (Unit 2)

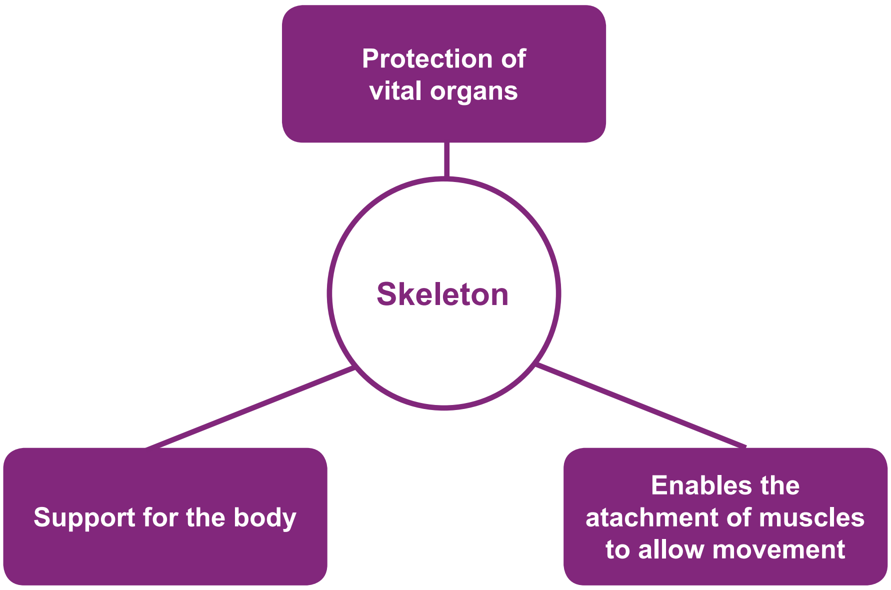
Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

The skeleton and exercise

The human skeleton serves a number of important functions:

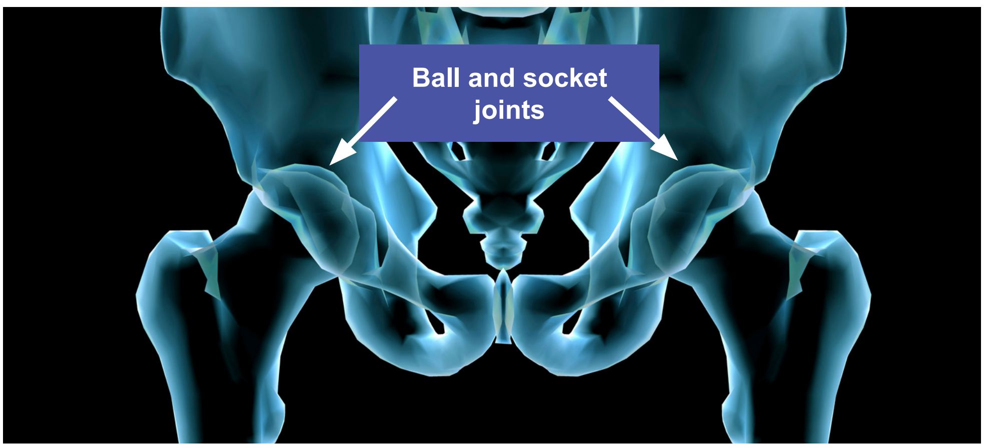
The human skeleton is made up of bone and cartilage, both of which are living tissues.



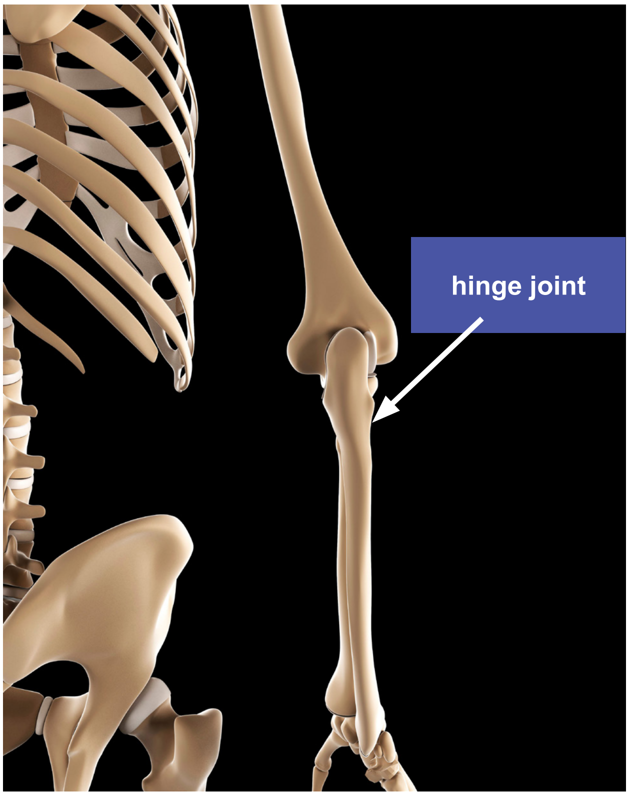
Joints

Where two bones meet there is a joint. Some of these joints are fixed but others allow for movement. There are a number of different joints in the human skeleton:

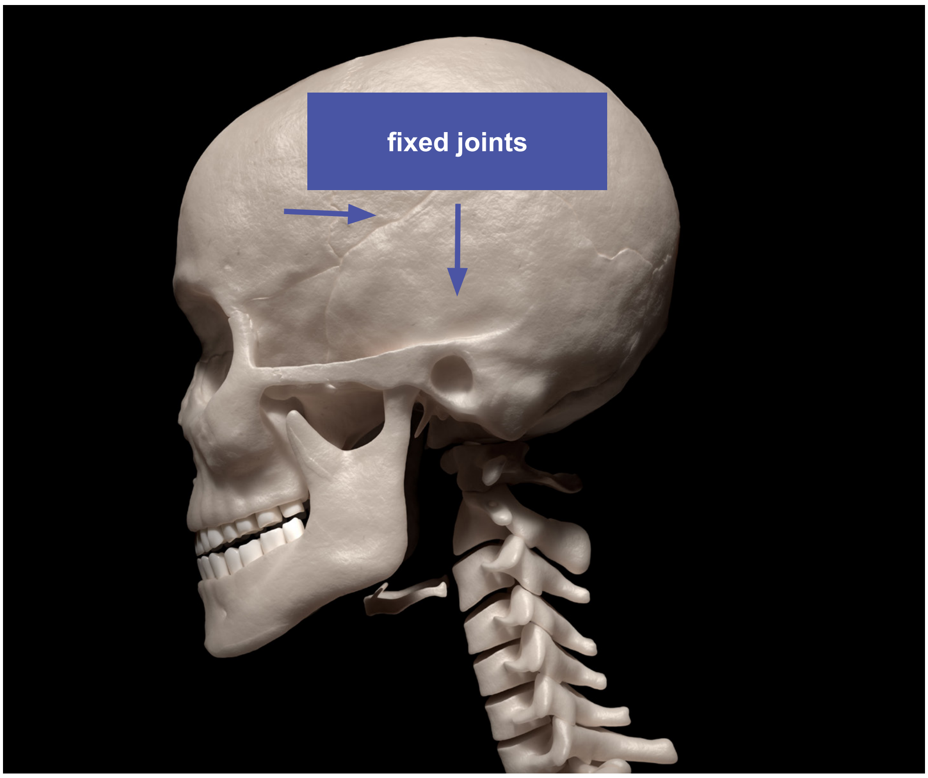
- ball and socket joint – allows almost all round movement (e.g. shoulder, hip)
- hinge joint – allows movement in one direction (e.g. elbow, hinge)
- fixed joint – no movement allowed (e.g. bones in the skull)



Ball and socket joints
Purestock / Alamy Stock Photo



Hinge joint
Science Photo Library / Alamy Stock Photo

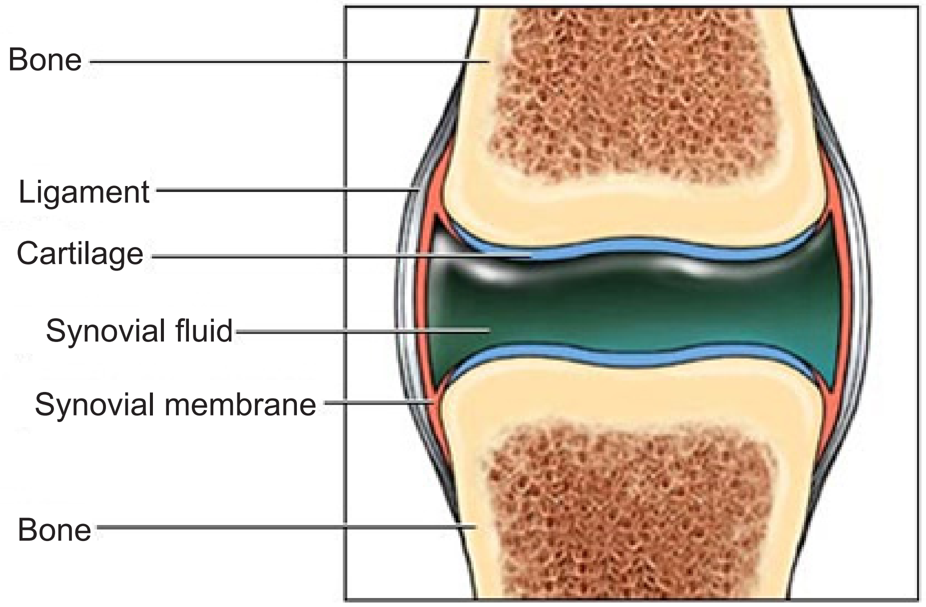


Fixed joints
David Marchal / Alamy Stock Photo

The synovial joint

The synovial joint is the most common type of moveable joint. Hinge joints and ball and socket joints are examples of synovial joints. Synovial joints are especially adapted to allow smooth movement.

The main parts of a synovial joint are shown in the diagram below:



The function of each part of the joint is summarised below:

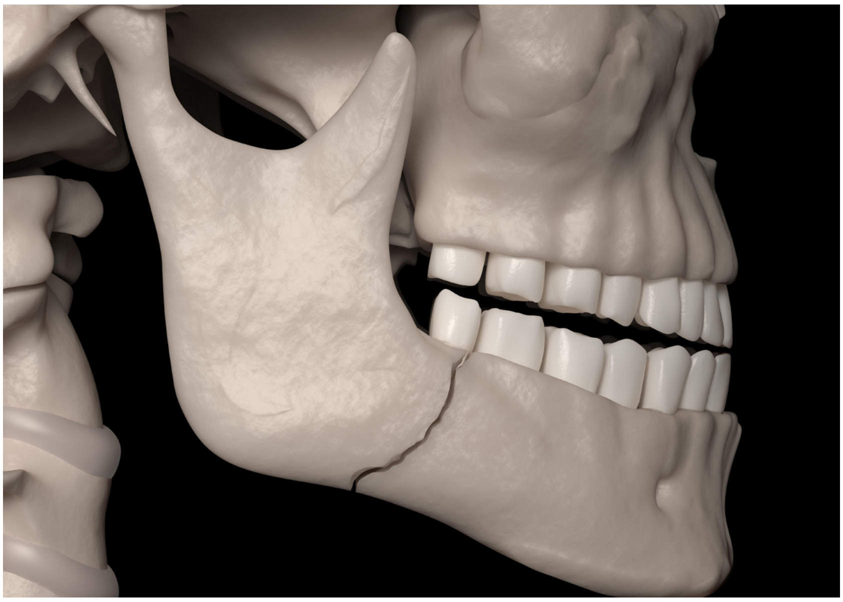
Part	Function
cartilage	reduce friction
synovial fluid	lubricates joints
ligaments	join bones to bones
tendons	join muscles to bones

Make sure you can label the parts of the synovial joint and state the function of each part.

Fractures to bones

Fractures are simply a break in a bone caused by forces that exceed the strength of the tissue in the bone.
All bone fractures are sorted into two major classes:

1. Simple fractures - The broken bones remain within the body and do not penetrate the skin.
2. Compound fractures - The broken bones penetrate through the skin and expose the bone and deep tissues to the external environment.



Simple fracture to the jaw
David Marchal / Alamy Stock Photo

Compound fracture to the forearm
Alamy Stock Photo

Within these two groups there are many specific types of fracture, one of which is greenstick fracture.

Greenstick fractures are only seen in children whose bones are more flexible than adults and therefore tend to bend and only partially break.

The X-ray below shows a bone that has been bent and partially broken.

X-ray of green stick fracture
© kidsfractures.com

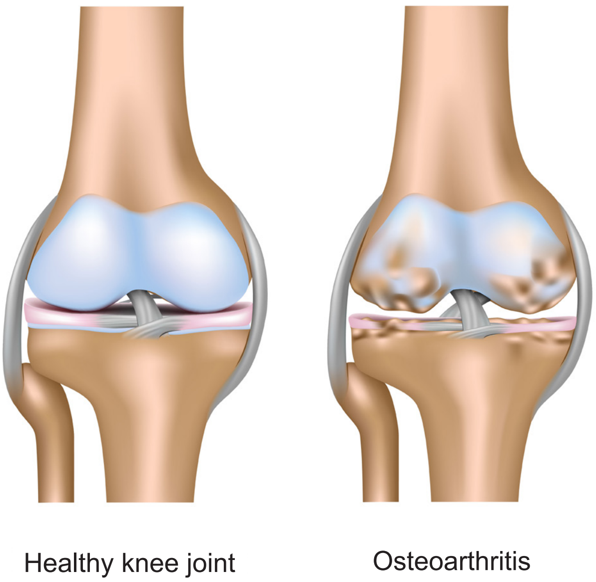
Damage to joints

Joints can be damaged through:

- injury (e.g. torn ligaments or dislocation of the joint)
- disease (e.g. by osteoarthritis)

Damage to joints will result in a limited movement of joints. The body will be able to heal most injuries with time. Damage done by disease is normally irreversible.

Osteoarthritis affects the cartilage and adjacent bone surfaces within joints. The cartilage in the knee or hip becomes damaged and worn away causing sore joints.



Osteoarthritis of knee joint
Alila Medical Images / Alamy Stock Photo

The symptoms of osteoarthritis include pain, stiffness in the joints and reduced movement. There may also be swelling.

Joint replacement surgery

If joints are badly damaged, worn or diseased they can be replaced by artificial joints. For example, knee replacement surgery involves replacing a damaged knee with an artificial joint. It is a routine operation for knee pain. More than 70 000 knee replacements are carried out in England and Wales each year. A replacement knee normally lasts over 10-20 years.

SOMETHING TO WATCH

A short video explaining how the knee works and how it can be replaced with a new joint:

http://www.nhs.uk/conditions/Knee-replacement/Pages/Kneereplacementexplained.aspx

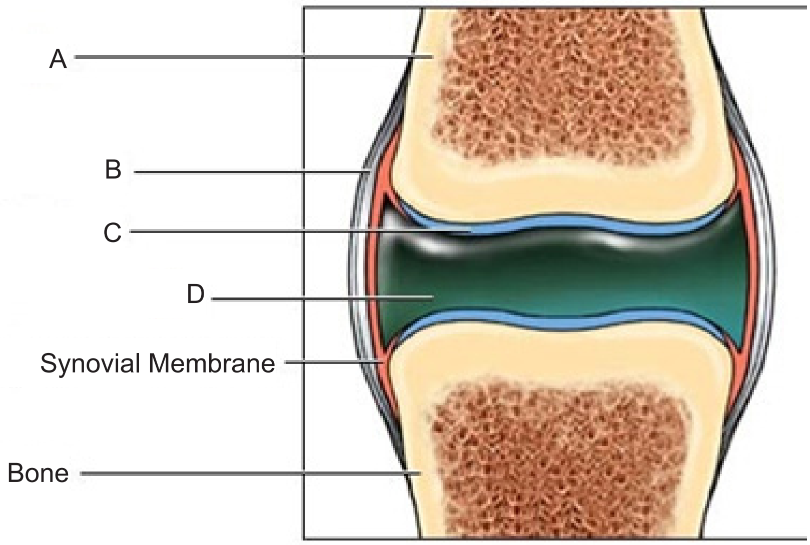
TEST YOURSELF

1. The hip is an example of a:
   - **A.** fixed joint
   - **B.** ball and socket joint
   - **C.** hinge joint

2. A compound fracture means:
   - **A.** the bone is broken and penetrates through the skin
   - **B.** the bone is broken in several places
   - **C.** the bone is partly broken

3. Identify **A**, **B**, **C** and **D** in the diagram below using the labels:

cartilage	bone	synovial fluid	ligament



A is:	cartilage	bone	synovial fluid	ligament
B is:	cartilage	bone	synovial fluid	ligament
C is:	cartilage	bone	synovial fluid	ligament
D is:	cartilage	bone	synovial fluid	ligament

4. The cartilage in the synovial joint:
   - **A** lubricates joints
   - **B** helps reduce friction
   - **C** joins bones to bone

Health, fitness and sport (Unit 2.3)

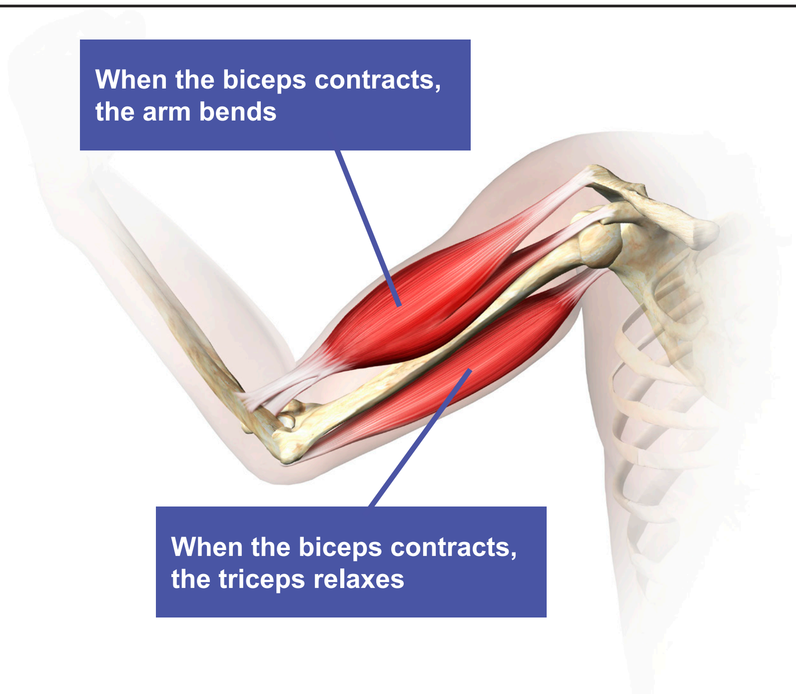
Exercise and fitness in humans (specification 2.3.4)

Antagonistic muscles

The muscles surrounding synovial joints are responsible for moving the body. The muscles around joints often work in pairs.

For example, movement about the elbow is achieved by the biceps and triceps. These two muscles are examples of an antagonistic muscle pair.

Antagonistic pairs of muscles create movement when one (the prime mover) contracts and the other (the antagonist) relaxes.



Antagonistic muscles in the arm
Henning Dalhoff / Science Photo Library

Movement about the elbow

Biceps	Triceps	Movement
biceps contract	triceps relax	arm bends
biceps relax	triceps contract	arm straightens

Movement about the knee

Another example of antagonistic muscles is the quadriceps and hamstring muscles which control the movement of the knee in the leg.

Hamstring	Quadriceps	Movement
hamstrings contracts	quadriceps relaxes	knee bends
hamstrings relaxes	quadriceps contracts	knee straightens

Energy for muscle contraction

Muscles need energy to contract.

This energy can only be provided by the breakdown of a chemical called Adenosine Triphosphate (ATP). A small amount of ATP is stored in the muscles but this is quickly used up when the muscles work.

ATP can be reformed by either aerobic or anaerobic respiration.

TEST YOURSELF

1. The arm bends when:

A the biceps and triceps both contract
B the biceps and triceps both relax
C the biceps relax and triceps contract
D the biceps contract and triceps relax

2. The arm straightens when:

A the biceps and triceps both contract
B the biceps and triceps both relax
C the biceps relax and triceps contract
D the biceps contract and triceps relax

3. Complete the following sentences by selecting the correct term from the brackets.

Muscles around (**fixed joints / synovial joints**) work (**singly / in pairs**) to cause movement. These are called (**antagonistic / antinostic**) muscles.

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

The nervous system

The nervous system is a complex collection of nerves and specialized cells (neurons) that transmit signals between different parts of the body. The nervous system is responsible for coordinating all of the body's activities. It not only controls normal functions but also the body's ability to cope with emergency situations.

The human nervous system consists of two parts:

- the central nervous system (CNS) - made up of the brain and spinal cord
- the peripheral nervous system - all other nerve fibres that connect to the CNS.

Information is sent through the nervous system as a series of small electrical signals.

Reflex reactions and the reflex arc

A **reflex** is a very fast, pre-programmed response to a stimulus. A reflex action is automatic and does not need to be thought about beforehand.

Reflex actions are there to protect the body.

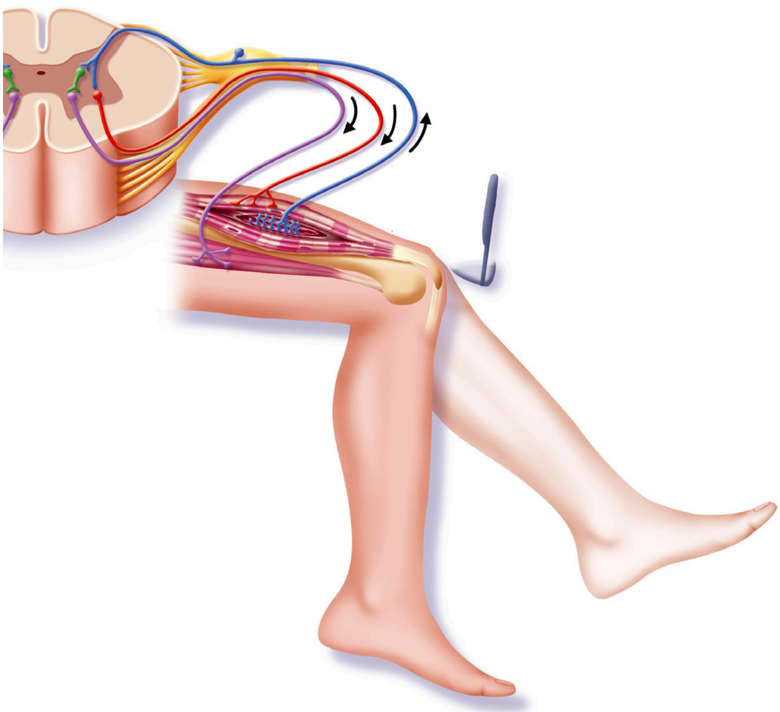
When our safety requires a very quick response, the signals are passed directly from a sensory neurone, via a relay neurone, to a motor neurone for instant action.

Reflex reactions are controlled by the reflex arc.
A reflex arc is the nerve pathway which makes such an automatic response possible.

Each reflex follows a series of steps:

stimulus → **receptor** → **sensory neurone** → **CNS** → **motor neurone** → **effector** → **response**

- The stimulus is picked up by a receptor, which transmits an impulse (electrical signal) to a sensory neurone.
- This sensory neurone passes the impulse to a relay neurone in the spinal cord (part of central nervous system).
- The relay neurone passes the signal on to a motor neurone which carries the response back to the effector organ.
- The response is carried out by the effector organ, e.g. a muscle contracts.



Reflex
Jacopin / BSIP / Science Photo Library

1. receptor detects a stimulus – hammer striking
2. sensory neurone (blue) sends signal to relay neurone (green) in the spinal cord (part of CNS)
3. relay neurone passes on signal to motor neurone (red) which carries the signal to effector (muscle)
4. effector produces a response (muscle contracts)

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

TEST YOURSELF

1. The central nervous system (CNS) is made up of:

A the brain and peripheral nervous system
B the brain and spinal cord
C the spinal cord and peripheral nervous system

2. When our safety requires a very quick response, the signals are passed directly from a:

A sensory neurone, via a relay neurone, to a motor neurone for instant action
B motor neurone, via a relay neurone, to a sensory neurone for instant action
C relay neurone, via a sensory neurone, to a motor neurone for instant action

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

Cardiovascular system

The **cardiovascular system** is also called the circulatory system. It is an organ system that allows blood to circulate around the body.

The cardiovascular system enables the transport of oxygen, carbon dioxide, nutrients and hormones to and from the cells in the body.

Components of the circulatory system

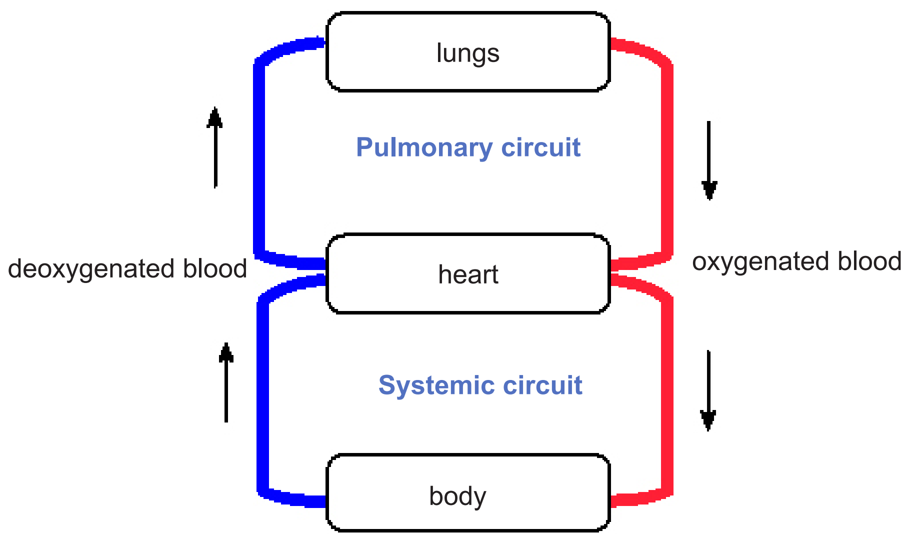
There are three components to the cardiovascular system:

- heart
- blood vessels (arteries, veins and capillaries)
- blood

The cardiovascular system is a double circulatory system. This means that it comprises of two separate circuits with blood passing twice through the heart before completing a full circuit around the body.

- one circuit links the heart and lungs (pulmonary circuit)
- the other circuit links the heart with the rest of the body (systemic circuit)

A schematic diagram of the double circulatory system is shown below:



An important **advantage** of a double circulatory system is that it allows a greater flow rate to tissues around the body since it is able to maintain a higher blood pressure.

Blood pressure is reduced by the lungs so a **one circuit** circulatory system would not be able to maintain such a high pressure around the body so reducing flow rate.

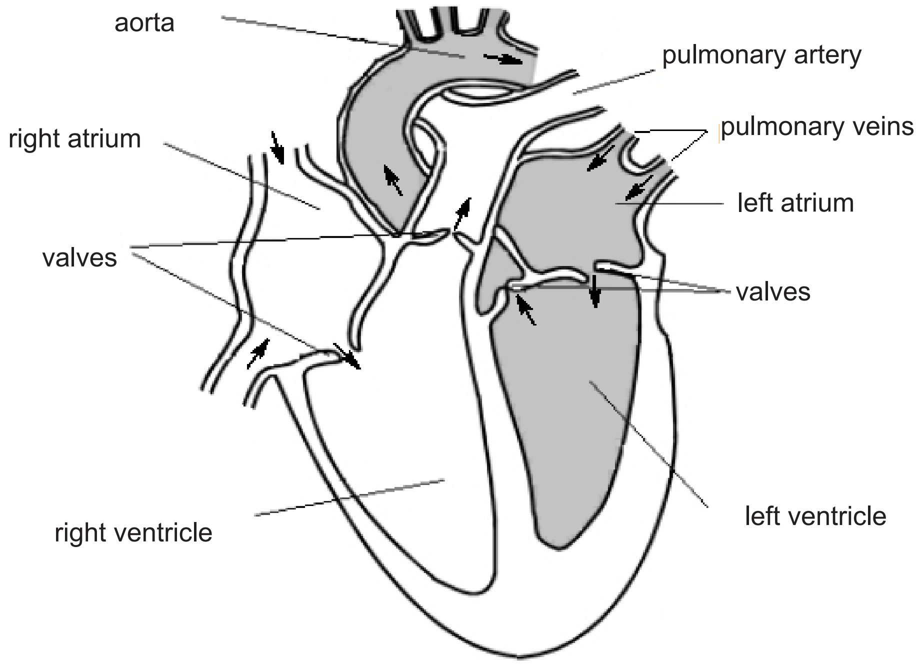
The heart

The heart is a muscular organ that pumps blood to all the tissues in your body through a network of blood vessels.

The heart pumps blood in two ways:

- the right side pumps blood to the lungs
- the left side pumps blood to the rest of the body

The diagram below shows the main parts of the heart.



The human heart has four chambers inside it. The top two chambers of the heart are called the atria (the right atrium and left atrium) and the bottom two chambers are called the ventricles.

Make sure you can label the right and left side of the heart correctly.

Look again at the labelling of the heart.

- Deoxygenated blood from the body enters the right atrium and passes into the right ventricle.
- The right ventricle pumps the blood to the lungs where it becomes oxygenated.
- Oxygenated blood returns to the heart by the pulmonary veins which enter the left atrium.
- Blood flows from the left atrium into the left ventricle. The left ventricle pumps the oxygenated blood to the aorta and then to all parts of the body.

Differences between right and left ventricles

The muscle in the left ventricle is much thicker than in the right ventricle.
This is because the left ventricle has to pump blood all the way around the body, but the right ventricle only has to pump it to the lungs.

Blood vessels

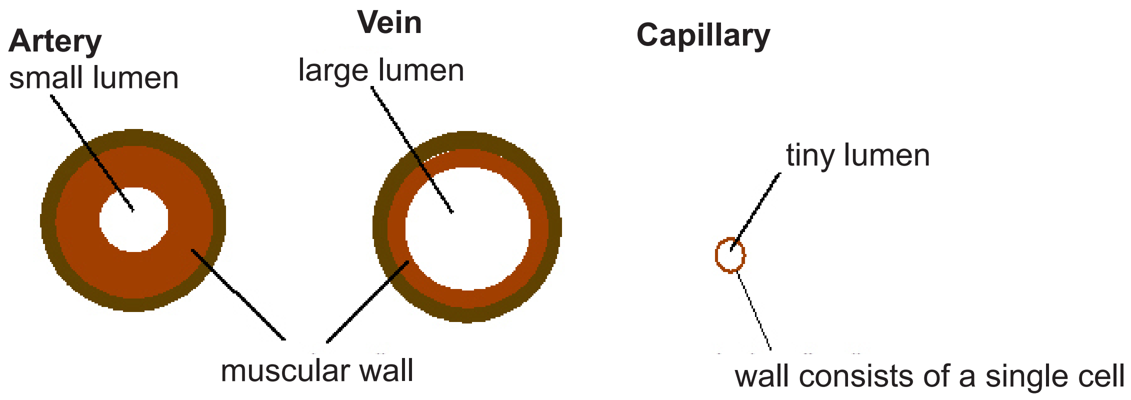
There are three types of blood vessel:

- arteries - carry blood from the heart
- veins - return blood to the heart
- capillaries - smallest of all blood vessels which allow for diffusion and exchange of substances

The structure of the different types of vessels is related to their function.

Vessel	Structure	Comment
arteries	• **thick** outer walls • thick layers of muscle	• blood in the arteries is under high pressure generated by the heart • arteries do not have valves
veins	• **thin** walls • thin layers of muscle • contain valves	• blood in veins is under lower pressure than the blood in arteries • veins have valves which stop the blood from flowing backward
Capillaries	• thin walls - only **one cell** thick	• bring nutrients and oxygen to tissues and remove waste products • thin walls needed to enable them to perform their function

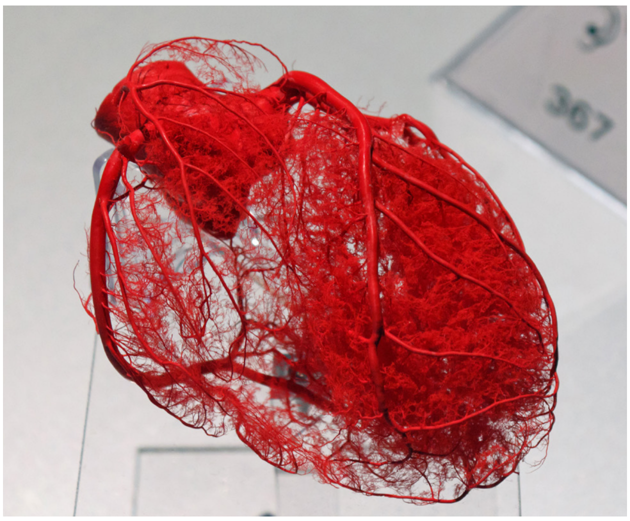
Cross sectional diagram of blood vessels



Micrograph of an artery and the accompanying vein

The heart also needs oxygen to keep beating.

This oxygen is delivered by the **coronary arteries.**



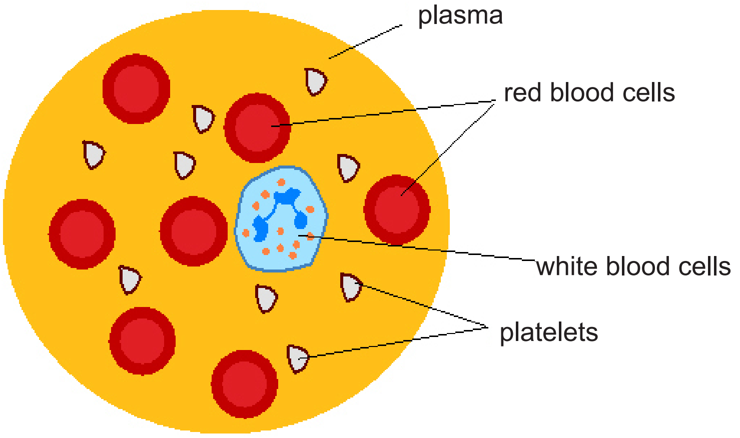
Coronary arteries
Agencja Fotograficzna Caro / Alamy Stock Photo

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

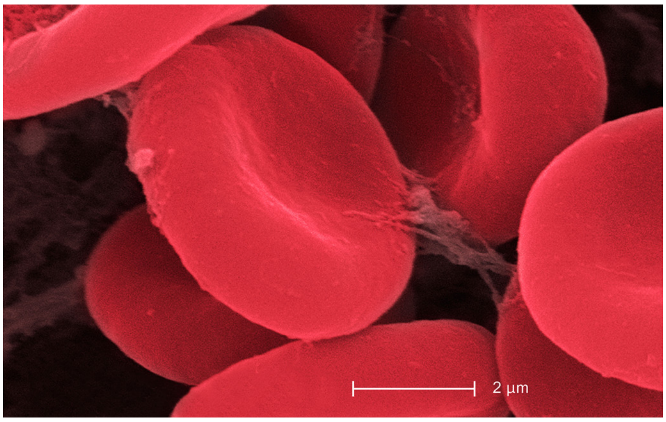
Blood

Blood transports materials around the body and protects against disease. It consists of red blood cells, white blood cells, plasma and platelets.



Each part of the blood has a special function.

Part of blood	Function	Comment
red blood cells	contain **haemoglobin** for transport of oxygen	• no nucleus • **biconcave** shape to maximise their surface area for oxygen absorption • small enough to fit through narrow blood vessels
white blood cells	defence against disease	• see immune system (earlier)
platelets	clotting	• clot at the skins surface after a cut or internally on damaged vessels
plasma	transport of CO_2, soluble food, urea, hormones and distribution of heat	• straw coloured liquid



Red blood cells showing biconcave shape
Cultura RM / Alamy Stock Photo

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

Physiological measurements

Pulse rate and breathing rate

Taking a pulse is a direct measurement of the rate at which the heart beats. The heart rate is the number of times your heart beats each minute.

The pulse is a measure of the heart rate since the arteries expand each time the ventricles pump blood out of the heart.

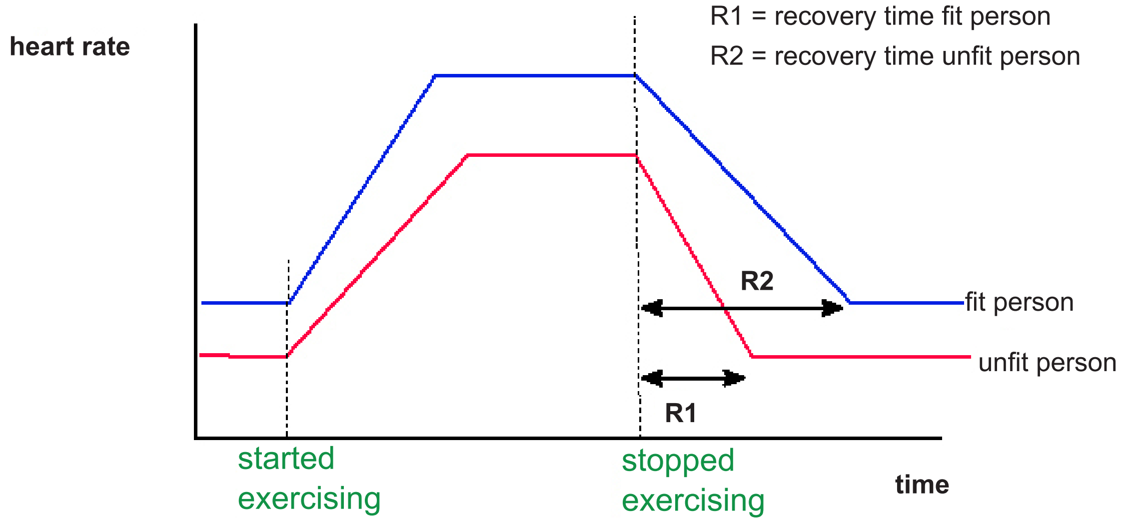
When you do exercise, you are making your muscles work harder. This means they need more glucose and oxygen for respiration than when you are at rest.

As a result your:

- breathing rate increases in order to get more oxygen and also to expel more carbon dioxide
- heart beats faster in order to pump the oxygen and glucose around the body more quickly.

When an **unfit** person exercises, his/her pulse rate and breathing rate rise **more quickly** than in a **fit** person.

The time which it takes for the pulse and breathing rate to return to normal is called the **recovery time**. The fitter a person is, the shorter the recovery time.



Notice that for the fit person:
- the recovery time is less
- their resting heart rate is lower than the unfit person

Measuring your pulse

The pulse may be taken in any place that allows an artery to be compressed against a bone, e.g. in the neck, or at the wrist.

1. Measure your heart rate by lightly pressing your forefinger and middle finger across the carotid artery in the neck or the radial pulse in the wrist.
2. Count the number of beats for 15 seconds, then multiply that number by 4 to determine heart rate.

Another way to measure heart rate is through the use of a heart rate monitor.

Why can't you take a pulse using a vein instead of an artery?

Arteries deliver blood from the heart under pressure. Once blood has passed through the fine capillaries and back into veins, the force of the heart beat is too weak to be felt.

Measuring breathing rate

The respiratory rate is the number of breaths that a patient takes each minute.
- Just count the number of breaths in 15 seconds and multiply this by 4.

Long term effect of exercise

Following an exercise programme is the best way to improve your cardiovascular fitness. During a 10-week fitness program, you can expect to see a reduction of about 10 beats per minute in your resting heart rate. This is the result of:

- strengthening the heart muscle
- improved efficiency of the heart muscle.

Your body also becomes more efficient at transporting oxygen. This means you will not need to breathe so fast. All of this leads to lower recovery times in people who are fit.

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

TEST YOURSELF

1. The components of the cardiovascular system are the:

A heart, lungs and blood vessels
B heart, blood and blood vessels
C heart, blood, lungs and blood vessels
D heart, blood and lungs

2. The human circulatory system is a:

A single circulatory system
B double circulatory system
C complex circulatory system

3. The size of the lumen in arteries, veins and capillaries, INCREASES in the order:

A	veins	arteries	capillaries
B	arteries	veins	capillaries
C	capillaries	arteries	veins

4. The cells that do not have a nucleus in the human body are:

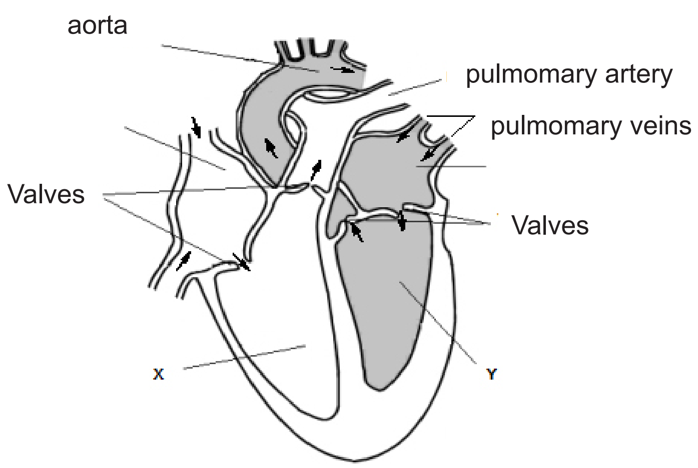
A white blood cells
B platelets
C red blood cells

5. Platelets are involved in:

A blood clotting
B carrying oxygen
C defence against disease

6. The structures marked X and Y on the heart labelled:

A X = left ventricle, Y = right ventricle
B X = right ventricle, Y = left ventricle
C X = right atrium, Y left atrium
D X = left atrium, Y right atrium



Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

PHYSICS AND MOVEMENT

Distance, speed and velocity

Speed is measured in metres per second.

It can be calculated using the formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Examples of calculations

The world record for running the 100 meters race set in 2009 by Usain Bolt was 9.58 seconds. His average speed can be calculated using:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{100}{9.58}$$ = **10.4 m/s** (This is the same as 23.3 mph)

In 2014, Dennis Kimeto set a marathon time of 2 hours 2 minutes and 57 seconds. The marathon is 42.195 kilometres. Calculate his mean speed around the course.

First find the time in seconds

Time in seconds = (2 × 60 × 60) + (2 × 60) + 57 = 7 377 seconds

Second find the distance in metres

Distance in metres = 42.195 × 1 000 = 42 195 m

Finally calculate the mean speed

His average speed can be calculated using:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{42\,195}{7\,377}$$

= 100 / 9.58

= **5.72 m/s**

Speed and velocity

There are two ways of looking at a journey

- Only the **amount** of distance travelled is important. It either stays the same or increases.

  It does not matter which direction you go in. In this case, the distance travelled is just a positive number.

- The **direction** you travel in is **also** important. If you travel one way it is a positive number. If you travel in the opposite way it is a negative number. Direction matters!

The first quantity is an example of a **scalar** quantity; the second, where direction also matters, a **vector** quantity.

Speed is a scalar quantity. It does not matter which direction you walk or run in. It is always a positive number.

Velocity is a vector quantity. It matters which way you walk or run.

If you run in one direction it is positive but if you run in the opposite direction it is negative.

New Illustrations by Alfonsodetomas / Alamy Stock Vector

We can show information about the distance and time taken on a **distance-time graph.**

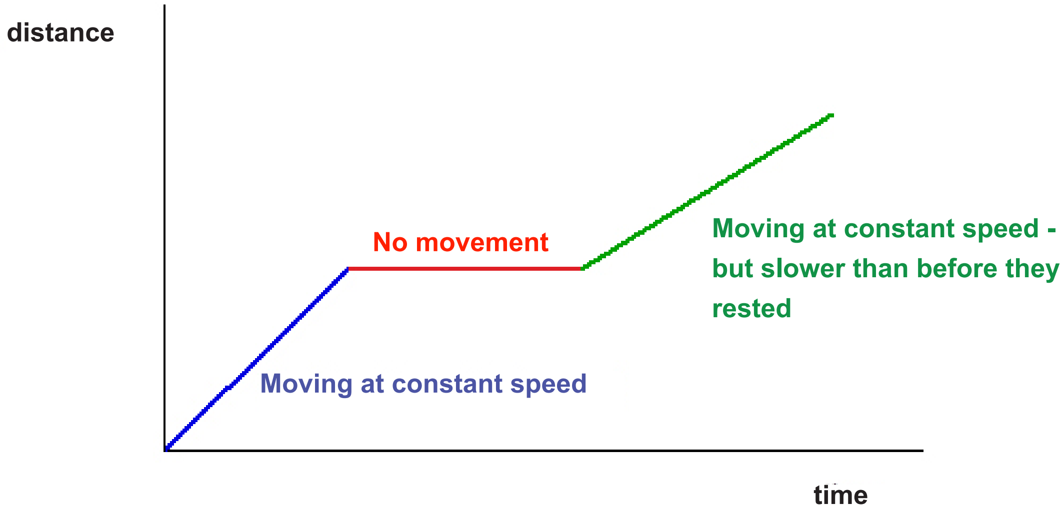
Distance-time graphs

Key things to notice on a distance time graph:

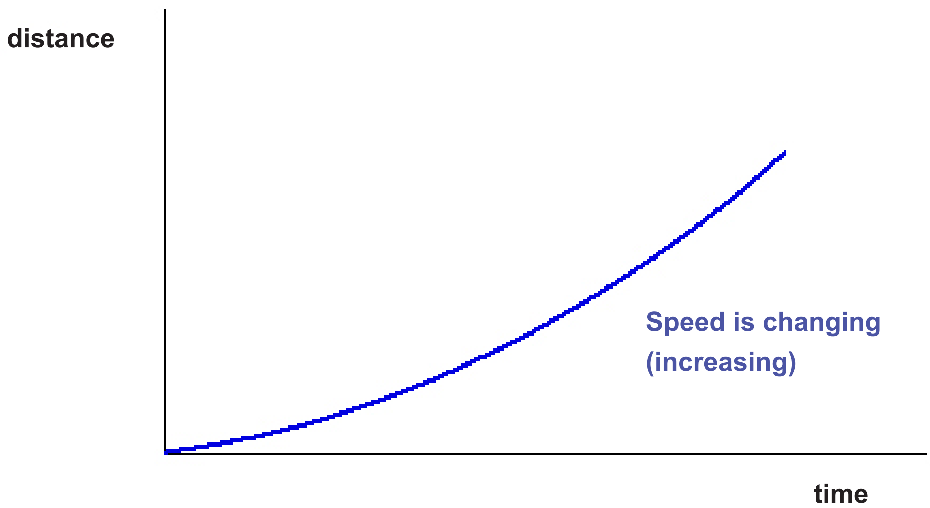
- a horizontal line means that the object is not moving
- a straight line sloping up means that the object is moving with constant speed
- the steeper the line the faster the movement
- a curved line means that the speed is changing

Look carefully at the graphs below and make sure you understand the information they give.

Graph 1

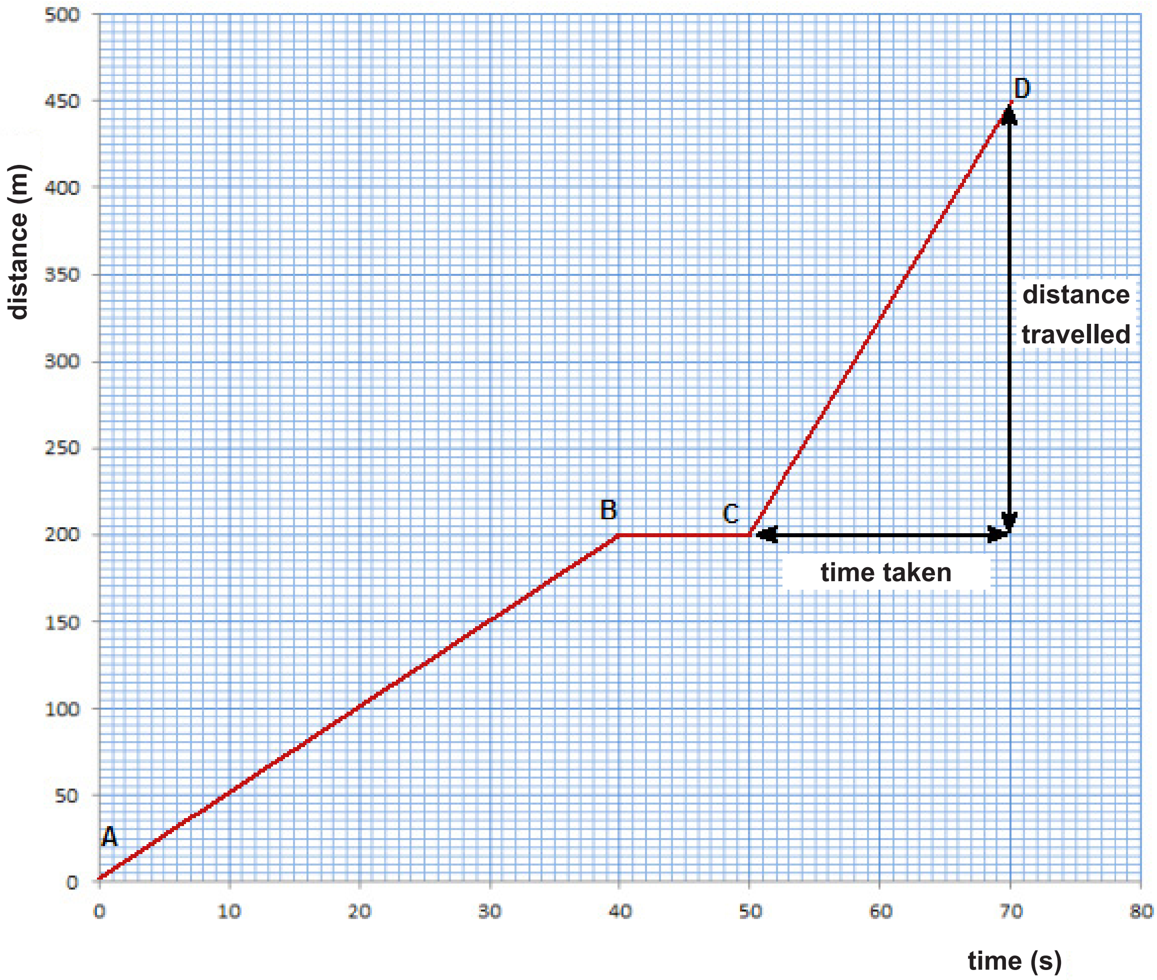


Graph 2



Example

A distance time graph for a cyclist is shown below.



The cyclist is:

- moving at constant velocity between point **A** and **B**, and between **C** and **D**
- moving faster between points **C** and **D** than between **A** and **B** (steeper slope)
- not moving between **B** and **C**

The speed between **C** and **D** can be found from the slope of the line **CD**.

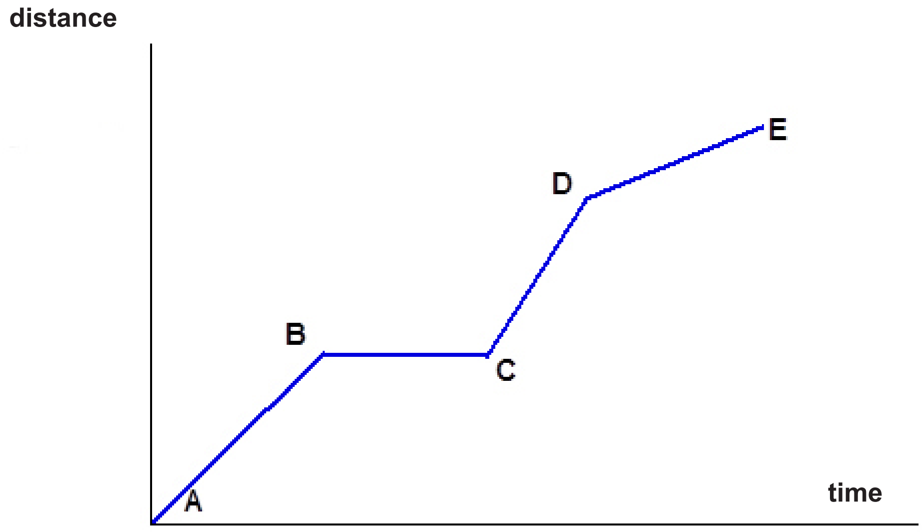
$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{(450 - 200)}{(70 - 50)}$$

$$= \frac{250}{20} = \mathbf{12.5\ m/s}$$

TEST YOURSELF

1. A cyclist travels 100 m in 5 seconds. Her speed is:
   - **A** 500 m/s
   - **B** 0.05 m/s
   - **C** 20 m/s
2. A man runs 200 m in 25 seconds. His speed is:
   - **A** 8 m/s
   - **B** 500 m/s
   - **C** 0.50 m/s
3. Look at the distance-time graph for the cyclist below and state the points between which the cyclist is moving fastest.



(a) The cyclist is fastest between:
- **A** **A** and **B**
- **B** **B** and **C**
- **C** **C** and **D**
- **D** **D** and **E**

(b) The man does not move between:
- **A** **A** and **B**
- **B** **B** and **C**
- **C** **C** and **D**
- **D** **D** and **E**

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

Acceleration

A change in velocity is called **acceleration**.

Acceleration is the change in velocity per second.

The units of acceleration are:

m/s^2
(metres per second squared)

It is calculated using:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

Examples

1. A cyclist accelerates from rest to 9 m/s in 10 seconds. Calculate the acceleration of the cyclist.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

$$\text{acceleration} = \frac{(9 - 0)}{10} = \mathbf{0.9\ m/s^2}$$

2. Calculate the acceleration when an athlete increases his speed from 4 m/s to 7.5 m/s in 5 seconds.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

$$\text{acceleration} = \frac{(7.5 - 4)}{5} = \frac{(3.5)}{5} = \mathbf{0.7\ m/s^2}$$

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

Velocity-time graphs

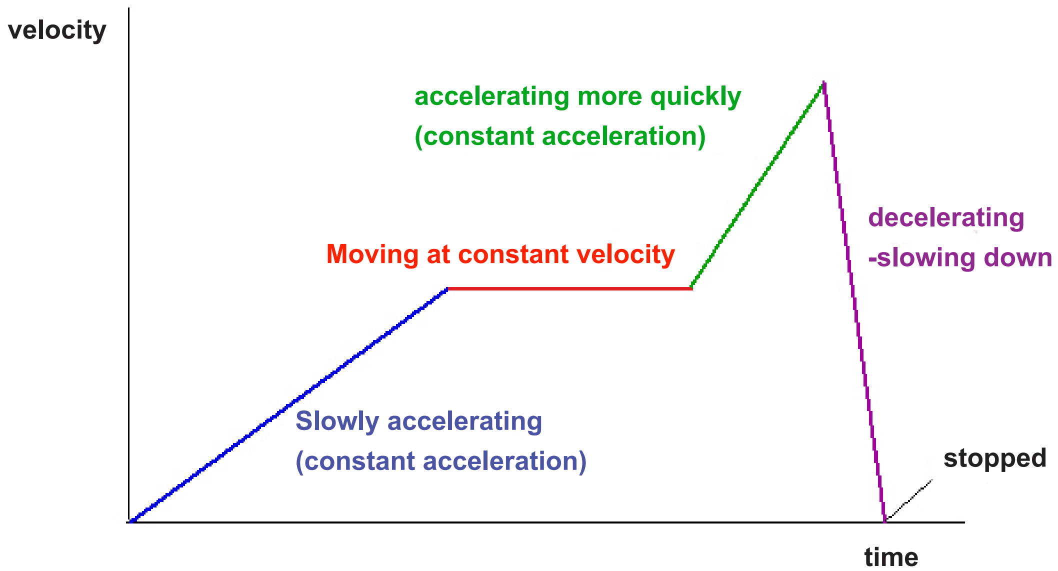
We can also represent motion using velocity-time graphs.

Key things to notice on a velocity-time graph:

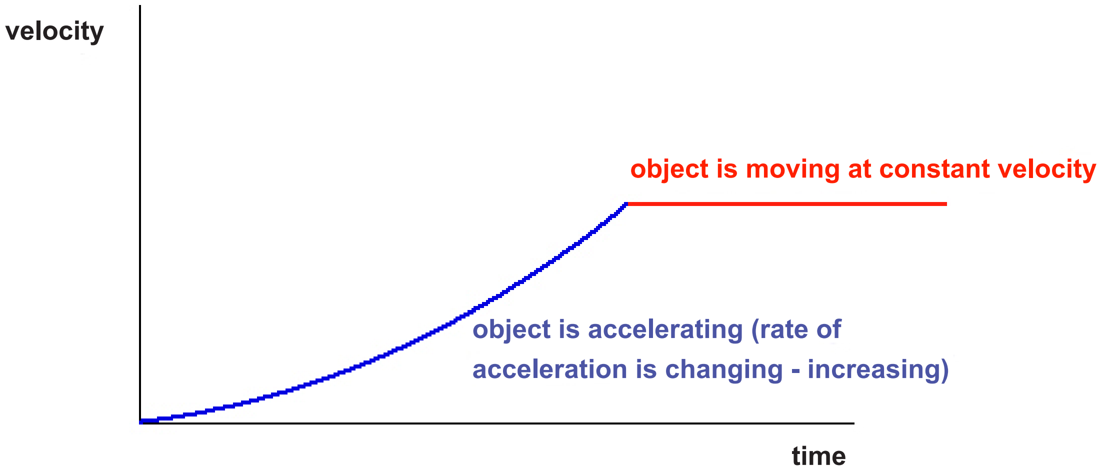
- horizontal line means that the object is travelling at a constant velocity
- a straight line slopping upwards means that the object is moving with a **constant** acceleration
- the steeper the line the faster the acceleration
- a curved sloping line means that the acceleration is changing
- a negative line means that the object is slowing down (decelerating)

Look carefully at the graphs below and make sure you understand the information they give.

Graph 1

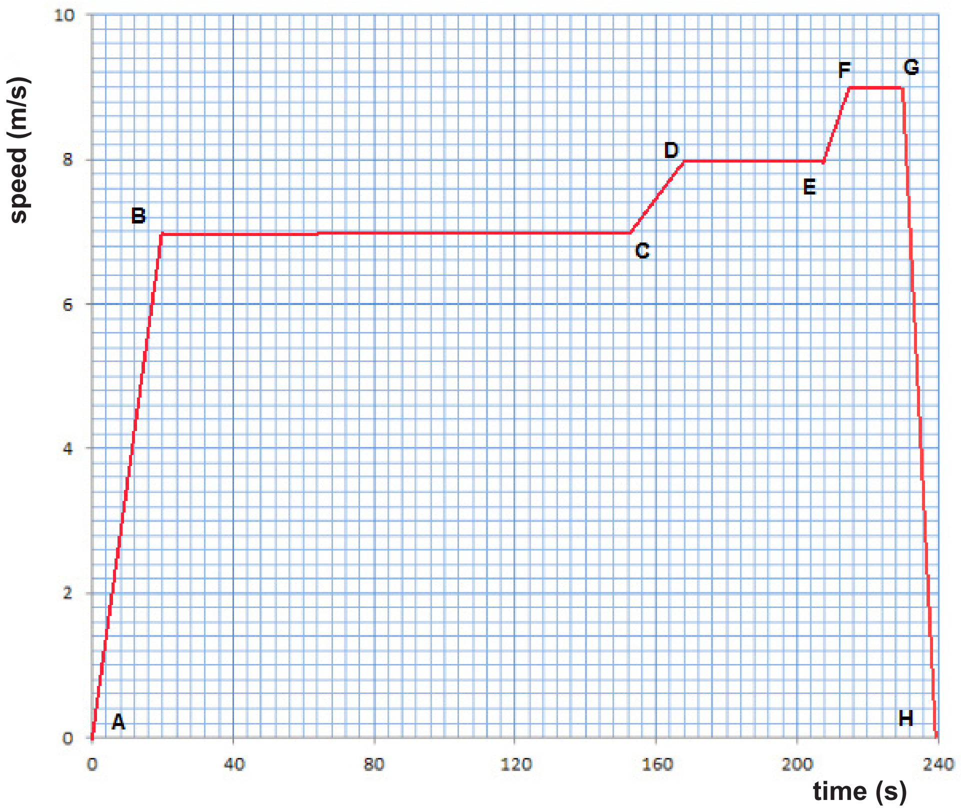


Graph 2



Example

The speed of an athlete running a 1 500 m race was recorded and the result shown on a speed-time graph.



The athlete was running with constant speed between points **B** and **C**, **D** and **E**, **F** and **G**.
At 120 seconds his speed was 7.0 m/s
The athlete accelerated between points **A** and **B**, **C** and **D**, **E** and **F**.
He slowed down (decelerated) between **G** and **H**
The acceleration was fastest between **A** and **B (steepest line upwards)**

$$\text{acceleration between A and B} = \frac{\text{change in velocity}}{\text{time}}$$

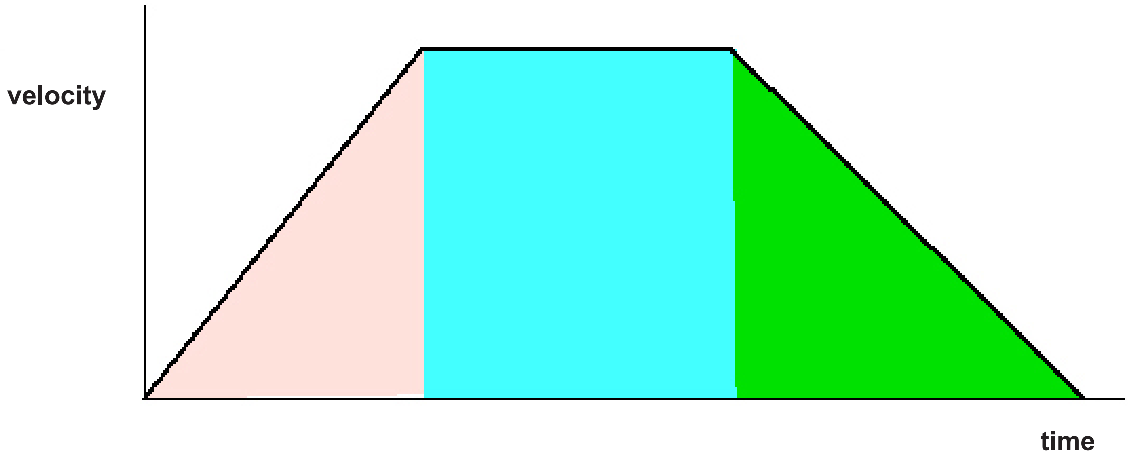
$$= \frac{(7.0 - 0)}{20} = \mathbf{0.35\ m/s^2}$$

Higher tier only

Finding distance travelled from a velocity-time graph

The area under the graph is the distance travelled by an object in a velocity-time graph

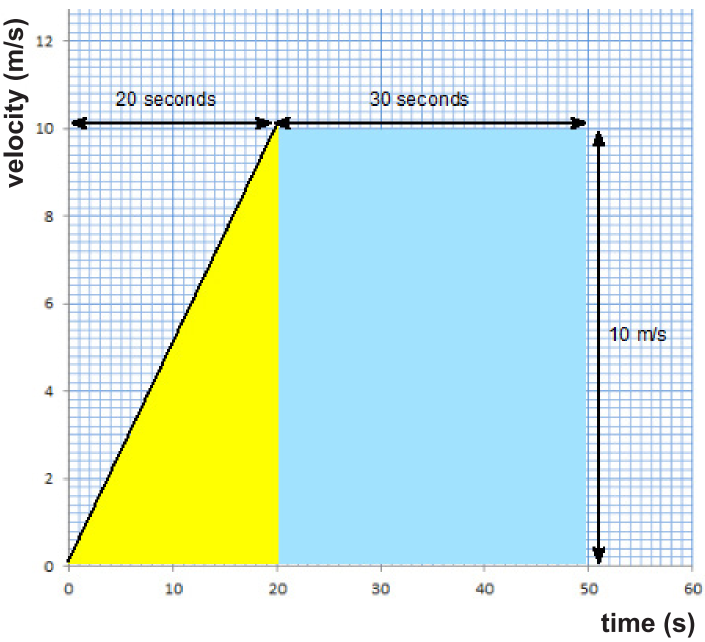
The graph shows an object accelerating from rest and then travelling at constant velocity until it slows to rest. The total distance travelled by the object will be the area between the graph and the time axis.



All that needs to be done is to calculate this area. This is best done by splitting the shaded area into three shapes, two triangles and a rectangle as shown above.

Example

Calculate the distance travelled by the cyclist in 50 seconds from the graph below.



Calculate the area that is shaded:

Blue rectangle = 30 × 10

= 300 m

yellow triangle = ½ × 20 × 10

= 100 m

Total distance travelled

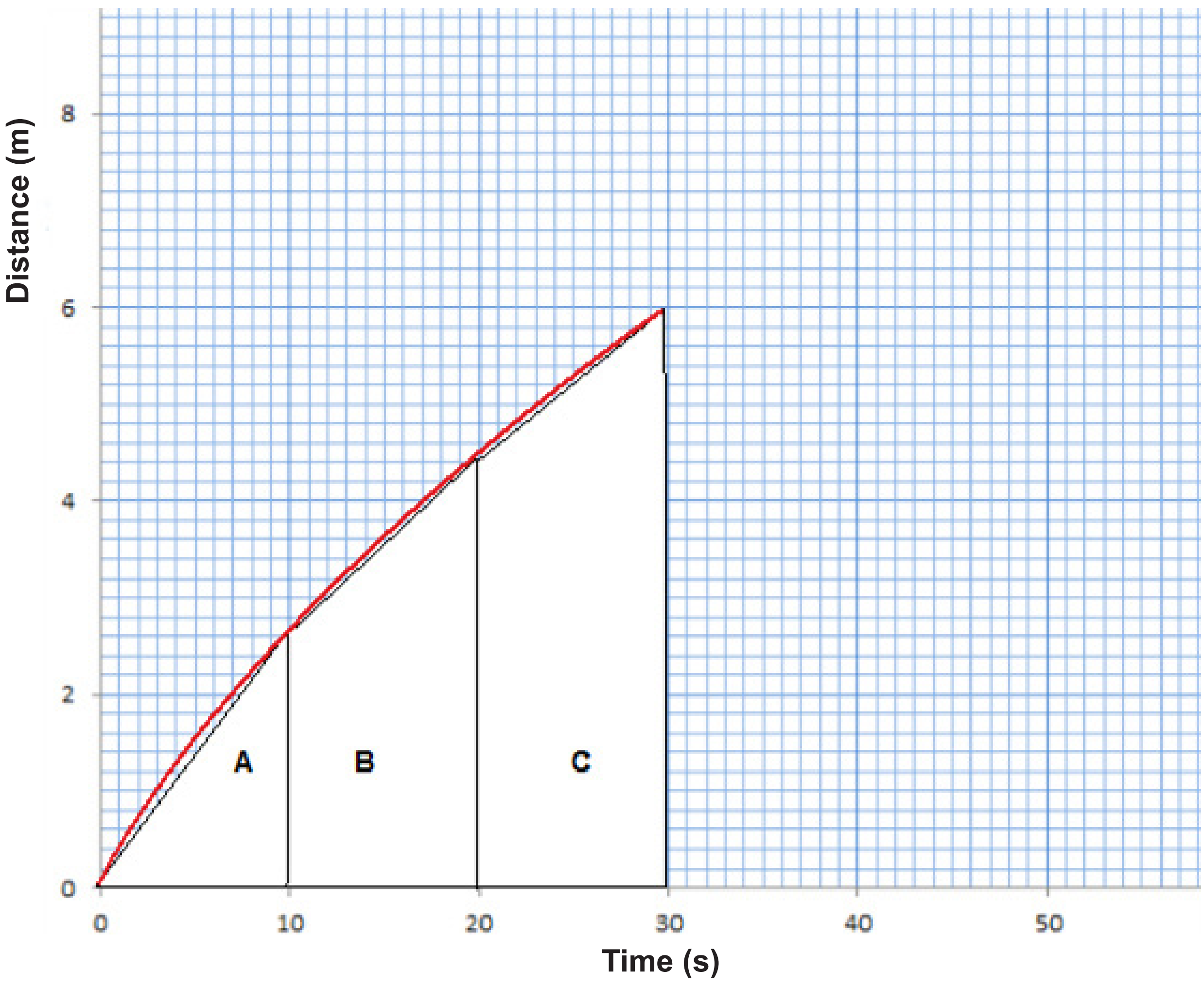
= 300 + 100

= **400 m**

Distance travelled when the acceleration is not constant

If the acceleration is not increasing at a constant rate then you will need to estimate the area under the curve.

In the example below we have broken the area up into three shapes, **A**, **B** and **C**.



The area of the right angled triangle, **A** = ½ × 2.6 × 10 = 13

The area of trapezium **B** = ½ (2.6 + 4.4) × 10 = 35

The area of trapezium **C** = ½ (4.4 + 6.0) × 10 = 52

Total area = 13 + 35 + 52 = 100 metres

This is an estimation of the area.

TEST YOURSELF

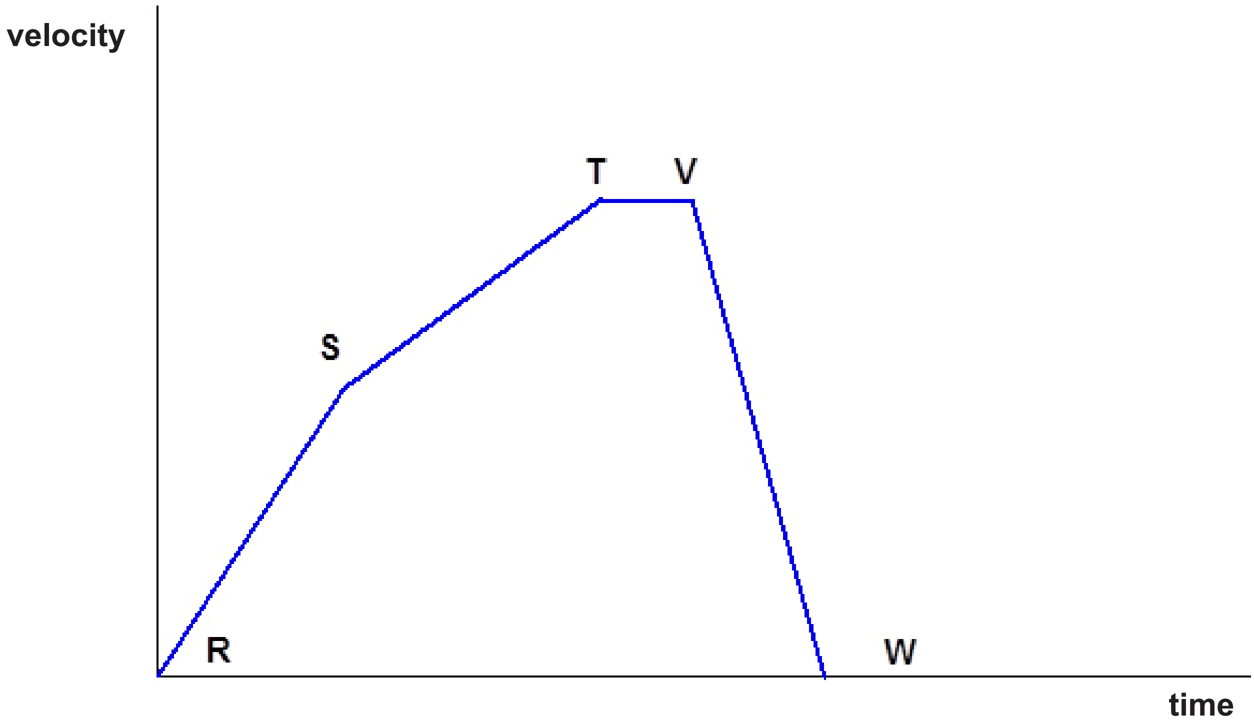
1. A man accelerates from 3.0 m/s to 6.0 m/s in 4 seconds. His acceleration is:

A $0.75\ m/s^2$
B $1.3\ m/s^2$
C $12\ m/s^2$

2. A cyclist accelerates from 5 m/s to 10 m/s in 5 seconds. Her acceleration is:

A $2\ m/s^2$
B $1\ m/s^2$
C $0.5\ m/s^2$

3. Use the velocity-time graph for the cyclist below to answer the questions that follow.



(a) The cyclist is accelerating fastest between:

A **R** and **S** **B** **S** and **T** **C** **T** and **V** **D** **V** and **W**

(b) The cyclist is decelerating between:

A **R** and **S** **B** **S** and **T** **C** **T** and **V** **D** **V** and **W**

(c) The cyclist is moving at constant velocity between:

A **R** and **S** **B** **S** and **T** **C** **T** and **V** **D** **V** and **W**

(d) The cyclist is not moving at:

A Point T **B** Point T **C** Point W

PRACTICE QUESTIONS

1. Dan works out on an exercise bicycle.

Cycling machine
walter zerla/gettyimages

Dan says he is fitter than Alex because his breathing rate returns to normal after exercise sooner than Alex's. You decide to test Dan's claim by carrying out a comparison of the effect of exercise on the breathing rate (number of breaths per minute) of these two students.

Describe your investigation. Make sure that it is a fair test. [6 QER]

....

....

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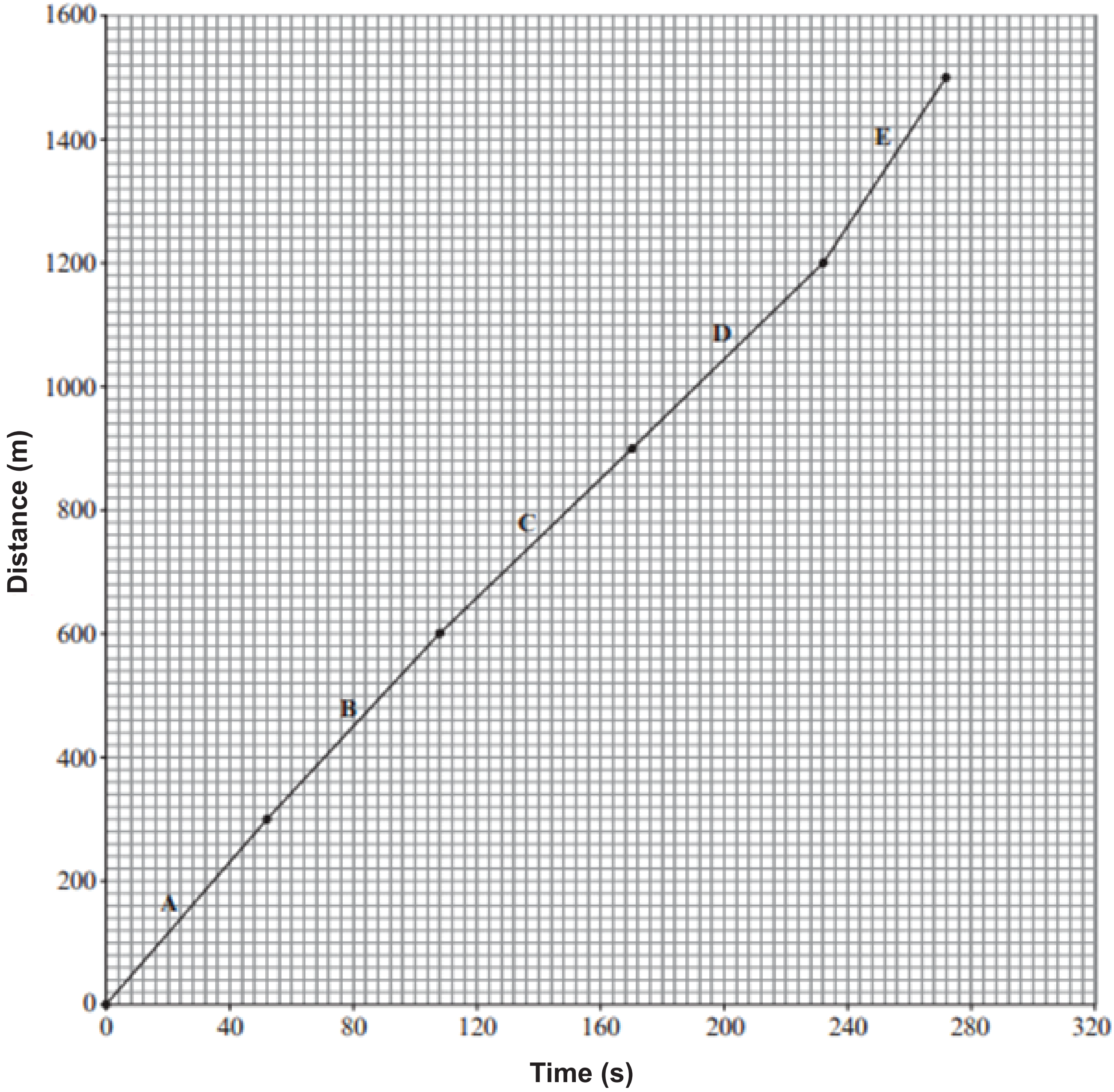
2. Gareth and Kevin entered a 1 500 m race. Their performance during the race was measured. The time they take to complete each 300 m stage of the race was measured. A distance–time graph is plotted below for Kevin.



(a) Use the graph to find the:

(i) time taken by Kevin to complete the race. [1]

.... seconds

(ii) fastest 300 m section (**A**, **B**, **C**, **D** or **E**) ran by Kevin. [1]

....

(b) Gareth's performance in the same race is recorded in the table below.

Time (seconds)	Distance (meters)
0	0
60	300
120	600
180	900
240	1 200
320	1 500

(i) On the same graph, plot the performance of Gareth using the values shown in the table above. [3]

(ii) Calculate the mean speed for Gareth during the first 900 m using the equation: [2]

$$\text{mean speed} = \frac{\text{distance}}{\text{time}}$$

answer = ... m/s

(c) Use the data to explain how the fitness of Gareth compares with Kevin. [2]

....

....

....

TEST YOURSELF - ANSWERS FOR UNIT 2.3

Genes, inheritance and health

1. C
2. (a) B (b) C
3. B

Lifestyle and health

1. B
2. A
3. A
4. C

Controlling blood glucose level

1. C
2. C
3. glucagon (B) insulin (A)
4. C
5. C
6. A

Ionising radiation

1. C
2. C
3. B
4. A
5. C

Medical imaging

1. B
2. B
3. C
4. C
5. B
6. A

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

Drugs

1. C
2. B
3. B

Microorganisms and the body's defences

1. C
2. A
3. B
4. A

Joints

1. B
2. A
3. A – bone B – ligament C – cartilage D – synovial fluid
4. B

Antagonistic muscles

1. D
2. C
3. synovial joints, in pairs, antagonistic

Nervous system

1. B
2. A

Cardiovascular system

1. B
2. B
3. C
4. C
5. A
6. B

Exercise and fitness in humans (specification 2.3.4)

Speed and velocity

1. C
2. A
3. a) C b) B

Acceleration

1. A
2. B
3. (a) A (b) D (c) C (d) C

PRACTICE QUESTIONS - ANSWERS FOR UNIT 2

Our place in the universe

1.	**(a)**	(i)	Ticks in boxes 1, 4 and 5	3
		(ii)	Values within the range -70 to -120 °C	1
	(b)	(i)	explosion	1
		(ii)	expand	1
		(iii)	million	1

World of life

1.	(a)	(Physical) change (in organism) (1), to improve survival/feature/ trait/characteristic/that helps an organism to survive (1)	2
	(b)	Mistaken for poisonous snake (1), predators avoid it (1).	2

Interdependency of organisms

1	(a)	Camouflage/blend in	1

	(b)		If the population of prey increases, there will be more food so predator population will increase. As the population of predators increases more food is needed so eventually the population of prey will decrease. Less food for the predators so their population falls again Three from the above. Must be correctly and coherently connected points to get 3 marks.	3
2.	(a)		130	1
	(b)		130/2 500 × 100 (1) 5.2 (1)	2
3.	(a)	(i)	Sun	1
		(ii)	Water beetles/perch/minnows	1
		(iii)	Weeds → tadpoles → beetles → perch **OR** Algae → fleas → minnows → perch (3 ending with perch (1); 4 no perch (1)	2
	(b)		Light not blocked, can pass to weeds	2
	(c)		Affects minnows, decreases, algae increases/pike decrease/perch decrease	3
4.	(a)		Increased nitrogen fixing bacteria /nitrogen fixation/ less denitrification.	1

	(b)		Economic-greater crop yield Environmental – no need to add fertilizer/manure therefore preventing eutrophication.	2

Environment under threat

1.	(a)	(i)	run off/leaching of (fertiliser / pesticides)	1
		(ii)	Heavy metal pollution or named copper/Cu, lead/ Pb, zinc/Zn.	1
	(b)		Most/highest nitrate/nitrogen OR phosphate (1) eutrophication / Fish suffocate (1)	2
	(c)	(i)	High levels of heavy metal pollution	1
		(ii)	Heavy metal/lead cause poisoning (1) build up to a toxic level / bioaccumulation in birds (1)	2

Factors affecting human health

1.		(i)	They have the highest energy content.	1
		(ii)	Diabetes (1) Cardiovascular disease (1)	2
		(iii)	37 000 kJ	1
		(iv)	kcal equivalent = 37 000 x 0.24 = 8 880 kcal/month (1) = 296 kcal/day (1)	2
2.	(a)		More affluent (money), able to buy a balanced/ healthy diet.	1
	(b)	(i)	3 410 Correct workings but wrong answer	2

		(ii)		All obese people are registered by the GP/have a GP	
		(iii)		Survey the populations (in the different regions)	

Health, fitness and sport

1.	(a)	(i)		Prevent radiation passing through healthy organs	1
		(ii)		Different directions so does not always pass through the same healthy tissue / Short time so dose to healthy tissues is limited	
		(iii)		Provides a steady & continuous source of radiation to the tumour (1) Less risk of damaging healthy surrounding tissue (1)	2
	(b)	(i)		Time difference is same or 60 days (1) So halves again to 50 units (1)	2

Microorganisms and the body's defences

1.	(a)	(i)	I	2 500 – 1 125 (1) = 1 375(1)	2
			II	Improved hygiene/improved living conditions/improved water quality	1
		(ii)		Number of cases increases **and** While death rate falls	1
		(iii)		Incidence fell and remained low 1960 onwards	1
	(b)			Overuse / over-prescription /poor hygiene / cross-contamination among patients	1

Health, fitness and sport (Unit 2.3)

Exercise and fitness in humans (specification 2.3.4)

PRACTICE QUESTIONS - ANSWERS FOR UNIT 2

Exercise and fitness in humans

1.

Indicative content
Record Dan's (breathing) rate at rest
then exercise (bike or other)
exercise specified (distance/speed/load)
for a certain time
record rate after exercise
rate must return to rest
repeat with Alex – must ref to same exercise regime
compare results to see which breathing rate returned to normal the fastest.

5 – 6 marks: Detailed description of the entire investigation to include specified exercise regime and ref. to same exercise again with Alex and take rate till return to resting level.
There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. The candidate uses appropriate scientific terminology and accurate spelling, punctuation and grammar.

3 – 4 marks: Outline general description of the investigation
There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. The candidate uses mainly appropriate scientific terminology and some accurate spelling, punctuation and grammar.

1 – 2 marks: Ref only to counting breathing rate and then exercise by Dan and repeat with Alex + comparison
There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure. The candidate uses limited scientific terminology and inaccuracies in spelling, punctuation and grammar.

0 marks: *No attempt made or no response worthy of credit. (6 QER)*

2.	(a)	(i)	272 ± 2(s)	1
		(ii)	E	1

(b) (i)	Points all correct (2). 4 or 5 correct (1) Line (1).	3
(ii)	900 / 180 (1)= 5.0 (m/s)(1)	2
(c)	Kevin is fitter than Gareth (1) because he has a lower time (1) **or** Kevin has trained more than Gareth (1) since he is able to complete the race in a shorter time. (1) Two marks can only be awarded for coherently and correctly linking points.	2