OCR Gateway Core Science B2 Revision Pack

Classification

We can understand the evolutionary and ecological relationships between organisms if we can classify them.

Kingdoms

Organisms can be classified into groups according to characteristics that they share. The first big division of living things in the classification system is to put them into one of five kingdoms. These are based on what an organism's cells are like. The table shows the names of the kingdoms and examples of the sort of organisms they contain.

Kingdoms and organisms

kingdom	characteristics	examples
Animals	Cells do not have a cell wall. Multicellular and feed on other organisms.	All multicellular animals, including: jellyfish, worms, arthropods, molluscs, echinoderms, fish, amphibia, reptiles, birds and mammals
Plants	Cells have a cellulose cell wall. They use light energy to produce food by photosynthesis.	All green plants, including: algae, ferns and mosses (plants that do not produce seeds); conifers and flowering plants (plants that do produce seeds)
Fungi	Cells have chitin cell walls. Reproduce using spores rather than seeds.	Moulds, mushrooms, yeast
Prokaryotes	Have a cell wall but not made from cellulose. Cells have no nucleus.	Bacteria, blue-green algae
Protoctists	Exist as single cells or colonies of single cells.	Amoeba, Paramecium

Classification

The first rank in the classification system is called a kingdom. There are five kingdoms, based upon what an organism's cells are like:

- animals (all multicellular animals)
- plants (all green plants)
- fungi (moulds, mushrooms, yeast)
- prokaryotes (bacteria, blue-green algae)
- protoctists (Amoeba, Paramecium).

Further divisions

There are several further ranks before we reach a particular species. In order, these are:

kingdom
phylum
class
order
family
genus
species.

- kingdom - animal
- phylum - vertebrate
- class - mammal
- order - carnivorous
- family - cat
- genus - big cat
- species - lion.

One way to remember this is by using a daft sentence like this one:

'King prawn curry or fat greasy sausages!'

Arthropods

Invertebrates are animals without backbones. Arthropods are an important group of invertebrates. There are four smaller groups of arthropods, based on how many legs they have:

arthropod	characteristics
 An ant	Insects (6 legs)
 Tarantula	Arachnids (8 legs)
 Crustacean - a crayfish	Crustaceans (10 to 14 legs)
 Myriapods - A millipede	myriapods (centipedes and millipedes – more than 20 legs).

You should be able to use these characteristics to classify a given arthropod.

Higher tier

Classification systems can be artificial. They use obvious differences in features so that the organism can be identified. Biologists often use 'field guides' so that they can work out what an animal or plant is. However, these classification systems may not accurately reflect the evolutionary relationships between organisms. For this, natural classification systems based on DNA are needed.

Today, scientists can sequence the DNA of many organisms relatively easily. Computer programs compare the DNA sequences of different species to look for similarities and differences. This allows evolutionary trees to be made.

Species

A species is a group of organisms that can interbreed to produce fertile offspring. Individuals of the same species have more characteristics in common than they do with organisms of a different species.

Sometimes a species may have different kinds or breeds that show great variation, but the individuals still belong to the same species. Different breeds of pedigree dog are like this.

From left to right - Beagle, Wheaten Terrier, Rhodesian Ridgeback, Red Siberian Husky, Irish Setter, Golden Retriever, Boxer, Sheltie

Species and habitats

Similar species tend to live in similar habitats. Closely related species share a relatively recent ancestor- a 'common ancestor'. If they live in different type of habitat, closely related species may have different features.

Binomial system

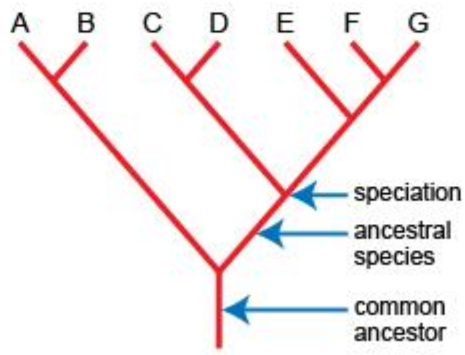
In the 18th century, Carl Linnaeus started the modern system of putting species of organism into certain groups and giving them scientific names. Each species is given a name using Latin words, so that the same name can be used all over the world. For example, the scientific name for human beings is Homo sapiens. The first part of the name tells you the genus, while the second part of the name tells you the particular species in that genus.

Higher tier

It can be difficult to classify some organisms into species. For example, evolution is a continuing process. Some organisms can only reproduce asexually, while some species can interbreed to produce hybrids. For example the liger is a hybrid cross between a male lion and a female tiger.

Evolutionary trees

Evolutionary trees are used to represent the relationships between organisms. The diagram shows an evolutionary tree.



An evolutionary tree

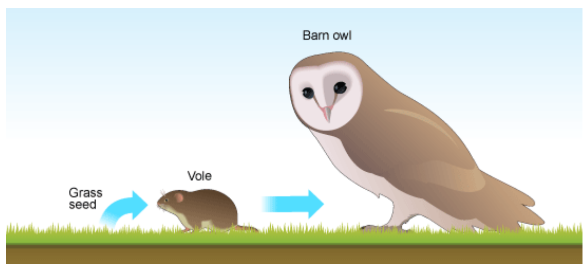
In this evolutionary tree, species A and B share a common ancestor. Species F and G share a common ancestor, which itself shared a common ancestor with species E. All seven species share a common ancestor, probably from the distant past.

Energy flow

Food chains show the feeding relationships in a habitat. Pyramids of biomass are charts that show the mass of living organisms at each step in a food chain. Energy is lost moving up in a food chain, and this limits the length of the chain.

Food chains

A food chain shows what eats what in a particular habitat. For example, grass seed is eaten by a vole, which is eaten by a barn owl. The arrows between each item in the chain always point in the direction of energy flow - in other words, from the food to the feeder.



Food chain

Radiation from the Sun is the ultimate source of energy for most communities of living things. Green plants and algae absorb some of the Sun's light energy and transfer it into chemical energy. This happens during photosynthesis, and the chemical energy is stored in the substances that make up the cells of the plants or algae. The other organisms in a food chain are consumers, because they all get their energy and biomass by consuming (eating) other organisms.

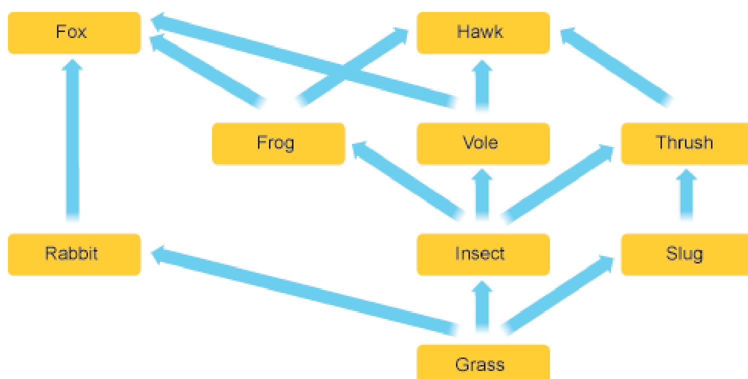
It helps if you can recall the meaning of some common words used with food chains. The table shows some of these words.

Food chain terms

word	meaning
producers	Green plants and algae. They make food by photosynthesis.
primary consumers	Usually eat plant material - they are herbivores. For example rabbits, caterpillars, cows and sheep.
secondary consumers	Usually eat animal material - they are carnivores. For example cats, dogs and lions.
predators	Kill for food. They are either secondary or tertiary consumers
prey	The animals that predators feed on.
scavengers	Feed on dead animals. For example, crows, vultures and hyenas are scavengers.
decomposers	Feed on dead and decaying organisms, and on the undigested parts of plant and animal matter in faeces.

Food webs

When all the food chains in a habitat are joined up together they form a food web. Here is an example of a food web:



An example of a food web
Although it looks complex, it is just several food chains joined together. Here are some of the food chains in this food web:

- grass → insect → vole → hawk
- grass → insect → frog → fox
- grass → insect → vole → fox.

Notice that the frogs, voles and insects have more than one predator, but the rabbits and slugs have just one predator. This leads to some interesting effects if the population of a particular organism in the food web decreases. Some animals can just eat more of another organism if food is in short supply, while others may starve and die. This in turn can affect the populations of other organisms in the food web.

What would happen if the population of slugs decreased?

Slugs, rabbits and insects all eat grass. If there were fewer slugs there would be more grass for the rabbits and insects. With more food the populations of rabbits and insects would increase. However, the thrushes would have to eat more insects to maintain their population, so it is also possible that the population of insects could decrease. This is turn may reduce the populations of voles and frogs.

What would happen if the population of insects decreased?

There would be more food for the rabbits and slugs, so their populations would increase. However, there would be less food for the frogs and voles, so their populations would decrease. This means less food for the foxes and hawks. However, there are likely to be more rabbits and thrushes for them to eat, so their populations are likely to stay the same.

Energy transfer

Energy is transferred along food chains from one stage to the next. But not all of the energy available to organisms at one stage can be absorbed by organisms at the next one. The amount of available energy decreases from one stage to the next.

Some of the available energy goes into growth and the production of offspring. This energy becomes available to the next stage, but most of the available energy is used up in other ways. For example:

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

All of the energy used in these ways returns to the environment, and is not available to the next stage. The animation shows how the level of available energy goes down as it is transferred through a temperate forest food chain.

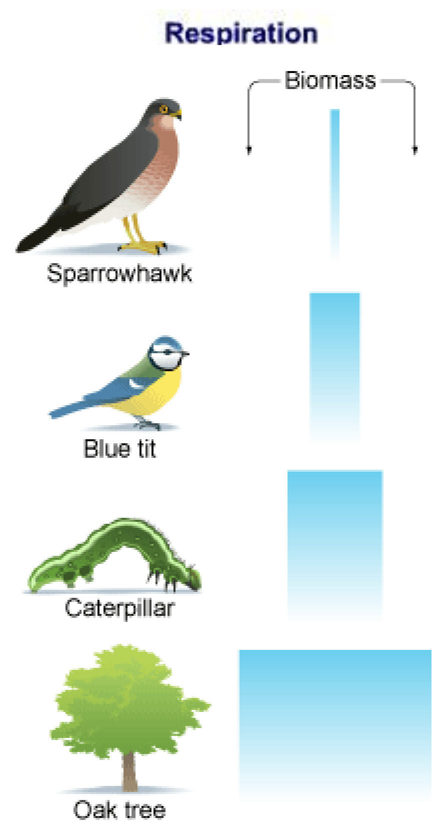
Most food chains are pretty short. There are rarely more than four stages, because a lot of energy is lost at each stage.

Calculating energy efficiency- Higher tier

This bullock has eaten 100 kJ of stored energy in the form of grass, and excreted 63 kJ in the form of faeces, urine and gas. The energy stored in its body tissues is 4 kJ. So how much has been used up in respiration?

The energy released by respiration = 100 - 63 - 4 = 33 kJ
Only 4 kJ of the original energy available to the bullock is available to the next stage, which might be humans. The efficiency of this energy transfer is:

efficiency = 4 ÷ 100 × 100 = 4%



Pyramids of biomass

Biomass means the dry mass of living material at a stage in a food chain. The biomass goes down as you go from one stage to the next, just like the amount of energy.

A pyramid of biomass is a chart, drawn to scale, showing the biomass at each stage in a food chain. The bars become narrower as you reach the top. This pyramid of biomass is for the food chain:
oak tree → caterpillar → blue tit → sparrowhawk

Note that you do not need to draw the organisms, but you must draw your pyramid of biomass to scale. Each bar should be labelled with the name of the organism. In your examination, you will not be asked to draw a pyramid of numbers.

Pyramids of biomass- Higher tier

Each stage in a food chain or pyramid of biomass is called a trophic level. It can be difficult to make a pyramid of biomass because:

- there may be problems measuring dry biomass
- an organism may belong to more than one trophic level, so it cannot easily be represented by one bar.

Recycling

The element carbon is present in all living organisms. It is recycled through various processes, which are described in the carbon cycle.

Nitrogen is essential for the formation of amino acids to make proteins. The nitrogen cycle describes the ways in which nitrogen is recycled.

Carbon cycle

Most of the chemicals that make up living tissue contain carbon. When organisms die the carbon is recycled so that it can be used by future generations. The model that describes the processes involved is called the carbon cycle.

1. Carbon enters the atmosphere as carbon dioxide from respiration and combustion.
2. Carbon dioxide is absorbed by producers to make carbohydrates in photosynthesis.
3. Animals feed on the plant passing the carbon compounds along the food chain. Most of the carbon they consume is exhaled as carbon dioxide formed during respiration. The animals and plants eventually die.
4. The dead organisms are eaten by decomposers and the carbon in their bodies is returned to the atmosphere as carbon dioxide. In some conditions decomposition is blocked. The plant and animal material may then be available as fossil fuel in the future for combustion.

Nitrogen cycle

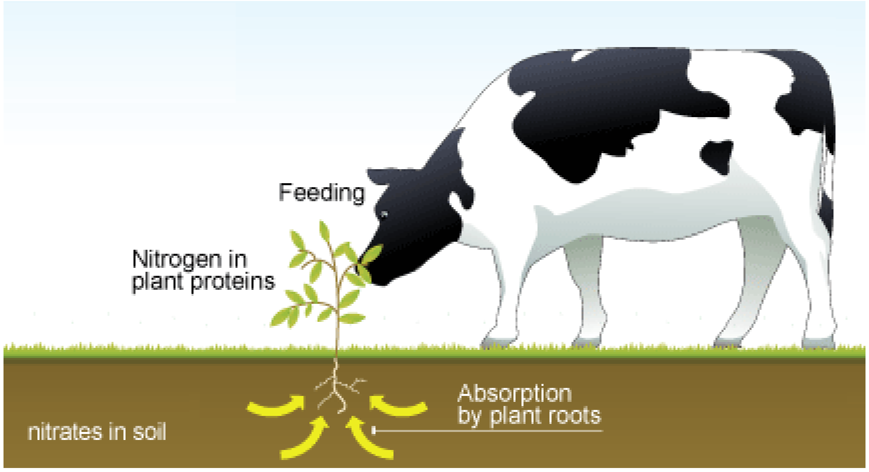
Nitrogen is essential for the formation of amino acids in proteins. The nitrogen cycle is a model that explains how nitrogen is recycled.

About 78% of the air is nitrogen. Because nitrogen is so unreactive, it cannot be used directly by plants to make protein. Nitrates contain nitrogen. Nitrates are soluble in water, so plants are able to absorb them from the soil through their roots. This is how nitrogen compounds can get into plants.

Once in plants, the nitrates are used to make proteins for growth. When animals feed, nitrogen compounds such as proteins are passed along the food chain or food web.

The nitrogen cycle

When animals and plants die, their nitrogen compounds are broken down by soil bacteria, fungi and other decomposers. In this way, nitrogen compounds are returned to the soil, where they may be absorbed by plants again



Read on if you're taking the **higher** paper.

Cycles - Higher tier

Carbon cycle

The oceans absorb carbon dioxide, acting as a ‘carbon sink’. Marine animals may convert some of the carbon in their diet to calcium carbonate. This is used to make their shells. Over time the shells of dead organisms collect on the seabed and form limestone. Due to earth movements this limestone may eventually become exposed to the air. It is weathered and its carbon is released back into the atmosphere as carbon dioxide. Volcanic action may also release carbon dioxide

Nitrogen cycle

Nitrogen is essential for the formation of amino acids in proteins. The nitrogen cycle is a model that explains how nitrogen is recycled.

About 78 per cent of the air is nitrogen. Because nitrogen is so unreactive, it cannot be used directly by plants to make protein. Only nitrates are useful to plants, so nitrogen must be converted to nitrates.

1. Nitrogen gas is converted to nitrate compounds by nitrogen-fixing bacteria in soil or root nodules. Lightning also converts nitrogen gas to nitrate compounds. The Haber process converts nitrogen gas into ammonia for use in artificial fertilizers. Ammonia is converted to nitrates by nitrifying bacteria in the soil
2. Plants absorb nitrates from the soil and use these to build up proteins. The plant may be eaten by an animal, and its biomass used to produce animal protein
3. Urea and egested material is broken down by decomposers. This results in nitrogen being returned to the soil as ammonia
4. Decomposers also break down the bodies of dead organisms resulting in nitrogen being returned to the soil as ammonia
5. In some conditions denitrifying bacteria in the soil break down nitrates and return nitrogen to the air. This is usually in waterlogged soil. Improving drainage reduces this effect, making the soil more fertile.

Interdependence

Different species compete to survive and breed. The size of a predator population depends on the size of the prey population, and the reverse is true as well. Mutualism benefits both species involved in the relationship, but parasitism only benefits the parasite, not the host.

Competition

Habitats have limited amounts of the resources needed by living organisms. Organisms must **compete** with others in order to get enough of these resources to survive. If they are unsuccessful and cannot move to another habitat, they will die.

Animals

Animals might have to compete for mates so that they can reproduce. They may also compete for:

- food
- water
- space.

Plants

Remember that plants make their own food using *photosynthesis*

photosynthesis: *The chemical change that occurs in the leaves of green plants. It uses light energy to convert carbon dioxide and water into glucose. Oxygen is produced as a by-product of photosynthesis.*, so they do not compete for food. They may have to compete for:

- light
- water
- minerals.

Higher tier

A niche is a particular place or role occupied by an organism within an ecological community. Similar species will occupy similar niches. For example, red squirrels and grey squirrels are two different species. They occupy similar but slightly different niches.

The two main types of competition are:

- interspecific competition, which happens between individuals of different species
- intraspecific competition, which happens between individuals of the same species.

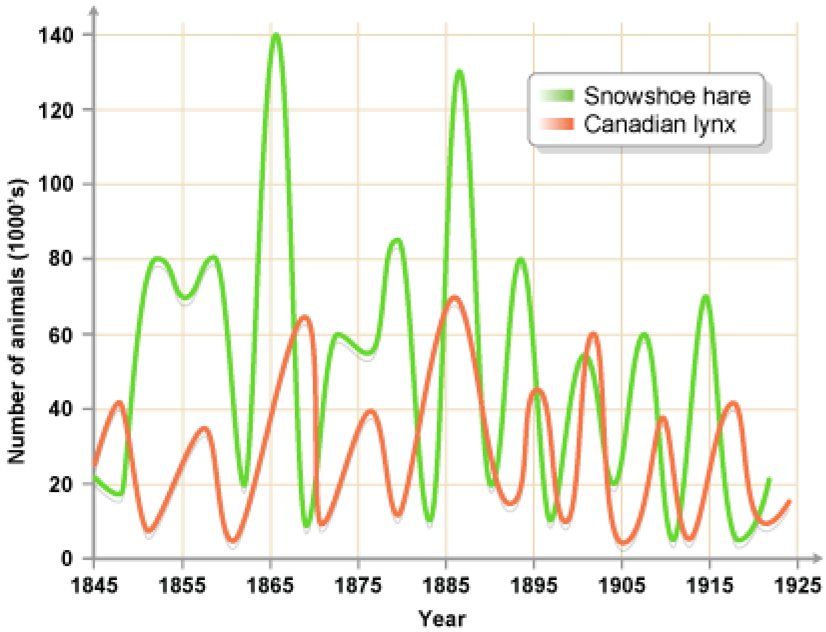
Intraspecific competition is often more significant than interspecific competition. For example, competition between grey squirrels is likely to affect the population of grey squirrels more than competition with red squirrels.

Predators and their prey

Predators are animals that eat other animals. Prey are the animals that get eaten. The size of the predator population and prey population depend on each other.

Lynx and hares

The Canadian lynx eats the snowshoe hare. The size of the two populations was estimated each year for 75 years from the number of animals caught by fur traders. There is a rise and fall in the snowshoe hare population with the lynx population following two years afterwards. No other cat is so dependent on a single prey species, which is why there is such a clear pattern of **interdependence** between the two populations.



The predator/prey dynamic between canadian lynx and snowshoe hare populations

If the prey population grows, predator numbers will respond to the increased food supply by increasing as well. But the growing predator population will eventually reduce the food supply to the point where it can no longer be sustained.

Higher tier

The simulation shows how the population of ladybirds and the population of aphids changes over time. The ladybirds are the predators and the aphids are their prey.

Look at the effects of increasing the predator population, or increasing the prey population, at the start. Toggle the graph on and off to see how the populations change. Notice that the cycles of each population are out of phase with each other - a peak in one population is followed later by a peak in the other population.

Mutualism and parasitism

Some organisms rely on the presence of organisms of a different species. This may be beneficial to both species, but it does not have to be.

Mutualism

In mutualism, both species benefit from their relationship. For example, oxpecker birds eat ticks and larvae infesting the skin of buffalo and other large animals. For this reason oxpeckers are called a cleaner species.

Lichens are another example of mutualism. They are formed by algae and fungi living together. Algae can photosynthesise and make food, which is shared by the fungus. The fungus in turn shelters the algae from a harsh climate.

Parasitism

Parasites are organisms that live on or in a **host** organism. The parasite benefits from this arrangement, but the host suffers as a result. Fleas are parasites. They live on the skin of other animals and suck their blood. This feeds the flea but weakens the host.

A tapeworm

A tapeworm lives inside another animal, attaching itself to the host's gut and absorbing its food. The host loses nutrition, and may develop weight loss, diarrhoea and vomiting. Parasites do not usually kill the host, as this would cut off their food supply.

Adaptations

Animals and plants are adapted to their environment. They have characteristics that allow them to survive there. This makes them better able to compete for limited resources.

Cold climates

Every organism has certain features or characteristics that allow it to live successfully in its habitat. These features are called adaptations, and we say that the organism is adapted to its habitat. Organisms living in different habitats need different adaptations.

For example, the Arctic is cold and windy with very little rainfall. Plants in the Arctic often grow very close to the ground and have small leaves. This helps to conserve water and to avoid damage by the wind.

The snowshoe hare has white fur in the winter and reddish-brown fur in the summer. This means that it is camouflaged from its predators for most of the year.

The polar bear

The polar bear is adapted to life in a cold climate

Polar bears are well adapted for survival in the Arctic. Their adaptations include:

- a white appearance as camouflage from prey on the snow and ice
- thick layers of fat and fur for insulation against the cold
- a small surface area to volume ratio, to minimise heat loss

- a greasy coat that sheds water after swimming
- large furry feet to distribute their load and increase grip on the ice.

Hot and dry climates

Animals and plants may have specific features that adapt them to their environment. These include barbs and spines, poisons and warning colours that deter predators and herbivores. Some harmless species may even resemble a poisonous or dangerous species to increase their chances of survival.

The camel

The camel is adapted to life in a hot climate
Camels live in deserts that are hot and dry during the day, but cold at night. They are well adapted for survival in the desert. Their adaptations include:

- large, flat feet to spread their weight on the sand
- thick fur on the top of the body for shade, and thin fur elsewhere to allow easy heat loss
- a large surface area to volume ratio to maximise heat loss
- the ability to go for a long time without water - they don't store water in their humps, but they lose very little through urination and sweating
- the ability to tolerate body temperatures up to 42°C
- slit-like nostrils and two rows of eyelashes to help keep sand out.

Desert plants

A cactus is adapted to life in a hot climate
Cacti are well adapted for survival in the desert. Their adaptations include:

- stems that can store water
- widespread root systems that can collect water from a large area.

In addition, cacti have spines instead of leaves. These minimise the surface area and so reduce water loss by transpiration. The spines also protect the cacti from animals that might eat them.

Predators and prey

Successful predators have adaptations that allow them to catch prey, and prey have adaptations to avoid being caught and eaten by predators.

Predators

A red fox with its prey
Here are some adaptations that make animals successful predators:

- built for speed
- sharp teeth and claws
- camouflage to avoid being seen by prey
- eyes to the front of the head to judge size and distance well (binocular vision).

Prey

A goat eating foliage
Here are some adaptations that help animals avoid being caught as prey:

- live in groups (herds or shoals)
- built for speed
- defences such as poison or stings
- camouflage to avoid being seen by predators
- eyes to the side of the head to get a wide field of view (monocular vision).

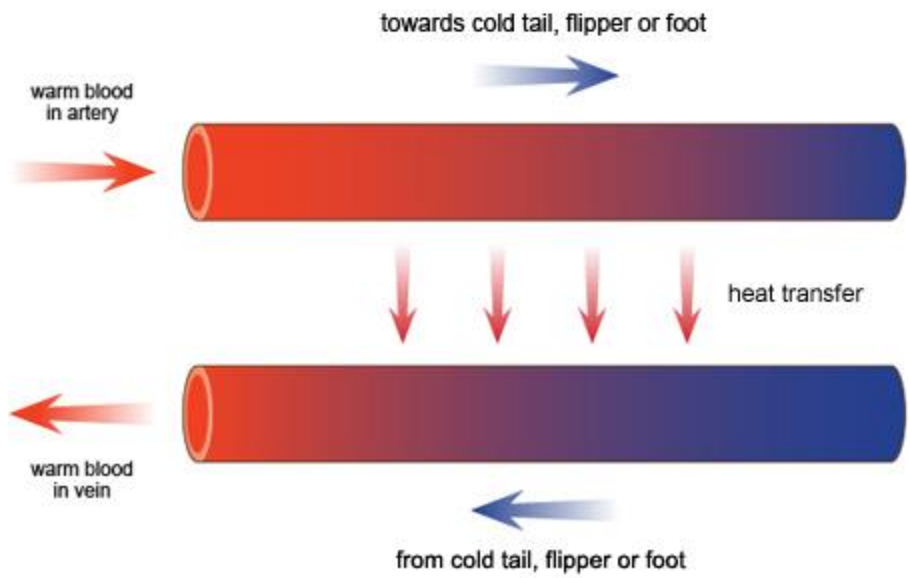
Both predators and prey can improve their chances of success through their breeding strategies. For example, prey species may reproduce when the population of predators is likely to be low. This is called synchronous breeding.

Adaptations - Higher tier

Some organisms are specialists and are well suited just to certain habitats. For example, cacti are adapted to hot, dry climates and would not survive in cold, wet places. On the other hand, some organisms are generalists and can survive well in a range of different conditions.

Counter-current heat exchange

Penguins and other animals in cold climates need to minimise their heat loss to the surroundings. Tails, flippers and feet are relatively flat. They have large surface area to volume ratios and will lose heat quickly. Warm blood entering tails, flippers or feet flows past cold blood returning to the rest of the body. This is called counter-current heat exchange.



Counter-current heat exchange in animals

This arrangement warms the cold blood entering the rest of the body, and cools the blood entering the tail, flipper or foot. It reduces the overall loss of heat from the body.

Extremophiles

Extremophiles live in very extreme environments. They can survive conditions that would kill most other organisms. The extreme conditions can include:

- very high or very low temperatures
- high concentrations of salt in water.

For example, certain bacteria can live in hot springs or around deep-sea hydrothermal vents, where the water can be very hot. Fish in very cold seas have ‘antifreeze proteins’ in their blood and tissues. Certain plants grow well in salt marshes where the salt concentration is too high for most plants. For example, samphire looks a bit like a dandelion but can grow close to the shore.

Natural selection

Darwin's theory of evolution explains how species of living things have changed over geological time. Scientists believe this is the reason why all living things on Earth exist today. Many species have become extinct in the past and the extinction of species continues to happen.

Evolution

The basic idea behind the theory of evolution is that all the different species have developed over time from simple life forms. These simple life forms first developed more than three billion years ago - the Earth is about 4.5 billion years old.

This timeline below shows some of the key events in the evolution of life forms on Earth, from the first bacteria to the first modern humans

Engraving of the extinct dodo

When environments change, some species survive or evolve. However, some species become extinct. The fossil record shows that many species have become extinct since life on Earth began.

Natural selection

Many theories have been put forward to explain how evolution happens. The theory accepted by most scientists is the theory of natural selection. This was first proposed by Charles Darwin.

Darwin

Charles Darwin (1809 - 1882)

Charles Darwin was an English naturalist. He studied variation in plants and animals during a five-year voyage around the world in the 19th century. Darwin later studied hundreds more animal and plant species. After nearly 30 years of research, in 1858 he proposed his theory of evolution by natural selection. He explained his ideas about evolution in a book called On the Origin of Species, which was published in 1859.

Darwin's ideas caused a lot of controversy. This continues to this day, because his ideas may be seen as conflicting with religious views about the creation of the world and creatures in it.

Darwin's theory

Key points of evolution by natural selection:

- individuals in a species show a wide range of variation
- this variation is because of differences in their genes
- individuals with characteristics most suited to the environment are more likely to survive and reproduce
- the genes that allow these individuals to be successful are passed to their offspring.

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. Given enough time, a species will gradually evolve.

Developing theories

Charles Darwin is famous for his theory of evolution, but he was not the only person to develop a theory of evolution.

Darwin's theory

Darwin's theory caused a lot of controversy and his ideas were only gradually accepted. Some people do not believe them today. Some of the reasons for this include:

- Darwin's theory conflicted with religious views that God had made all the animals and plants on Earth
- Darwin did not have enough evidence at the time to convince many scientists
- It was 50 years after Darwin's theory was published that the way that inheritance and variation worked was discovered
- the genes that allow these individuals to be successful are passed to their offspring.

Darwin's theory is now widely accepted because it explains a wide range of observations. It has also been tested and discussed by many scientists.

Lamarck’s theory- Higher tier

Jean-Baptiste Lamarck was a French scientist who developed an alternative theory at the beginning of the 19th century. His theory involved two ideas, which are:

- a characteristic that is used more and more by an organism becomes bigger and stronger, and one that is not used eventually disappears
- any feature of an organism that is improved through use is passed to its offspring.

However, we now know that in most cases this type of inheritance cannot happen.

Lamarck's theory cannot account for all the observations made about life on Earth. For instance, his theory implies that all organisms would gradually become complex, and simple organisms disappear. On the other hand, Darwin's theory can account for the continued presence of simple organisms.

Population and pollution

The human population is increasing rapidly and stretching the Earth’s finite resources, such as fossil fuels and minerals. As a result, the amount of waste and pollution is also on the rise. Certain living organisms act as indicator species, and their presence or absence shows the level of pollution in the air or water.

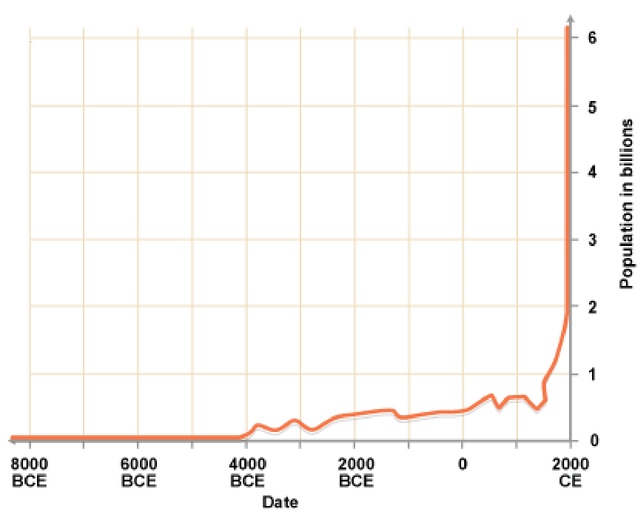
The human population

Like all living things, humans exploit their surroundings for resources. Before the beginning of agriculture about 10,000 years ago, small groups of humans wandered across large areas, hunting and gathering just enough food to stay alive. Population numbers were kept low because of the difficulty of finding food.

Population growth

The development of agriculture led to a population explosion that has accelerated enormously during the past 500 years. Unlike other species, humans can adapt to and survive in almost all habitats and climates.

Human population growth over the past 10,000 years



The graph shows that the human population is growing exponentially- the population increases by more each year. This is because the birth rate is greater than the death rate.

Resources

The growth in the human population is increasing the use of finite resources. These resources include:

- fossil fuels such as coal, oil and natural gas are being used up rapidly
- raw materials such as metal ores and other minerals are being used up rapidly.

Higher tier

People in the developed world enjoy a high standard of living, with abundant food, cars and comfortable housing. Their impact on the use of resources is greater than the impact of poorer people, even though the population of the developed world is much smaller.

Pollutants

Pollution is the addition of substances to the environment that may be harmful to living organisms. The increase in the human population is also increasing the amount of pollution.

Household waste and sewage

Most rubbish is buried in landfill sites and not all of it comprises safe materials. Even common household items can contain toxic chemicals such as poisonous metals. Many smoke alarms contain radioactive americium, for example.

Raw sewage is harmful to the environment. It kills aquatic organisms and harms human health. Sewage must be treated to make it safer before it can be released into the environment.

Carbon dioxide

Carbon dioxide is released when fossil fuels are used. It is a greenhouse gas that can prevent heat escaping from the Earth into space. Increased emissions of carbon dioxide are causing a rise in carbon dioxide levels, which in turn contribute to global warming. People have different 'carbon footprints', depending on how much carbon dioxide their activities produce.

Sulfur dioxide

Many fuels contain small amounts of sulfur compounds. When these fuels are burned sulfur dioxide is released into the air. Sulfur dioxide causes acid rain that can damage buildings, and kill plants and aquatic animals.

CFCs

In the past, chlorofluorocarbons or CFCs were widely used in aerosol cans, refrigerators and insulating materials. CFCs destroy ozone in the upper atmosphere, leading to ozone depletion. This causes increased levels of ultraviolet light to reach the Earth's surface.

Indicator species

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.

Air pollution

The most common source of air pollution is the combustion of fossil fuels. This usually happens in vehicle engines and power stations. Sulfur dioxide is released if the fuel contains sulfur compounds. This gas contributes to acid rain. Lichens can be used as air pollution indicators, especially of the concentration of sulfur dioxide in the atmosphere.

Lichens are plants that 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.

For example:

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

In places where no lichens are growing it is often a sign that the air is heavily polluted with sulfur dioxide.

Water pollution

Water pollution is caused by the discharge of harmful substances into rivers, lakes and seas. 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.

Indicator species for levels of water pollution

level of water pollution	indicator species
clean	mayfly larva
low	freshwater shrimp
high	water louse
very high	rat-tailed maggot, sludgeworm

Sustainability

Certain species are endangered - if they are not helped, they are likely to become extinct. Conservation measures aim to protect species from extinction and habitats from destruction.

Endangered species

Individuals that are poorly adapted to their environment are less likely to survive and reproduce than those that are well adapted. Similarly, it's possible that a species that is poorly adapted to its environment will not survive and will become extinct.

Factors that can cause a species to become extinct include:

- changes to the environment, such as a change in climate
- destruction of habitats

- hunting
- pollution
- competition from other species.

The fossil record shows that many species have become extinct since life on Earth began. Extinction is still happening and a lot of it occurs because of human activities. Human beings compete with other living things for space, food, water and very successful predators.

The dodo

Engraving of the extinct dodo

The dodo was a large flightless bird that lived on Mauritius, an island in the Indian Ocean. The island was uninhabited and the dodo had no natural predators. Then Mauritius was colonised by the Dutch in 1638. Dodos were hunted for food and were easy to catch. New competitors were brought onto the island, including pigs, cats and rats. These ate the dodos' eggs and their young and within 80 years the dodo was extinct.

Helping endangered species

An endangered species is at risk of becoming extinct. For example, the panda and gorilla are endangered and may become extinct. A species can become endangered for several reasons, including:

- the number of available habitats falls below a critical level
- the population of the species falls below a critical level.

A Quagga

For example, the South African quagga was a type of zebra that became extinct because of hunting. The last wild quagga was shot in the late 1870s. However, a lone female quagga later died in a zoo in Amsterdam in 1883, the last of her species.

A species may even be at risk of become extinct if there is not enough genetic variation in the population. This can happen even if the population is still quite large.

Conservation measures

It is important to conserve the variety of living things on Earth. Not only do we have moral and cultural reasons for conserving endangered species, but conservation:

- maintains the future possibility that plant species might be identified for medicines
- keeps damage to food chains and food webs to a minimum
- protects our future food supply.

Some species in Britain are endangered, including the red kite, red squirrel and osprey. They could be helped by conservation measures such as:

- education programmes
- captive breeding programmes
- legal protection and protection of their habitats
- making artificial ecosystems for them to live in.

Plant species can also be endangered. Seed banks are a conservation measure for plants. Seeds are carefully stored so that new plants may be grown in the future.

Whales and fish

Conservation measures are difficult to implement when dealing with certain organisms, such as whales and fish. These animals live in international waters, so international laws and agreements are needed to protect them.

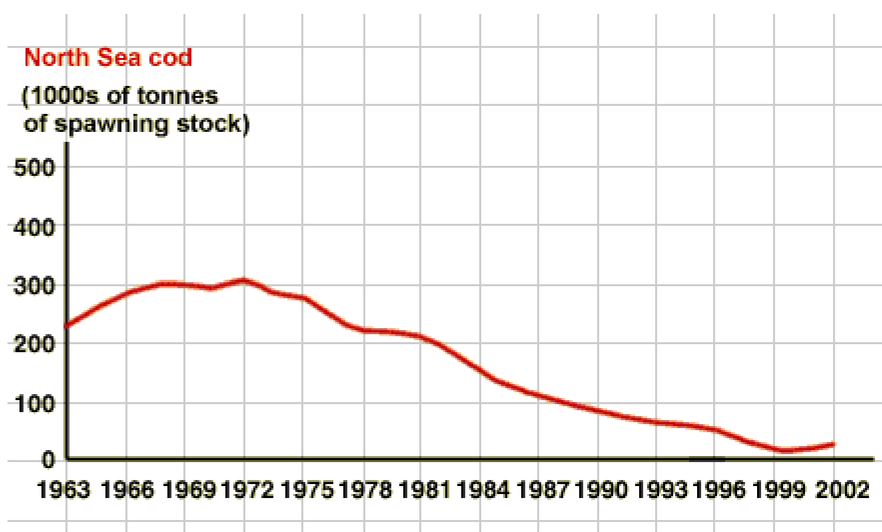
Whales

Many species of whale have been hunted almost to extinction. Whales are a valuable source of raw materials such as whale oil which was used as a fuel in the past. Whale meat can also be eaten. It is part of the diet of some traditional communities, but it is also seen as a delicacy by some people. International agreements protect whales but these are difficult to enforce. For example, some whale hunting still continues as research.

Living whales also have value. Tourists are keen to pay to see whales in the wild, and people may also want to see captive whales in shows. However, there are ethical issues surrounding keeping whales in captivity, including the lack of freedom for a large ocean-going animal.

Fish

Fish are an important part of the human diet, accounting for a worldwide average 15 per cent of humans' protein intake. Most of these fish are caught wild, and if fish are caught at a faster rate than the remaining fish can reproduce, the stock of fish will obviously decline. Trying to harvest more fish than the sea can produce is an example of unsustainability.



Graph showing the decline of North Sea cod stocks since the 1960's.

Since the 1960s North Sea cod have been overfished. More, and larger, fishing boats caught more and more cod. At first, catches continued to increase each year. But then they started to decline, as there were not enough breeding fish left to maintain the cod population. Today, North Sea cod are in danger of extinction.

Fishing quotas are one way to protect stocks of fish. Fishing boats are limited to the species, size of fish, and size of catch that they may take.

Forestry

Humans have now been cutting down trees for around 10,000 years. This was done to obtain wood to burn or build with, or to clear land for farming.

Forestry is sustainable as long as forests are allowed to replace themselves, or are replanted after harvesting. However this is not always done and the result is that the area of forest is steadily shrinking. This is called deforestation and it has profound consequences for ecosystems and biodiversity. Deforestation has a number of consequences including:

- the destruction of forest habitats, endangering many forest-dwelling species
- Causes soil erosion, as the soil-stabilising effect of tree roots is removed- this leads to barren land and a risk of flooding
- increased atmospheric pollution - mostly carbon dioxide - as forests are cleared by burning trees
- a reduction in the amount of photosynthesising vegetation, which increases the levels of carbon dioxide in the atmosphere.

The maps give an idea of how much of the Earth's forest has been lost in the last 10,000 years.

Forestry can be protected by replanting woodland as it is used. Many wood and paper products carry labels to show that they have been harvested in a sustainable way.