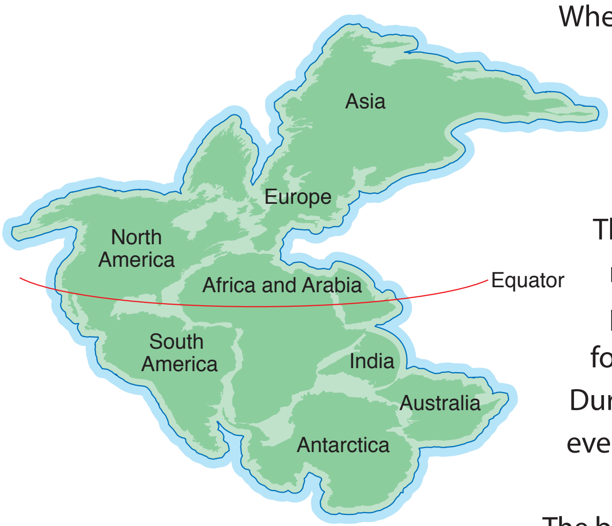
EXPLORING SCIENCE 11

DINOSAURS EXTRA

ALWAYS LEARNING

PEARSON

1 THE CHANGING CONTINENTS



A Pangaea, showing the position of the continents over 230 million years ago.

When dinosaurs first appeared over 230 million years ago in the Triassic period, all the continents were joined together into one land mass called Pangaea.

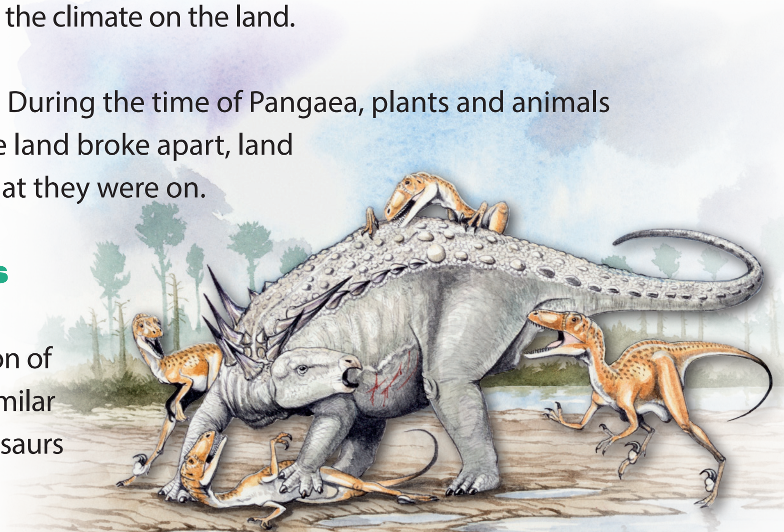
During the Jurassic period, this land mass split in two. The northern part, called Laurasia, included the land that now forms North America, Europe and Asia. The southern part was Gondwana, which included the land that now forms Antarctica, Australia, India, Africa and South America. During the Cretaceous period, Gondwana split up even further, eventually forming the southern continents that we know.

The break-up of the land had major effects. At first, huge areas of shallow seas formed between the continents as they moved apart. This created new habitats for organisms to live in. The smaller continents changed the way in which ocean currents moved. This affected the winds in the atmosphere, which changed the climate on the land.

The distribution of plants and animals also changed. During the time of Pangaea, plants and animals could spread throughout any suitable habitat. As the land broke apart, land organisms could only spread across the continent that they were on.

Evidence for drifting continents

Some of the evidence that persuaded scientists that continents moved over time came from the distribution of dinosaur fossils. During the Jurassic, most areas had similar kinds of dinosaurs, including carnivores like the ceratosaurs and carnosaurs, and herbivores such as early kinds of sauropods. This is what could be expected if there were no barriers to dinosaur movement, such as oceans.



B This illustrator has imagined a pack of Laurasian Cretaceous *Deinonychus* attacking a larger herbivorous dinosaur.

FACT

Groups of fossil *Deinonychus* are found together, but they may have gathered together to feed on a dead animal rather than working together as a group to kill it.

During the Cretaceous, however, there were oceans between Laurasia and the different parts of Gondwana. Dinosaurs in different regions evolved differently, so that different groups were found in different places. Huge sauropods, such as *Giganotosaurus* and *Argentinosaurus,* continued to dominate the part of Gondwana that became South America. Their predators were ceratosaurs, such as *Abelisaurus*.

In Laurasia the main herbivores were hadrosaurs, ceratopsians and ankylosaurs. They were preyed on by tyrannosaurs.

2 CLIMATE AND DINOSAURS

C Parts of the south coast of England are known as the Jurassic Coast. The cliffs are made of limestone and other rocks, formed in warm shallow seas. The rock contains fossils of many sea organisms, such as ammonites.

During the time that dinosaurs were around, the climate on Earth changed significantly. These changes affected the many different kinds of plants and animals that lived with the dinosaurs.

Jurassic period (201–145 million years ago)

The Triassic period that came before the Jurassic had been a time of hot deserts, probably because of the large landmass of Pangaea. As Pangaea broke in two, shallow seas formed between the pieces of land, and wetter winds carried rain over the land.

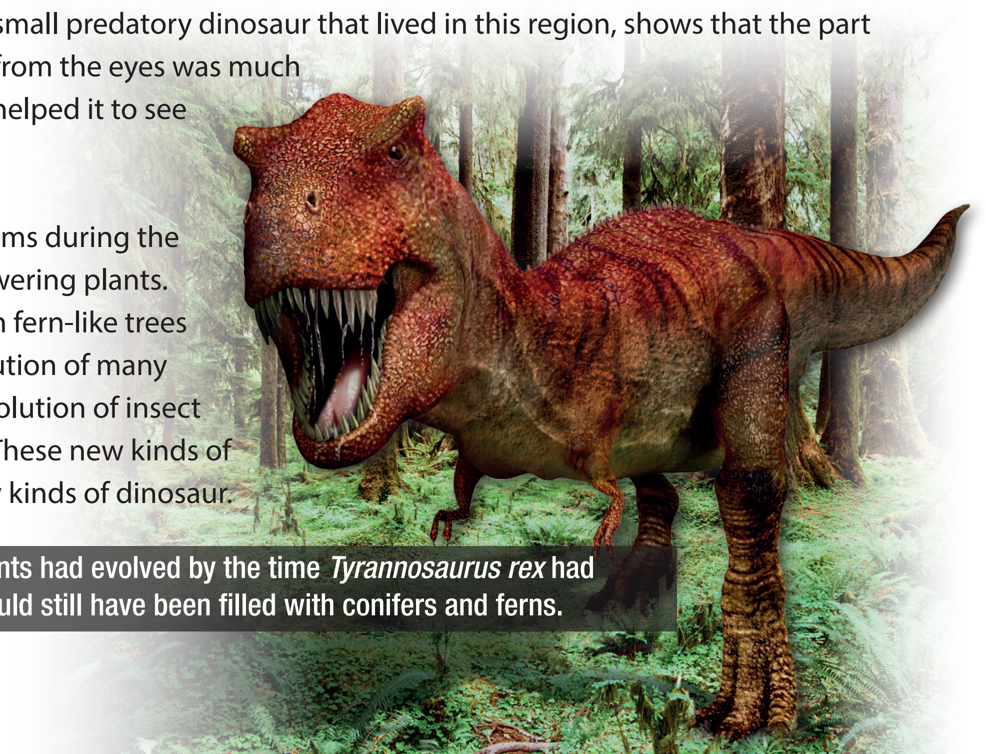
The rain allowed large areas of lush tropical forest to grow, which increased food for herbivores including the large sauropods such as *Brachiosaurus* and *Diplodocus*. The forests were also habitats for insects, which became prey for small insect-eating dinosaurs and for small shrew-like animals that were the first mammals. During the Jurassic period, the first birds evolved from feathered dinosaurs.

Cretaceous period (145–66 million years ago)

In the early Cretaceous period, world temperatures cooled a little, but then warmed again. Part of this effect was caused by the continents breaking up even more and moving apart. Even greater areas of shallow warm seas developed between the continents.

Large areas of warm forest grew over the northern continents. In the south, in areas now part of Antarctica, there was no snow. Instead, they were covered by cool forests where dinosaurs and other animals lived all year round. However, the animals had to cope with cool winters when the sun didn't rise for several months. The skull of *Leaellynasaura*, a small predatory dinosaur that lived in this region, shows that the part of the brain that receives information from the eyes was much larger than usual. Scientists think this helped it to see better in the dark.

The most important change in organisms during the Cretaceous was the appearance of flowering plants. Before then, the land was covered with fern-like trees and conifers. Following the rapid evolution of many new types of plant, there was rapid evolution of insect pollinators, such as bees and beetles. These new kinds of organism provided food for many new kinds of dinosaur.



D Although flowering plants had evolved by the time *Tyrannosaurus rex* had appeared, many forests would still have been filled with conifers and ferns.

3 DINOSAUR FOSSILS

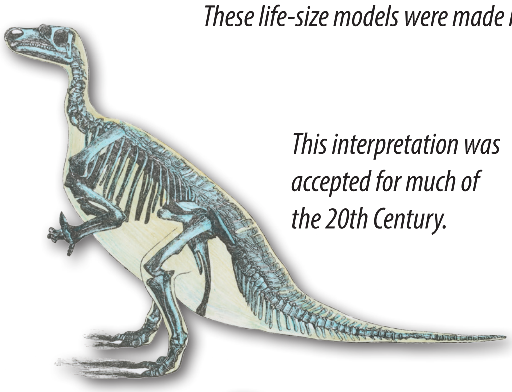
Over 10 000 dinosaur fossil sites have been found. Some have produced many dinosaur fossils, while others only have a few. Most of the fossils are bones, the hardest parts of the skeleton which take the longest to decay. So there is a greater chance that bones will turn to stone if conditions are right.

Even in good sites, it is rare to get more than a few pieces of bone from one skeleton. However, scientists can often interpret from just a few fragments and suggest what kind of dinosaur it was, how big it was and even how it stood. Much of this is done by comparing the new fossil with the many other fossils that the scientists have.

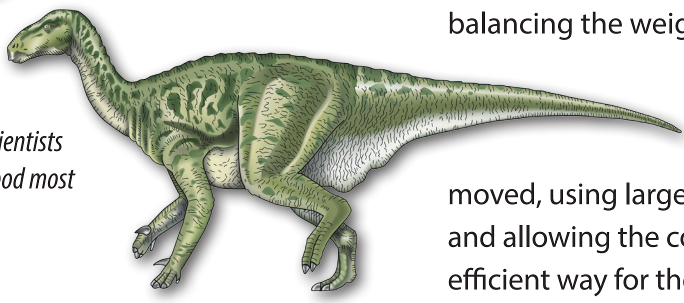
E Scientists were lucky with this fossil as there were several bones from the same animal. This made it easier to interpret what it looked like.

F Models of *Iguanodon* from different times.

These life-size models were made in 1853.



This interpretation was accepted for much of the 20th Century.



This model shows how scientists now think Iguanodon *stood most of the time.*

Fossil interpretations

Interpreting fossil bones can help us understand a lot about dinosaurs, but it can also tell us about how scientists think. In 1878 a large collection of *Iguanodon* fossil bones were discovered in a coal mine in Belgium. Scientists realised that *Iguanodon* was a reptile, because the shape of its bones were like those of the living lizard *Iguana*. The first models of *Iguanodon* set it on all fours, walking like a lizard. They also showed a horn on its nose, rather like a rhinoceros. Later it was realised this was a special thumb.

Closer investigation of the bones showed how the bones were held together, and where muscles were attached. This suggested the animal stood more upright and walked on two legs, with its tail dragging behind. The study of biomechanics (how the skeleton works) developed, and by the 1980s scientists decided that *Iguanodon* most probably walked on all fours much of the time, with its tail balancing the weight of its body.

Computers are often used today, to help work out how dinosaurs moved, using large amounts of biomechanical data and allowing the computer to work out the most efficient way for the skeleton to move.

DINOSAUR FOSSILS CONTINUED

G These serrated cheek teeth of *Edmontonia* suggest it chewed tough plant material.

Ideas from fossil parts

Teeth are also hard parts of the body, and often fossilise. The shape of a tooth can often identify the animal's diet. Small sharp teeth indicate an animal that eats fish. Larger sharp teeth, with points or slicing edges, suggest the animal ate meat, either as a carnivore or scavenger (dead meat). Broad grinding surfaces indicate a herbivore.

FACT

One fossil contains a *Tyrannosaurus* (a predator) and *Triceratops* (its herbivorous prey) that killed each other in a fight. The teeth of the *Tyrannosaurus* were stuck in the skull of the *Triceratops*, while the skull and chest of the *Tyrannosaurus* had been crushed by a blow from the *Triceratops*.

Bones grow as a young animal develops, and the patterns in the bones can suggest how fast they grow. Living reptiles cannot control their body temperature by chemical reactions inside the body. This means they grow slowly, compared with mammals and birds that can keep their body temperature higher than the air around them.

Until the 1970s most people thought that dinosaurs were 'cold-blooded' like living reptiles. However, evidence from inside dinosaur bones shows they grew quickly, and so must have been more like mammals and birds. This means dinosaurs could have been much more active than living reptiles, and could live in colder environments.

H Living lizards bask in the sun to raise their body temperature so they can be more active.

Evidence from eggs

Living reptiles use internal fertilisation, where the male places his sperm inside the female to fertilise her eggs. The female then lays eggs, and the young develop inside the egg before hatching. Many examples of fossil dinosaur eggs have been found.

One of the best dinosaur egg sites, in North America, showed that many *Maiasaura* nested together, with each nest containing 30–40 eggs. Some of the nests contained hatchlings which were probably not able to walk or run for some time after hatching. This means the adult dinosaurs probably looked after their young by bringing food to the nest. Similar evidence of parental care has been found for other species, including *Psittacosaurus* and *Hypacosaurus*.

I A fossil *Apatosaurus* egg is about 30 cm long. An adult was over 20 m long, so the young have a lot of growing to do!

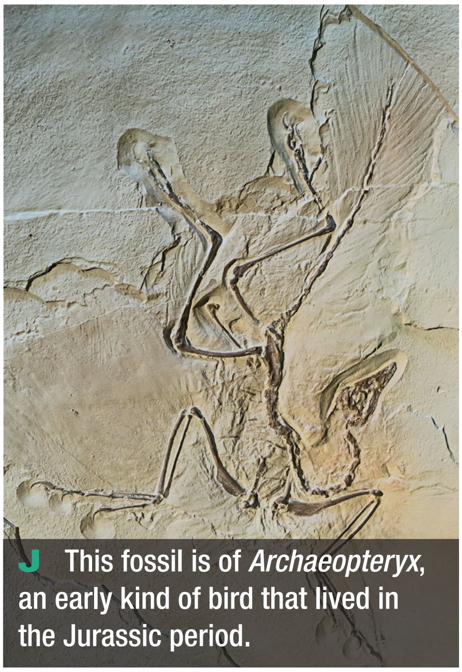
Scientists have suggested that the adults probably did not sit on the eggs to keep them warm, as birds do. The adults were heavy and would have crushed the eggs. However, they may have placed rotting plants around the nest, to help keep the eggs warm.

DINOSAUR FOSSILS CONTINUED

Special preservation

The conditions in which a fossil forms affects what is fossilised. If the sediment that settles around the dead animal is very fine-grained, then a cast of the body shape may be left around the bones. Fossils of *Archaeopteryx*, a bird, in fine-grained limestone show details of feathers. If the fossils had formed in sediment with larger grains, the feather traces would not have been visible, and the skeleton would probably have been identified as a coelurosaur dinosaur.

This evidence was used to support the idea in the 1970s that birds evolved from dinosaurs. It also suggested that dinosaurs may have had feathers. Fossils from China, found in the 1990s, proved this. Scientists think that feathers evolved as insulation, particularly for smaller dinosaur species, and only developed for flight in birds. Larger dinosaur species may have used feather crests for display, such as in courtship.



J This fossil is of *Archaeopteryx*, an early kind of bird that lived in the Jurassic period.

Only very rarely are preservation conditions right for the fossilisation of soft body tissues. The body must be buried very quickly after death, so that decay is prevented. Rare fossils have shown the scaly skin of some dinosaurs, like the skin of crocodiles. What most fossils cannot show is how the skin or feathers were coloured and patterned, although it is quite probable that they were. Illustrations usually use ideas from living reptiles and birds to colour their drawings of dinosaurs.

The rarest kind of fossil is of soft tissue. In 2007 a hadrosaur fossil was found with skin, muscles, tendons and other tissues. This showed that, even with the understanding of biomechanics, some models of dinosaurs are wrong, because the sizes of the muscles in the fossil were much larger than predicted.

K Dinosaur tracks.

Evidence from trace fossils

Trace fossils are made by organisms, but don't include part of the organism. The most common trace fossils of dinosaurs are tracks. These were made in soft sediment, such as mud by a river or seashore. The tracks were then buried by other sediments, which preserved them. When the rock formed from one of the sediments erodes, and wears away, the tracks are visible again.

The size and pattern of fossil dinosaur footprints can suggest which kind of dinosaur made them. It can also indicate if the dinosaur was walking or running. The depth of the footprint can indicate how heavy the dinosaur was. And since taller animals generally have longer strides, the distance between footprints can suggest how tall the animal was.

4 WHAT WE MAY NEVER KNOW ABOUT DINOSAURS

Fossils can give us a lot of information about the structure of the animal, and the conditions in which they died. However, there are some things, such as colour and behaviour, that we can only make guesses about.

Some dinosaur fossils have strange structures that are unlike anything that living animals have. For example, *Stegosaurus* had a set of bony plates along its back, and spikes along its tail. *Stegosaurus* was a large herbivore, so maybe the plates and spikes were for defence against predators, or for displaying to other *Stegosaurus*. There are grooves on the plates, which may have carried blood vessels. So this could have helped to cool the animal's blood, like the large ears of the African elephant today. We will never know the right answer, because maybe the plates had all these functions.

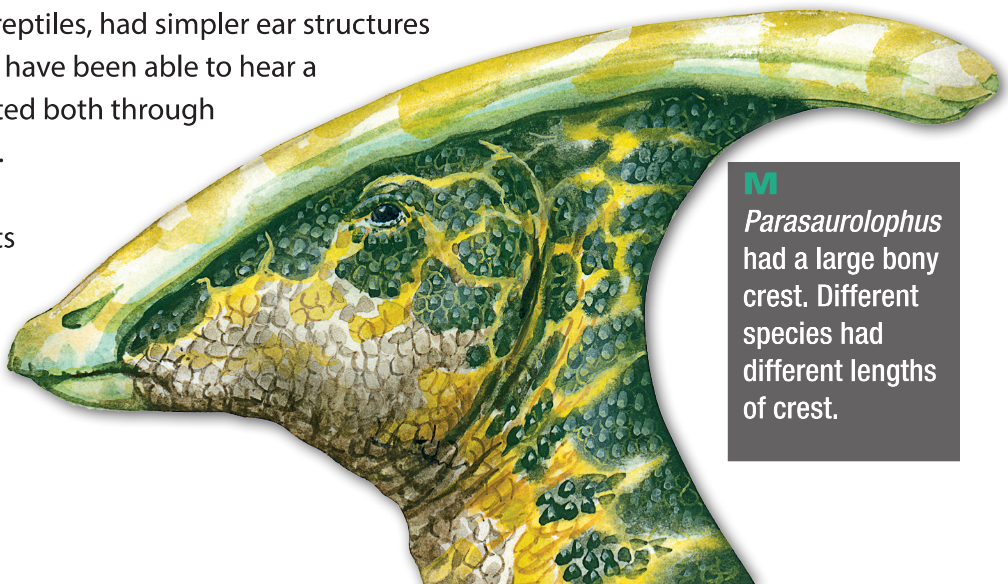
L In the early Jurassic period, there were many species of stegosaurids, like this one. They all had large plates along their spine, and spikes along the tail.

There are several kinds of dinosaur with strange structures on their heads. *Pachycephalosaurus* had an extremely thick rounded skull. Scientists think the thickening would have been protection when males fought with each other by bashing their heads together, like male deer do today. The most likely explanation for the males fighting would be to decide which male would mate with a female.

Parasaurolophus had a long bony crest at the front of its skull. This wasn't protection for fighting as it contained extremely long nasal tubes. One possible reason for the long tubes would be to warm air coming through the nose, which is an adaptation to living in cold regions that is seen in living animals. Experiments have shown, however, that these tubes could have resonated at a frequency that is within hearing range. The sound would have been a low bellow, rather like an elephant trumpeting. Communication by sound would be useful in herds of dinosaurs, for example, to warn of predators.

Although dinosaurs, like living reptiles, had simpler ear structures than mammals, they would still have been able to hear a wide range of sounds, transmitted both through the air and through the ground.

So maybe the Cretaceous forests were filled with the sounds of chattering birds and trumpeting dinosaurs. Sadly, we can only guess what it sounded like.



M *Parasaurolophus* had a large bony crest. Different species had different lengths of crest.

EXPLORING SCIENCE EXTRA

Progression in Exploring Science

Welcome to the latest *Exploring Science Extra*. The theme this time is dinosaurs, a subject that seems far from extinct given the recent discoveries of two new species of dinosaur – *Anzu wyliei*, dubbed the 'chicken from hell', and *Torvosaurus gurneythe*, which was the largest terrestrial predator ever to have roamed Europe.

For the new edition of *Exploring Science* we have been thinking a lot about progression, both within a lesson and across the whole of 11–16 learning. It is now vitally important that Science in secondary schools is taught following a coherent 11–16 approach to ensure KS3 gives students the best possible starting point for KS4.

To this end all the learning objectives in *Exploring Science: Working Scientifically* will be based on Bloom's taxonomy statements. In the taxonomy a scientific concept is broken down into statements that reflect an increasing cognitive demand in the understanding and use of a particular concept. The statements build up into a grid, with statements increasing in conceptual difficulty going up the grid and with statements for each concept increasing in cognitive difficulty going across the grid. The statements are then used as the basis of the learning objectives for each topic. As students progress through the course, they should develop their understanding both conceptually and cognitively (as shown by the arrow on the diagram below).

For this *Exploring Science Extra* pack we have included the grids within the teaching notes to give an example of the methodology we have developed. We also hope it will be useful for teachers to see the objectives for a topic arranged in the grid in this way. Allowing teachers to see how the different objectives relate to one another in terms of concepts and cognition gives an idea of where certain statements have come from or where they are leading to. Since we've used the familiar Bloom's taxonomy in the grid, it should also provide a convenient framework for teachers to create their own additional objectives should they so wish.

Best wishes

The Exploring Science Team

		Cognitive Statements					
		Remembering	**Understanding**	**Applying**	**Analysing**	**Evaluating**	**Synthesising and Creating**
	• most difficult conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this
	• conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this
	• conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this
	• conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this
divided into Conceptual Statements	• conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this
	• conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this
	• conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this
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	• easiest conceptual statement	students remember this	students understand this	students apply this	students analyse this	students evaluate this	students synthesise and/or create this

Exploring Science Extra 11
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Dinosaur footprints activity (Activity Sheet 4 and associated teaching notes): The publisher would like to thank Earth Learning Idea for use of their link to 'How to weigh a dinosaur'
http://www.earthlearningidea.com/PDF/How_to_weigh_a_dinosaur.pdf

Dinosaur life cycles

***Exploring Science* link: 7B**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Different animals have different life cycles.	Identify stages in the life cycle of an animal. Identify ways in which animals care for their offspring.	Describe the life cycle of a dinosaur. Describe how some dinosaurs care for their offspring.	Show a dinosaur life cycle as a diagram.	*Compare the amount of care of offspring in different species.*	*Explain the implications of aftercare in different situations.*	

Ask students what we know about the life cycles of dinosaurs. (Students may have already have a range of background knowledge from different media.) Use an example of one species, such as *Tyrannosaurus rex*, to roughly outline a life cycle on the board, including whether fertilisation and development of the young is internal or external, and whether there was parental care of the young. Students should consider what evidence there is for each stage of the life cycle, and how reliable are the conclusions made from that evidence. Knowledge may be patchy about this species, but the discussion should focus on raising awareness of topics to include in their own research.

Ask students to choose a different dinosaur species, and to carry out research using the Student Booklet or other sources in order to draw as detailed a life cycle as possible. You may wish to draw students' attention to http://prehistoric-wildlife.com/ or the iDinoBook app for iPad/iPhone.

They should include the evidence for each stage of the life cycle and how reliable they think that evidence is. This can be simply done by adding between 1 and 3 smiley faces to each statement, with 1 being 'low reliability' and 3 being 'high reliability'.

Note that there are web pages that discuss how some of the larger species may have managed sexual reproduction. Although some students may find this distracting, keep them focused on the reliability of the conclusion based on the evidence available (mostly by comparing how living species of lizards and birds manage this).

Dinosaur adaptations

***Exploring Science* link: 7C**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Organisms have physical and behavioural adaptations to their habitats.	Describe the adaptations of some dinosaurs to their habitats.	Explain how particular adaptations increase the chances of survival.	Explain how particular adaptations limit an organism's distribution and abundance.	*Make predictions about how changes in [physical, biological] factors will interact with adaptations and affect survival.*		

Ask students to read the Student Booklet to find adaptations in shape and form in a range of dinosaur species. They could extend their research using books, the Internet or other media. They should compare the adaptations to try to identify which environmental factors they helped the dinosaurs to survive. Students should give a reason for why each adaptation improves survival.

This could be extended to suggest other useful adaptations that dinosaurs might have had but for which there is currently little or no evidence, such as colouring, and form and function of soft tissues.

Why aren't there more fossils? *Exploring Science* link: 7H

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Fossils can be found in sedimentary rocks.	State the meaning of: fossil.	Explain how fossils form.	Use an understanding of fossil formation and of erosion to explain why there aren't more fossils.			

Ask students to consider how many dinosaurs (individuals not species) lived during the 135 million years that the group dominated the Earth. (As there will have been more than one of each species alive each year, a rough guess would possibly be billions.) Then ask them to suggest how many dinosaur fossils have been found. (Currently there are about 3 000 complete skeletons, but there may be many thousand fossils of parts of dinosaurs or the traces they left.) By comparing the two, students should realise that many organisms do not form fossils when they die.

Ask students to work in pairs or small groups, and ask each group to focus on one of the following study areas:

- How many different ways can dinosaur fossils be made (both from parts of the body and from traces of what they did), and what conditions are needed to make them?
- How many ways could dinosaur fossils that have been made then be destroyed or remain undiscovered?

Groups should research their study area and record notes of what they find in a table or concept map. The *Skills Sheet RC3 Note making* may be useful to support them with this activity.

Pair up groups covering different study areas and ask them to combine their notes to help explain why we haven't discovered more dinosaur fossils. They could present their findings in different ways, such as a poster, slideshow presentation, or even developed as a card game 'Will my dinosaur become a fossil?'

Resources: Skills Sheet RC3.

Sauropod support *Exploring Science* link: 7J

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Upthrust is a force that acts in liquids and gases.	Recall the unit for measuring forces. State what is meant by: upthrust. Recall the factors that affect the amount of upthrust on an object.	*Explain why an object floats.*	Represent sizes and directions of forces using arrows.	Compare the size of different forces. Use the size of different forces to predict their effect on a body.	*Evaluate the usefulness of different ways of representing the size and direction of forces.*	

This activity gives students the opportunity to draw force diagrams for a sauropod dinosaur walking on dry land and in a swamp, and to use the diagrams to make comparisons of the forces on the animal in different environments. *Activity Sheet 1* presents this activity. Some students may need help drawing the force diagrams, and explaining why the upthrust of the water reduces the reaction force of the ground on the sauropod.

Useful background information about the modelling of sauropod movement that could be used to introduce the activity can be found by carrying out an internet search for 'digital animated sauropod'.

Resources: Activity Sheet 1.

Answers:

8 The diagram should show one arrow, from the middle of the dinosaur's body pointing down to the ground, and one pointing up from the ground surface to the dinosaur of equal size and length. The value on each arrow should be 80 000 N.

9 **a** and **b** The diagram should show one arrow from the middle of the dinosaur's body pointing down to the ground. This should be the same size and shape as the arrow used in the answer to Q1. There should be one arrow pointing up from the dinosaur's body representing the upthrust from the water. This should be smaller than the downward arrow (though relative size is not important). There should be a second arrow pointing up from the ground to the dinosaur, like the one in Q1 but smaller.
c The combined length of the two upward arrows should be the same as the length of the downward arrow because the dinosaur is neither moving up nor down.

10 **a** The reaction force from the ground is less in the swamp diagram than the dry land diagram because some of the weight of the dinosaur is balanced by the upthrust of the water.

b Sauropods were very large and heavy. Supporting some of their weight by the water in a swamp would have made it easier for them to move around.

Dinosaur extinction ***Exploring Science*** **link: 8D**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Changes to an area can lead to endangerment and extinction for some organisms living there.	Define the meanings of: endanger, extinct.	Explain how changes in an ecosystem can lead to endangerment and extinction.	*Suggest methods of conservation that can be used to ensure the survival of [organisms, habitats].*	*Compare the benefits and drawbacks of conservation efforts to protect [organisms, habitats].*	*Develop an argument for or against a certain conservation effort.*	*Use evidence from a range of resources to justify the targeting of conservation efforts.*

Students could extend the task on dinosaur extinction in unit 8D to consider not just the end of the Cretaceous 65 million years ago, but the appearance and loss from the fossil record of a number of dinosaur species over the Jurassic and Cretaceous, such as *Stegosaurus, Hadrosaurus, Argentinosaurus, Tyrannosaurus* and *Velociraptor.* They should then look for evidence of the changing environment during this long period, such as evidence from fossil plants and other animals, and evidence from the rocks that indicate sea level and surface temperature.

Students should summarise their findings by writing one or two paragraphs under the heading *Dinosaur extinction caused by meteorite: fact or fiction?* Encourage students to structure their paragraphs in order to present their ideas as clearly as possible.

Evidence for plate tectonics ***Exploring Science*** **link: 8H**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Movements of the Earth's crust and upper mantle cause changes in the Earth's surface.	Describe the evidence used to support the theory of continental drift as a result of tectonic plates. State the meaning of: continental drift, plate tectonics.	Describe how the Earth's crust and the upper part of the mantle are cracked into a number of tectonic plates.	Use the idea of tectonic plates to predict the distribution of dinosaur fossils	*Describe how the theory of plate tectonics became accepted.*	*Evaluate other theories about the Earth.*	

Students could consider how the distribution of dinosaur fossils provides evidence for the theory of plate tectonics. They should be introduced to the fact that Laurasia (the northern landmass) and Gondwana (the southern land mass) separated during the Jurassic, and that Gondwana underwent further break-up, resulting in Africa, South America, and eventually India, Australia and Antarctica, during the Cretaceous period. Many dinosaur families evolved and went extinct during these two periods. Students could search the internet for an animation that shows how the continents have moved over the last 800 million years, to help them appreciate some of the effects this might have had on life.

Students could consider the distribution of one particular family of dinosaurs, for example, sauropods or hypsilophodonts, and use their knowledge of plate tectonics to answer the question *Why are fossils of Jurassic dinosaur species found across many continents, but Cretaceous species are found within a smaller area?* A simpler question for some students is *Dinosaur fossils have been found in the mountains of Antarctica. Why are they there?* Students could prepare an illustrated poster or slideshow to present their answer.

What could dinosaurs hear? ***Exploring Science*** **link: 8L**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
The vibrations of sound waves can be detected.	State the meaning of: pitch, volume and intensity. Recall that sounds can be detected by sound meters and microphone. Recall that different animals have different hearing ranges.	Describe the parts of the ear and their functions. Describe the connections between frequency and pitch.	*Describe how to make sounds of different pitches using a variety of sources.*	*Relate the size/length of a source of sound to the pitch of the sound it produces.*		

Use the Student Booklet to introduce the question *What could dinosaurs hear?*

Activity Sheet 2 presents a graph of hearing range and questions that lead to a deduction of what dinosaurs might have been able to hear. Some students may need help interpreting the graph before they answer Questions 2 and 3.

Ask students of lower ability to work in pairs or as a group to read through the information in the Activity Sheet and identify the different sources of evidence for a deduction that large dinosaurs probably felt sounds through their feet as much as hearing sounds transmitted through the air.

Resources: Activity Sheet 2.

Answers:

1 The higher the frequency, the higher the pitch of the sound.

2 **a** Mouse, because the lowest point of its hearing curve (the most sensitive part) is at the highest frequency.

b Elephant.

3 The curves suggest that the bigger the body mass, the lower the hearing range.

4 **a** Possibly between the human and mouse curves, along the *x* axis, with a shallower curve sitting higher on the *y* axis. This is because it is smaller than a human, but larger than a mouse, and its hearing was not as sensitive.

b Probably a lower range than the elephant (to the left of the elephant) with a shallower curve sitting higher on the *y* axis. This is because the dinosaur was much larger than the elephant, and its hearing was not as sensitive.

5 **a** *Argentinosaurus* because its hearing was probably most sensitive to low-frequency sounds that are transmitted better through the ground.

b This could have helped in several ways, for example, the animal would be aware of other dinosaurs of the same kind, so they might group together for protection (as elephants do); or it would help identify an approaching large predator such as *Spinosaurus*, so it could prepare to defend itself.

The effect of outer ears — ***Exploring Science*** **link: 8L**

Using the fact that mammals have outer ear flaps but dinosaurs did not, students could carry out a simple practical investigation of the effect of the outer ear on hearing. They could use a sound meter or microphone connected to an oscilloscope or datalogger to gather data, and compare results with and without a cone of paper to model an outer ear. Students could be shown how to use the equipment, and then asked to design their own experiment to test if the cone affects sensitivity to the direction of the sound, or to different frequencies of sound. They should use their results to try to draw conclusions about differences in hearing between mammals and reptiles.

Social behaviour in dinosaurs — ***Exploring Science*** **link: 9D**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Animal behaviour can be social.	Recall that some animal behaviour is social. Describe how social behaviour requires communication.	Describe how social behaviour is beneficial to an organism.	*Classify behaviours as [innate, learned, social].*			

Challenge students to find as many examples of social behaviour in dinosaurs as they can in the Student Booklet. They could extend their research by looking in books or on the Internet. For each example of behaviour, students should try to explain how it helped that species to survive.

More able students should also consider how the evidence for that behaviour has been interpreted using examples from living animals, and whether the evidence is reliable enough to conclude that the dinosaur behaved in that way.

Climate change in the time of the dinosaurs — ***Exploring Science*** **link: 9G**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Some gases in the atmosphere help to keep the Earth warm.	State the meaning of: climate change Recall some effects of climate change.	Explain how some change in some factors could lead to climate change.	Explain how proxies can be used to identify climate change in the past.		*Evaluate evidence from proxies for climate change.*	

This activity extends the work in the *Year 9 Student Book* on temperatures in the past, by looking at other sources of evidence for temperature. *Activity Sheet 3* provides examples of different kinds of rock and conclusions that can be made about the environment in which they were formed. Students should cut out the boxes, then link each pieces of evidence with one or more conclusions.

Then describe the dominant rocks during the time of the dinosaurs as follows:

- Triassic: large areas of red sandstone and salt deposits
- Jurassic: large areas of limestone and mudstone, with no evidence of glacial deposits even in land at polar regions at the time

- Cretaceous: large areas of chalk, and also mudstones in freshwater environments.

Students should use this information to draw conclusions about how the environment changed over the time that dinosaurs lived on Earth.

More information about past climates and how they are identified can be found at http://www.scotese.com by selecting 'Climate history'. A general description of the rocks of this period in the UK, and the general climate, can be found at http://www.naturalengland.org.uk by searching for 'geological history' and selecting the appropriate periods.

Resources: Activity Sheet 3.

Answers E1 C6, E2 C3, E3 C1, E4 C5, E5 C4, E6 C2.

How fast were dinosaurs? ***Exploring Science*** **link: 9K**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
There are different methods of measuring speeds.	Recall the measurements needed to calculate a speed.	Explain how the distance travelled and the time taken affects the speed.	*Describe changes of speed shown on a distance-time graph.*	*Calculate speeds from a distance–time graph.* *Calculate the relative speed between two objects moving along the same line.*	*Measure speed in various ways and evaluate the methods.*	*Draw a simple distance–time graph.*

The calculation of speed of dinosaurs from the stride length (distance between footprints) measured from dinosaur tracks is beyond most students at this level. Details can be found on the University of Sheffield Sorby Geology group website: do a search on a search engine using 'University Sheffield dinosaur footprint calculator' to find the relevant information. However, the link between speed and stride length could be investigated quite simply by using students as models for dinosaurs. Students need to consider a way of recording footprints (safety note: wet feet is a simple method, but students should not run with wet feet on a slippery surface) and speed. The distance between footprints at different speeds should be measured and plotted on a graph, to identify a relationship.

Dinosaur footprints ***Exploring Science*** **link: 9L**

Conceptual statement	Remembering	Understanding	Applying	Analysing	Evaluating	Synthesising and creating
Pressure is a way of saying how concentrated a force is.	State what is meant by: pressure. Recall some common units for measuring pressures.	Describe how the pressure depends on force and area.	Use the formula relating force, pressure and area.	*Explain applications of pressure in different situations.*		

This activity uses information from a demonstration to estimate the mass of a dinosaur from the pressure indicated in a footprint. Details are given on 'How to weigh a dinosaur' available at http://www.earthlearningidea.com/PDF/How_to_weigh_a_dinosaur.pdf, copyright © Earth Learning Idea. *Activity Sheet 4* supports this activity.

Carry out the demonstration described at the start of the PDF from the website, to produce a 'footprint' for a 1 kg mass. Ask students to measure the depth of the 'footprint' and to use this measurement to begin the calculations on *Activity Sheet 4*. Some students may need help with the calculations.

Safety (during demonstration): Make sure the container is at least 20 cm from the edge of the surface, to reduce the risk of harm from falling weights. Remind students to wash their hands after the practical work as they will have been handling wet sand.

Resources (per student): Activity Sheet 4, copy of footprint diagrams from final page of PDF from the website.

Resources (for the teacher demonstration): Rectangular block 10×2×2 cm, large wide container, sand, water, 1 kg mass or 1-litre plastic bottle filled with water and sealed.

Answers: Note: these calculations are based on a depth of 1.5 cm for the block 'footprint'.

1 1.5 cm **2** 10 N **3** 4 cm^2

4 10/4 = 2.5 N/cm^2

5 325 cm^2 **6** 3 cm **7** $2.5 \times 3/1.5 = 5$ N/cm^2

8 $5 \times 325 = 1625$ N **9** 1625/10 = 162.5 kg.

10 The dinosaur mass is nearly twice that of a 2 m man. This suggests either a dinosaur taller than 2 m, or a very bulky animal.

11 The calculation is not very accurate for many reasons, including:
- it is calculated from one footprint, and we don't know if that footprint was from an animal standing on both legs (when the mass would be shared between the legs) or in the process of moving from one leg to the other (when the mass would be carried completely by one leg for some of the time)
- we don't know what the sediment was like in which the dinosaur footprint was made, and how it compares to the wet sand used in the model
- we don't know if the dinosaur was walking or running (which might change the pressure on each footprint).

1 Sauropod support

Sauropod dinosaurs are possibly the largest land animals that have ever lived and walked on Earth. Fossils of *Argentinosaurus*, the largest sauropod found so far, suggest it grew to around 40 metres long and weighed around 80 tonnes, ten times more than the largest living elephant. The forces on such a large body cause great strain, and this limits how an animal can move.

Over the years scientists have suggested different habitats for sauropods, based on forces. Answer the following questions to help you understand more about these ideas.

1 **a** Use the image in the Student Booklet to sketch a sauropod walking on land.

b Add arrows to the diagram to show the force due to gravity acting on the mass of the dinosaur on the ground, and the reaction from the ground that supports the dinosaur. Remember that the length of each arrow represents the size of the force.

c Label the force arrows on your diagram and add values for their size. Explain why you chose those values.

Notes

Weight is the force of gravity acting on the mass of a body. It pulls on every kilogram with a force of about 10 N.

1 tonne = 1000 kg

Some scientists suggested that the forces on a sauropod's body were too large for it to have lived on land. Instead, they suggested it lived in swamps, which are areas of shallow water.

2 **a** Sketch another sauropod diagram, this time standing in water that reaches about halfway up its body.

b Add arrows to the diagram to show:
- the total force due to gravity acting on the mass of the dinosaur
- the upthrust on the sauropod from the water
- the reaction force of the ground on the legs of the sauropod.

Remember to use appropriate lengths for the arrows.

c Explain the lengths of the arrows that you used in your diagram.

3 **a** The reaction force of the ground in the two diagrams should be different. Explain why it is different.

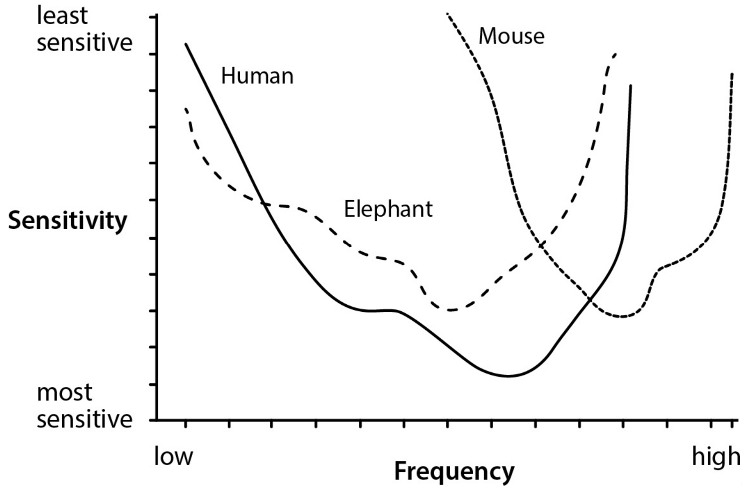
b Use your answer to part **a** to explain why some scientists suggested that sauropods lived in swamps.

Scientists can now use computer models to investigate how sauropods moved. Although they would have a limited range of movements, these models show that even *Argentinosaurus* could have walked on dry land (though it might have had difficulty getting up again if it fell over!).

2 What could dinosaurs hear?

To help us work out what dinosaurs might have been able to hear, we need to look at living animals.

The graph shows the hearing ranges of three living animals of very different sizes.



1 What effect does frequency have on the pitch of a sound?

2 Looking at the graph:

a Which of the animals is most sensitive to the highest sounds? Explain your answer.

b Which animal is most sensitive to the lowest sounds?

3 Use your answers to **2a** and **2b** to suggest a relationship between body size and hearing range.

Dinosaurs were reptiles. The animals shown in the graph are mammals. Mammals and living reptiles have different ear structures. The ear structure of mammals makes their ears more sensitive than those of reptiles to all sounds that come through the air.

4 Use this information to suggest what a hearing range curve on the graph above might look like for:

a a small dinosaur such as *Coelurus* (about the size of a chicken).

b a massive dinosaur such as *Argentinosaurus* (about 10 times the mass of an elephant)

Explain your answers.

The vibrations that we detect as sound can also reach our ears through our body. Low frequency vibrations travel better through solid substances (such as the ground or the body) than high frequency sounds. Elephants are better at detecting low frequency sounds from the ground than humans. This helps them detect the movement of large animals (such as other elephants) at a distance where they are out of sight.

5 **a** From your answers to **4a** and **4b**, which dinosaur would more likely have sensed sound vibrations from the ground? Explain your answer.

b Suggest how this would have helped the dinosaur to survive.

3 Evidence from rocks

When scientists try to work out the temperatures of the past, and the environments that existed, they can use evidence from ice cores and pollen grains to look at the past 1 million years or so ago. However, the dinosaurs lived many millions of years ago. So we need other sources of evidence for environments to help work out what the Earth was like when dinosaurs lived. Much of this evidence comes from the type of rocks that were formed at the time.

1 Cut out the boxes below and link each piece of evidence from the rocks to the conclusion that is drawn from it.

2 Try to explain the link between each piece of evidence and the correct conclusion.

3 Your teacher will describe some of the rocks found during the Triassic, Jurassic and Cretaceous periods.

Use your conclusions to suggest what the environment was like during each of the periods.

Ages of periods

Triassic period: 252–201 million years ago

Jurassic period: 201–145 million years ago

Cretaceous period: 145–66 million years ago

Evidence 1 Red sandstone (formed from sand grains in very dry regions)	**Evidence 2** Coal (formed from the remains of trees and other plants growing in freshwater swamps)	**Evidence 3** Glacial till (large amounts of jumbled stones and pebbles dropped by glaciers)
Evidence 4 Chalk and limestone (formed from the bodies of tiny shelled organisms that lived in warm salt water)	**Evidence 5** Rock salt (salt collects in sediments when salty water evaporates, before the rock forms)	**Evidence 6** Mudstone (formed from layers of mud that settle on the bottom of shallow seas, lakes or in river estuaries)
Conclusion 1 This area was very cold, and covered by ice.	**Conclusion 2** A lot of rain was falling on the land, creating freshwater rivers and lakes.	**Conclusion 3** This area was warm and wet.
Conclusion 4 This area had been a shallow sea but dried out.	**Conclusion 5** This area was covered by warm shallow seas.	**Conclusion 6** This area was very hot and dry.

4 Dinosaur footprints

Name ______________________________ **Class** ____________ **Date** _____________

We can use the size and depth of dinosaur footprints to help estimate the mass of a dinosaur.

Your teacher will show you how a 'footprint' can be made in wet sand using a standard mass of 1 kg.

1 Measure the depth of the block 'footprint', and record it here.

Depth of block 'footprint' = _______ cm.

2 Earth's gravity pulls on every kilogram with a force of 10 N. So the force (or weight) of the block is: force = mass (kg) × 10 = _______ × 10 =_______ N.

3 The size of the block is 10 × 2 × 2 cm. So the area of the block pressing on the sand was:

____________ cm^2.

Pressure = $\frac{force}{area}$

4 Use your answers to questions **2** and **3** to calculate the pressure on the sand from the block.

Your teacher will give you a copy of one footprint of a dinosaur. The fossil track that this footprint was taken from showed that this was a two-legged dinosaur. The top picture shows what the footprint looks like from above. The bottom picture shows the depth of the footprint.

5 Use the squares on the top footprint to estimate as accurately as you can the area of the footprint.

area of footprint =______ cm^2.

6 From the bottom picture, estimate the average depth of the footprint.

average depth of footprint =______ cm.

Assume that the depth of a footprint is proportional to the pressure on the foot. (So, a pressure that is twice as large will cause a footprint twice as deep.)

7 Calculate the pressure of the dinosaur's foot like this:

pressure of dinosaur's foot = pressure of block 'footprint' × $\frac{\text{average depth of dinosaur footprint}}{\text{depth of block 'footprint'}}$

pressure of dinosaur's foot = _______ × ________ =_______ N/cm^2.

8 Calculate the force of the dinosaur's foot using force = pressure (from Q**7**) × area (from Q**6**).

force of dinosaur's foot = _______ × _______ = _______N.

9 The mass of the dinosaur is the force (from Q**8**) divided by 10 (for gravity).

mass = _______ / 10 =_______ kg.

10 The average mass of a man 2 m tall is about 90 kg. Compare this value to the mass you calculated for the dinosaur.

____

11 How accurate is the dinosaur mass you have calculated? Give reasons for your answer.

____

____

Good notes help you to:

- organise the information you find
- make sure you have covered all the important points
- focus on the key points and ignore unnecessary detail
- write a report or a summary in your own words.

Step 1: Start by thinking about what your notes are for:

- writing a summary
- comparing things (e.g. similarities and differences, points for and against)
- showing problems and their solutions
- showing how one thing (a cause) leads to another (an effect) (e.g. when you think up a hypothesis or make a prediction).
- writing lists
- revising.

Step 2: Decide how to organise your notes. It often helps to use different colours. Here are some examples:

Timeline

If your information needs to be organised chronologically, use a timeline to note key points.

1590
first light
microscope

1664
Robert Hooke
sees plant
cells with
microscope

1833
Robert Brown
sees nucleus
in cells

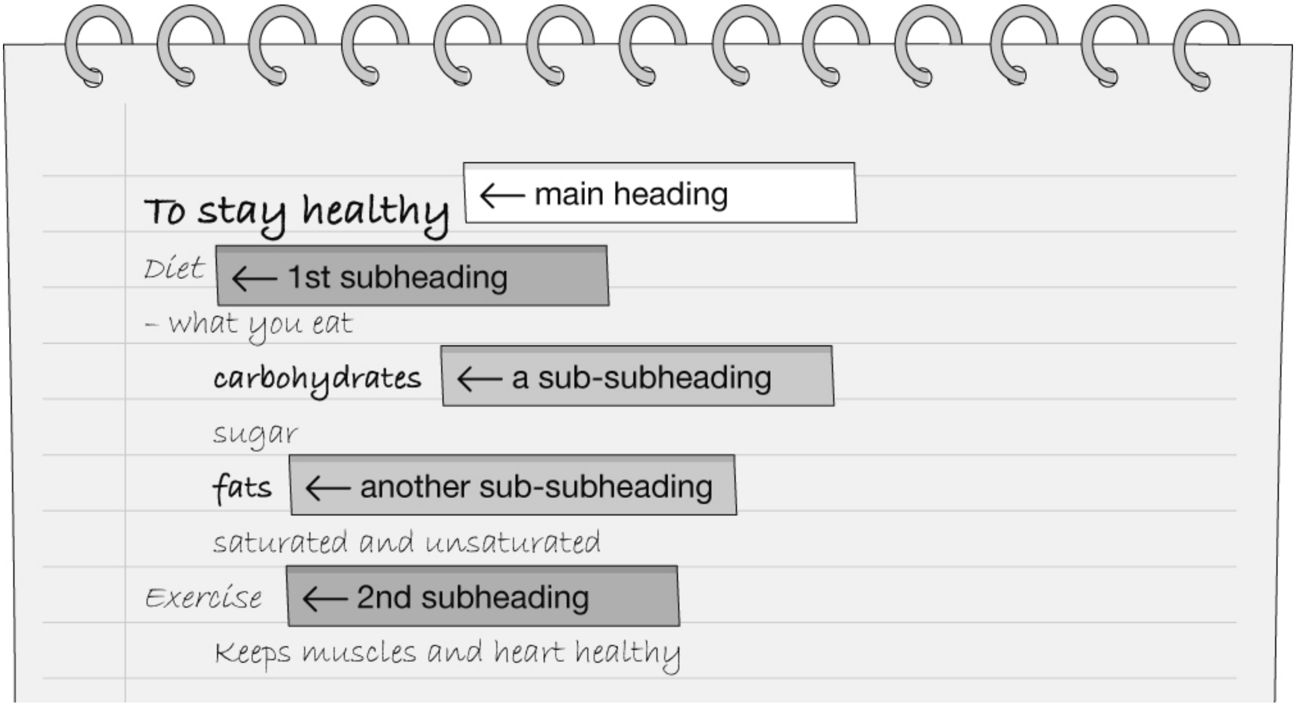
Table

If you need to organise your notes into a few categories, then a table might be more useful.

Advantages	Disadvantages
brakes – allows car to slow down	car working parts – causes overheating
between road and types – allows car to grip the road	brake pads, tyres, engine parts – wears things away

Lists with headings

If you have a lot of information that can be grouped into several categories, a list with headings and subheadings can be useful. This can make writing a report easier because you already have the headings for your report.

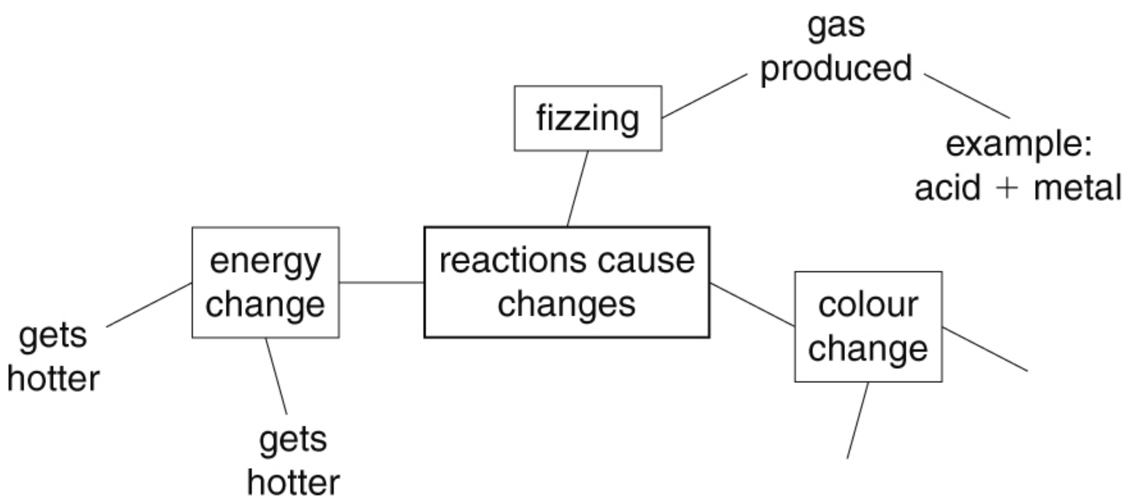


Concept maps

Some people prefer to use concept maps, rather than lists. Concept maps also makes it easier to add new groups of notes to those that you have already recorded.

Concept maps can easily get cluttered, so:

- Start with a clean sheet of A4 and write a title in the middle.
- Add ideas as branches to the map.
- Group similar ideas and link them with lines or arrows.
- Use just one or a few words for each note, to keep the map as tidy as possible.
- Highlight the most important idea in each group – these can make good headings for your writing.



Flow diagrams

Flow diagrams can show how one idea leads to another or can show a sequences of events.

water turned to steam → steam rises → turns turbine → turbine turns generator

Step 3: Skimming and scanning.

The first time you read a text, skim through it quickly. Look for:

- main ideas – these may be shown by headings
- text structure – e.g. from simple to more complex ideas, from old to new
- key words
    - key nouns (what the text is about)
    - signal words and phrases such as:
        - comparisons (e.g. alternatively, although, as well as, but, however, in contrast to, on the other hand, similar to)
        - problems and solutions (e.g. difficulty, problem, solution, question, answer, to overcome this)
        - causes and effects (e.g. as a result of, because, caused by, depends on, due to, if … then …, leads to, so that, therefore, which in turn)
        - lists (which often start with: such as, for example).

Then scan through the text more slowly to look for any specific information that you need. While you are reading, keep in mind what information you are looking for. If your text is printed out, you may be able to highlight anything useful using coloured pens or pencils.

I can...

- Make and organise notes.