The Bristol Dinosaur
Teacher Resource Pack

Keystage 3 & 4

Introduction

The Bristol Dinosaur Project is committed to widening participation in science subjects. The aims of the project are to highlight the accessibility of science and to show students that science is exciting and fun, being on of the only subjects in which they can discover something new, something that has never been found before.

This teacher resource pack supports both of the options available to Key Stage 3 & 4 and post-16, the outreach visit and the university visit. The purpose of the resource pack is to provide background information and classroom–based activities that can be used by teachers. Where relevant, links to the National Curriculum are highlighted. This is by no means the limit of information available on these subjects, more just an insight into the types of information currently around. A list of other good resources is provided in the Resource section.

Contact Us

We hope that this resource has been educational, fun and exciting. The Bristol Dinosaur Project is committed to widening participation in science subjects and this could not be accomplished without the help of committed individuals like you. If you have any questions or comments please feel free to contact us, we always appreciate feedback!

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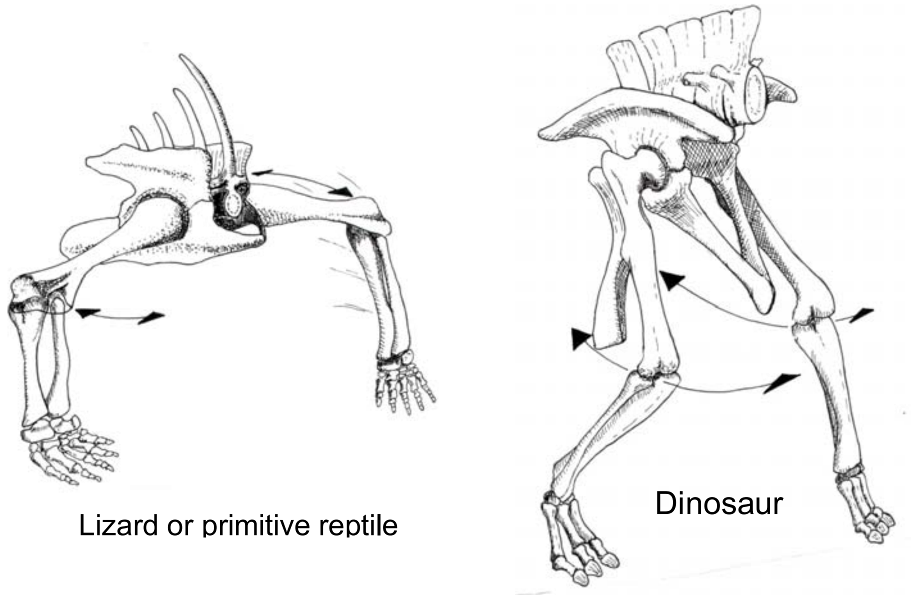
Introduction to Dinosaurs

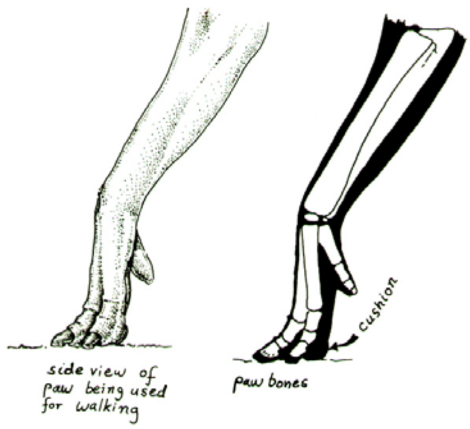
Dinosaurs are not just any large animal that roamed the landscape in the geological past. They are a well-defined group of reptiles known as Dinosauria. All members of this group have to show all of the special features.

All members of this group must show a unique set of special features to be classified as a dinosaur. These include:



✓ Standing upright, with legs tucked directly underneath, like an elephant. Other reptiles (like crocodiles) have a sprawling stance with their legs at the sides of the body; dinosaurs' joints have adapted to enable an upright posture.

✓ More than two sacral (hip) vertebrae and stand on their tiptoes, this is called a 'digitigrade' stance.
✓



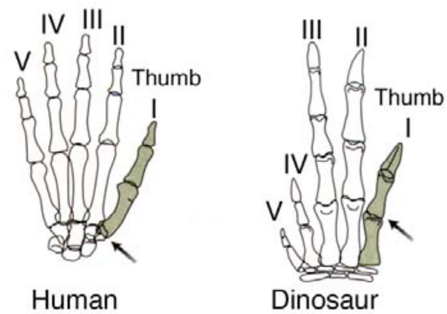
✓ An opposable thumb that can be used to grasp things, like humans'.

✓ A modified ankle joint that forms a simple straight hinge.

✓ Dinosaurs stand on their tip-toes, their phalanges (finger bones). This is known as digitigrade posture.

✓ Dinosaurs have a unique hip joint with an open area between the bottom two bones.

✓ Dinosaurs have more than two fused sacral (hip) vertebrae.



With features like the ones listed above the group Dinosauria is very clearly defined. It does not include flying reptiles (pterosaurs), although they are closely related and it doesn't include any swimming reptiles (ichthyosaurs and plesiosaurs).

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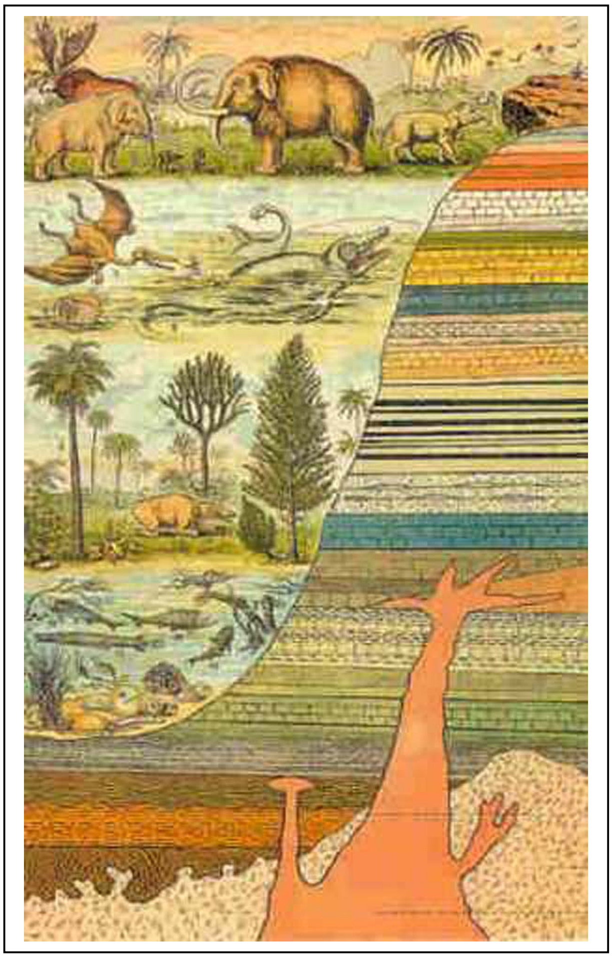
Dinosaurs evolved about 230 - 235 million years ago and died out in the big extinction at the end of the Cretaceous period, 65 million years ago. Dinosaurs were certainly not unsuccessful; they dominated the Earth for around 165 million years. Dinosaurs lived on all continents including Antarctica and were very diverse, ranging from chicken sized to over 30m long.

Mammals did live at the same time as the dinosaurs, but they were very small and made up a small part of the community. Some scientists believe the dominance of the dinosaurs held back the evolution of the mammals, so that it was only after the dinosaurs became extinct, that the mammals flourished.

But then did dinosaurs really become extinct? Many scientists believe that they now live on in the form of birds.

The Geological Time Scale

ERA	PERIOD	AGE (Myr)	ICE AGES	EPOCH
PALEOZOIC	Quaternary	0.01		Holocene
		2		Pleistocene
	Tertiary	5		Pliocene
		26		Miocene
		37		Oligocene
		53		Eocene
		65		Paleocene
MESOZOIC	Cretaceous	136		
	Jurassic	190		
	Triassic	225		
CENOZOIC	Permian	280		
	Carboniferous	345		
	Devonian	395		
	Silurian	430		
	Ordovician	500		
	Cambrian	570		



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Websites

- **Bristol Dinosaur Project** http://palaeo.gly.bris.ac.uk/bristoldinosaur

Information about the project, the Bristol Dinosaur itself, and current research.

- **Dinobase** http://dinobase.gly.bris.ac.uk

Information about dinosaurs including what they were like and how they went extinct.

- **Ask a Biologist** www.askabiologist.com

Ask a question about biology or palaeontology and the experts will answer it!

- **Dinobase** http://dinobase.gly.bris.ac.uk

Information about dinosaurs including what they were like and how they went extinct.

- **Dino Directory** http://flood.nhm.ac.uk/cgi-bin/dino/index.dsml

Up to date dinosaur directory from the Natural History Museum in London. Includes information about where dinosaurs lived and what the Earth was like.

- **Dinosaur Room** www.cotf.edu/ete/modules/msese/dinosaur.html

This website is has two 'floors': the Dinosaur Floor has information on how dinosaurs died out and the Earth Floor discusses topics in earth sciences.

- **Enchanted Learning** www.EnchantedLearning.com/subjects/dinosaurs

A good educational website and easy for children to use. It has information of individual dinosaurs and a number of classroom activities.

- **Journal of Dinosaur Palaeontology** www.dinosauria.com/jdp/jdp.htm

In depth topics about dinosaurs, covers most of the current controversies. An ideal resource for the Debate section.

- **Palaeo Links** www.geology.iupui.edu/classes/g304/Links.htm

Find information on different aspects of palaeontology and prehistoric life.

- **Timeline Gallery** www.prehistory.com/colorchr.htm

A summary of each period of the geological time scale. Shows what animals were around at the time and any major events.

- **Walking with Dinosaurs** www.bbc.co.uk/dinosaurs

This student friendly site discusses the hit BBC program, Walking with Dinosaurs.

Books

Focus on Dinosaur by M. Benton
ISBN 074961076x Gloucester Press, 1993
A non-fisction book which explains basic facts about dinosaurs along with other interesting topics, such as why people think dinosaurs were stupid.

Walking with Dinosaurs The Facts by M. Benton
ISBN 0563537442 BBC Worldwide, 2000
This in depth book about BBC's television show explains facts behind the scenes.

Encyclopedia of Dinosaurs and Prehistoric Life by K. Blount and M. Crowley
This full colour encyclopedia is an excellent fact finder on all aspects of dinosaurs and prehistoric life.

Dinosaurs by S. Pollock
ISBN 0563347538 BBC, 1990
BBC Fact Finder Series book has plenty of great dinosaur info and quiz questions.

Careers in Palaeontology

Careers information should ideally be acquired from a qualified careers advisor; however subjects as narrow as palaeontology very often aren't covered by the scope of normal career advice. This section is split into two areas: Careers in Palaeontology and Careers in Geoscience and aims to give suggestions of the type of courses to take, the experience needed and the personal attributes that would be suited to such a career. Included in this section are also relevant websites and case studies.

What is palaeontology?
Palaeontology is a very broad science, it encompasses many other sciences, particularly biology, geology, chemistry, physics and maths. It is not just dinosaurs! Palaeontology is the study of the history of life on Earth. This can be studied looking at fossils and rocks. Fossils are the remains or traces of living organisms that lived in the geological past and are now preserved in the Earth's crust. Even within a subject like palaeontology there are lots of different fields. Some of which are listed below:

- **Vertebrate Palaeontology -** The study of fossil animals with backbones, this includes amphibians, fish, reptiles, mammals and birds.

- **Invertebrate Palaeontology -** The study of animals without backbones, this includes insects, arachnids, crustaceans and molluscs.

- **Palaeobotany -** The study of fossil plants.

- **Palynology -** The study of organic-walled microfossils, especially pollen and spores.

- **Palaeoecology and Biodiversity -** The study of ancient environments and the organisms living in them.

- **Micropalaeontology -** The study of microscopic fossils which are important to the petroleum and mining industries. Most universities with courses in economic geology offer courses in micopalaeontology.

- **Macroevolution -** The study of large scale patterns of how organism adapt to their environment and change through time.

- **Taphonomy -** This is the study of how an organism enters the fossil record. It includes the study of death, decay, burial and fossilisation of an organism.

What personal attributes do I need to be a palaeontologist?
The attribute that will get you the furthest in a career like this is enthusiasm in your chosen subject. If you are interested in what you are studying you are much more likely to do better in it. You have to be able to work well as a team and on your own as well as being able to pay close attention to detail. Some of the work can be a bit repetitive so you have to be patient and be able to write clear field notes. Unfortunately you cannot become a professional palaeontologist without getting good grades at school.

What do I need to study in school?
The first thing you need to do is get good grades at G.C.S.E. level, in particular in the following subjects: Biology, Chemistry, Physics, Maths, Computer Studies, writing and other languages. With the current AS and A' Levels you have quite a lot of choice about what you take. Taking any of the science subjects will help you get into a relevant course at university. Some schools don't offer Geology A level, but it is not essential to continuing into university. The ideal choice would be A levels in Maths,

Chemistry and Biology. Geography and other languages are also useful subject to take at AS/A level.

What and where do I study at university?
You can get into palaeontology through a number of routes, although unfortunately very few universities do degrees in just Palaeontology. The usual route is doing a Geology degree. This often includes palaeontology options and you may be able to choose a palaeontology research project in your final year. Below is a list of universities that have good palaeontology departments:

- Aberdeen
- University of Birmingham
- University of Bristol
- Cambridge University
- Cardiff
- Durham
- Edinburgh
- Glasgow
- Imperial College, London
- Leeds
- Leicester
- Liverpool
- Manchester
- Oxford
- Plymouth
- Portsmouth
- Royal Holloway, London
- Southampton
- University College, London

Many palaeontologists do biology, zoology or ecology degrees. All of these are useful and make you eligible for an MSc or PhD in palaeontology. After a degree most palaeontologists have to complete either an MSc or a PhD. There are currently only three universities in Britain that run palaeontology MSc programs:

- University of Bristol
- University College London
- Imperial College London

Many of the universities listed as having good palaeontology departments often offer palaeontology PhDs. These change every year, so keep an eye on the different university websites and contact the universities directly if you are interested in doing postgraduate study there.

What experience will help?
Start off by finding out as much as you can about your area of interest. Books are the main traditional source for finding out information, but the internet is quickly becoming an important way to find out current information. Newspapers and magazines like New Scientist and Nature can also give you accurate up to date information about new finds. Visiting museums and talking to experts is valuable as are the field trips that many museums offer. First-hand experience in the field is valuable, although such experiences depend greatly on where you live. Local museum curators or collectors will be able to point you in the right direction and may even need volunteers.

What jobs can I do with an interest in palaeontology?
After a PhD, a graduate may continue their research and get a lectureship at a college or university. Working in a museum as a curator is another popular choice as is working as a rock preparator. Preparators extract bones and fossils from rocks using different tools, including dentist drills! They work in both museums and universities. There are also many jobs in industry, particularly for micropalaeontologists in the oil and gas industries. Many palaeontologists go on to teach in schools, in a wide range of science subjects. An up and coming area of interest is science communication, one in which palaeontologists are gradually seeping in. Science communication covers all types of media (TV and journalism), education and state of the art science centres that concentrate on public understanding of science. At present there are quite a lot of jobs in this area, but sometimes they can be hard to get into as there is a lot of competition. Other jobs that some palaeontologist end up in that aren't directly linked are zoo work, computer programming and retail (often mineral and gem shops).

Careers in Geoscience

What is geoscience?
Geoscience is a word that is used to describe all sciences of a geological nature. These include: Petroleum geoscience, Economic geoscience, Environmental geoscience, Engineering geology, Applied geophysics and many others.

What personal attributes do I need to be a geoscientist?
A genuine interest in your subject and an inquiring mind will be very beneficial to you. You need to be quite analytical and patient and be able to work well in a team and on your own. Good written and oral skills are useful as are computer skills. While having an enthusiastic and capable personality you will also need to be able to get good grades at school.

What do I need to study in school?
At G.C.S.E. level you will need to get good results in the sciences and maths. Knowledge of computing and other languages is also beneficial. At present there is a wide range of AS/A levels available and studying either Biology, Chemistry, Physics or Maths is essential. If Geology is offered at your school you should take a course in that, however it is not essential to get into university. The ideal A level combination is Maths, Physics and Chemistry, or at least two of these. Computing, Geography and languages are also useful.

What and where do I need to study at university?
There are a wide range of Geology courses offered at universities, ranging from straight Geology to Applied Geology (i.e. engineering, environmental, economic etc). Many universities in the UK have geology degrees, however it is generally the older universities that have the better departments. For more information regarding geology courses at universities have a look at some of the websites below.

What experience will help?
It can be quite difficult to get experience before you go to university, but before you go make use of geological books and websites. These contain a wealth of information that will help you when you go to university. Keep a track of newspapers and scientific magazines, such as New Scientist and the National Geographic. They will have up to date information about a wide range of areas. Your local area may have important geology. Contact your local museum or geological society and they will be able to help you. Through them you may gain experience of fieldwork, a very valuable skill to have. As you go to university the opportunity for experience will increase dramatically, particularly if you can find a course with a placement year in industry.

What jobs can I do with an interest in geoscience?
There are many jobs out there for graduates of a geoscience and there are particular industries that will always need geologists: the oil, gas and coal industries and the metals industry. Work is also available for geophysists, analysing the rocks below the Earth's surface and looking at earthquakes. There are also limited jobs for geologists looking at volcanoes, but this is very popular and quite hard to get into. The government employs a number of geologists in environmental control and management. Apart from these jobs there are also jobs as curators in museums and teachers in schools, Science communication includes the media (TV, radio and journalism). This is very popular with scientists and luckily the field of science communication is expanding.

Useful Careers Websites

UCAS www.ucas.com

This website is the quickest and easiest way of finding information on universities in the UK. You can easily search through universities, courses and disciplines.

University Map www.scit.wlv.ac.uk/ukinfo/uk.map.html

This is a 'hot' map showing all the universities and higher education institutions around Britain. Click on a particular institution and you will be sent directly to the university homepage.

Science Careers www.the-aps.org/education/k-12misc/careers.htm

This website has a list of a wide range of science careers. Click on a career you like the look of and it will take you to a page describing the career and how to get into it.

Palaeontology Careers www.palass.org/pages/careers.html

Part of the British Palaeontological Association, this website has good information about how to get into different palaeontological jobs and also good case studies.

Geoscience Careers www.colorado.edu/GeolSci/careers.html

This is a good website describing how to get into geoscience careers and exactly each area of geoscience. It is an American website though so not all the university information will be relevant.

Debates

This section has been included for this age group as something interesting and informative to do, although it may be more suitable for the older age groups. Four debates are described here; two are of a more ethical nature, that need less knowledge of the subjects and the other two are current controversies in dinosaur palaeontology. Each debate comes with a summary of the key points and a resource paper to read, but it is anticipated that the students do their own research into the subject area. These debates get the students to think about the scientific method and how information becomes fact, rather than opinion.

In addition to the debates discussed here, consider these additional palaeontological debate topics.

There are many areas of controversy in palaeontology, not all of which could be covered in this debate section. Most of the areas of controversy have extensive information on the web, so you could choose your own debate topics. Some ideas:

- Did birds evolve from dinosaurs?
- Should the commercial trade of fossils be legal or illegal?
- Were dinosaurs warm-blooded or cold-blooded?
- Is the fossil record complete and accurate?

1. Genetic Reengineering

✐ Do you think scientists should use advances in genetics to bring back dinosaurs?

✐ Should we try to bring back animals that went extinct because of human activity? e.g. Dodo, marsupial wolf, etc.

✐ Think about what effect the dinosaurs would have on the current ecosystem and on humans. Would there be any benefits?

✐ Do the you trust scientists?

✐ Should the public have a greater role in deciding what scientists are allowed to do?

Resource Information

In Michael Crichton's fantasy *Jurassic Park*, DNA was recovered from the stomachs of Cretaceous mosquitos that were trapped in amber shortly after sucking dinosaur blood for their last supper. A recent claim by Scott Woodward of Brigham University and colleagues that fragments of DNA molecules had been extracted directly from Cretaceous dinosaur bones seemed to put us on the scientific road to *Jurassic Park*. A modern technique called polymerase chain reaction (PCR) enables biologists to amplify extremely tiny amounts of DNA into samples large enough that researchers can measure the characteristic sequences of nucleic acids in the DNA. With such a genetic blueprint for an extinct dinosaur, could we implant this DNA into a living egg and clone a Mesozoic beast?

Using PCR, Woodward and colleagues measured several short DNA sequences. But when they were compared to those of modern reptiles, the sequences showed no special similarities to any. Blair Hedges of the University of Pennsylvania and Mary Schweitzer of the University of Montana later demonstrated that the DNA sequences are probably human – an artefact of human contamination of the original sample. More importantly, Hendrik Poinar of the University of Munich and his colleagues reported evidence that DNA quickly decays, in a process known as racemization. Over a scale of hundreds to thousands of years, racemization leads to severe deterioration of the original DNA structure. Apart from environments like amber, which embalm and preserve soft tissues, it looks unlikely that we will ever obtain DNA from Mesozoic dinosaurs. Even if we could somehow recover Mesozoic dinosaur DNA from amber, we would need not just DNA fragments but a complete, intact genome.

From *The Mistaken Extinction: dinosaur evolution and the origin of birds.* (1997) Lowell Dingus & Timothy Rowe. Published by W.H. Freeman & Company, New York.

Mad scientists are cloning dinosaurs as weapons of the future

EGGHEAD SCIENTISTS are secretly cloning dinosaurs — and terrified humans may soon be fleeing for their lives from gigantic monsters belonging to the prehistoric past.

Monsters would be last line of defense in nuclear war

FLESH-EATING BEASTS disappeared from Earth over 200 million years ago.

Nature

Report

Palaeontology – Keystages 3 & 4

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EARTH SCIENCES TEACHING RESOURCES

2. Biodiverisity Crisis or Mass Extinction?

✐ Do you think our current biodiversity crisis is equivalent to past mass extinctions?

✐ Think about the effects we have on our ecosystems, eg. pollution, extinction, etc.

✐ According to the fossils record there are animals going extinct continually (ie. a background extinction rate) through the fossil record, are the animals we see going extinct currently part of the natural processes?

✐ Did humans cause the extinction of 'megafauna' such as the mammoth and Irish elk?

✐ Should the public listen to palaeontologists as well as ecologists in regards to issues about our biodiversity crisis?

Resource Information
Is the fossil record complete and reliable enough to use as an analogue to our current situation?

Palaeontologists always have been and always will be stuck with the problem that not all the organisms that have ever existed in the world are preserved as fossils, that is, the fossil record is incomplete. If this is the case, how can palaeontologists and evolutionary biologists make sensible theories about the evolution of life on Earth if most of this life will never be discovered, living or as fossils?

There are several reasons why the fossil record is incomplete:

- Not all organisms live and die in an area that is likely to fossilise them.

- Not all organisms have suitable body parts to be preserved as fossils. Animals and plants with hard parts are more likely to be preserved as fossils.

- Organisms that do become fossilised may be destroyed by earth movements i.e. metamorphism of the rock they are preserved in.

- Rocks that fossils are preserved in may not be exposed at the surface of the Earth.

- We may simply not find them!

The ocean is the best place for organisms to stand a chance of becoming fossilised. This is because the bottom of the deep ocean has a constant supply of fine particles raining down from the upper parts of the ocean. This rain, or 'marine snow' as it is called, is composed of fine particles of cosmic dust, volcanic ash, wind-blown dust and dead microscopic sea creatures such as foraminifera, radiolarans, coccolithophores and diatoms. If a larger animal or plant comes to rest on the bottom of the calm sea floor, and is not scavenged by other animals, then it stands a good chance of becoming buried and starting the process of fossilisation.

There are not as many places on land that are as calm as the bottom of the ocean floor, and there are also fewer places with such continuous deposition of fine-grained particles suitable for fossilising organisms. This is one reason why most of the fossils we find are sea creatures and why rocks that were once mud on the bottom of the ocean preserve a better, more continuous record of the creatures that lived in the sea and how they changed over time.

3. What killed the dinosaurs?

✐ Most students have heard the theory of the asteroid impact that may have caused the demise of the dinosaurs. Discuss the problems and uncertainties of this theory.

✐ Look up and discuss other theories about this extinction (e.g. volcanoes, climate change, evolution of flowering plants etc).

✐ The K-T extinction was actually the fifth mass extinction to hit earth, and certainly not the largest. Get the students to find out more about the other extinctions and see if they can find any similarities and differences.

Resource Information
Ever since fossils were discovered, humankind has wondered: "Why did they die?" A poignant question, for it has relevance to us - if extinct animals were wiped out by some catastrophe, couldn't that just as easily happen to us? Could we be found as fossils someday, and could someone figure out why we died?

- **Inquiring into the Great Mystery**

Until recently, people simply knew that dinosaur fossils were found in rock layers (strata) of the Mesozoic era ('The Age of Dinosaurs') but not in the following Cenozoic era ('The Age of Mammals'). So, dinosaurs went extinct about 65 million years ago at the K-T Boundary (the Cretaceous is K and the Tertiary is T). Many wild ideas about how the dinosaurs were rendered extinct were presented over the years. But few satisfactory answers to the mystery behind the extinction of dinosaurs were offered.

Then in 1980 a group of scientists at the University of California, Luis and Walter Alvarez, Frank Asaro, and Helen Michel, proposed a stunning and convincing mechanism for the K-T Extinction. Since the Alvarez hypothesis was proposed, the search for the 'perpetrator' of the K-T Extinction has been a thriving area of scientific research, incorporating scientists from many disciplines including astrophysics, astronomy, geology, palaeontology, ecology, and geochemistry. The mystery has drawn extensive media coverage over the last 25 years.

- **Mass Extinctions**

Before we dive into the complexities of the K-T extinction (often referred to as 'The Great Dying'), here's some essential background information about the controversy. The K-T mass extinction was an episode in evolutionary history where more than 50% of all known species went extinct in a short period of time (< 2 million years).

Several mass extinctions have occurred in the history of life; the largest was the P-T extinction between the Permian and Triassic periods. Catastrophically, life on Earth nearly was wiped out: an estimated 90% of species were extinguished likely ebcasue of large-scale changes to global conditions at that time, but even that is not solved yet. The issue has not received much press because the dinosaurs were not involved, but another familiar group, the trilobites, were wiped out among others.

- **Who Died?**

How does the K-T extinction compare to this debacle? Well, about 60% of all species that are present below the K-T boundary are not present above the boundary. Dinosaurs were among numerous casualties - the worst hit organisms were those in the oceans. Foraminifera (microscopic, shelled organisms), Echinodermata (including starfish), Mollusca (including clams), and the marine reptiles (pleisiosaurs and ichthyosaurs) were devastated by the K-T event. On land dinosaurs and pterosaurs went extinct. Mammals and other reptiles seemed to be relatively unaffected.

Terrestrial plants suffered to a large extent, except for ferns, which show a dramatic increase in diversity at the K-T boundary.

- **Complications**

Now we're heading into the tough stuff; the reasons why we have no conclusive answer to the mystery of the K-T event. There are several complications that make it hard for the scientific detectives trying to crack this case:

1: The Fossil Record is not perfect, which is why palaeontologists keep finding new fossils: so much is hidden in the rocks! Most data on the K-T event comes from North America, which has a somewhat continuous fossil record (remember, fossils are only formed under certain rare conditions, and are only found in sedimentary rocks). The infamous Hell Creek locality in Montana is one such continuous site enclosing the K-T boundary. But there are many fossils we have not yet studied and one palaeontologist, David Raup, estimated that of all of the animals that ever lived on Earth, less then 1% were fossilized.

2: The Nature of Extinction is not a simple event; it is not simply the death of all representatives of a group. It is the cessation of the origination of new species that renders a group extinct; if species are constantly dying off and no new ones originate, then that group will go extinct over time no matter what happens. New dinosaur species ceased to originate around the K-T boundary; the question is, were they killed off (implying causation, especially a catastrophe), or were they not evolving and simply fading away (perhaps implying gradual environmental change)?

3: Time Resolution, that is determining the age of rocks or fossils that are millions of years old is not easy; carbon dating is only a reasonable resolution when used with organic material that is less than about 50,000 years old. Other methods of istope dating suffer from the same problems as carbon dating: accuracy depends on the situation and always has a margin of error. So we don't know exactly when the dinosaurs went extinct, and so the ultimate question of a gradual decline of dinosaurs vs. a sudden cataclysm is almost intractable.

4: Reconstructing the Palaeoecology of Earth at the time of the dinosaurs is necessary to understanding conditions around the K-T boundary. Palaeoecology attempts to understand the interactions of past organisms with their environment using the geologic record (the rocks tell you what the soil and environment was like) and the fossil record (plants, animals, and microrganisms tell us a lot about the past environment). But with the patchiness of the fossil record and poor time resolution, it is difficult to understand the palaeoecology of a region at a specific time in the past.

5: The Signor-Lipps Effect, proposed by Phil Signor and Jere Lipps, helps us understand the limitations of the fossil record. The theory states that organisms may seem to go extinct in the fossil record before they actually do due to an artefact of the fickle nature of the fossil record. Thus, it is possible that some organisms we think died at the K-T Boundary did not go extinct until later.

6: Falsifiability - Hypotheses about the K-T event may sound convincing, but are only a theory until proven or disproven. It is very difficult to prove or disprove whether the dinosaurs were rendered extinct by a catastrophic event 65 million years ago, or whether they just died out gradually around that time. It is also difficult to pin down a direct cause. Ultimately, "Why did the dinosaurs die out?" may only be answered by a time machine.

4. Was T. rex a predator or a scavenger?

✐ *T. rex* is known to most people as a fearsome meat eater that terrorised the Cretaceous landscape. There are some scientists however that think *T. rex* may not actually been capable of predation and was more likely to have been a scavenger.

✐ Get students to research both sides of the argument and discuss what evidence supports each argument.

✐ Scientists compare what they know about animals today with dinosaurs. What do these studies show and is it this a valid approach?

✐ Is there any point arguing about something we may never know the answer to?

Resource Information

The tyrannosaurids were a group of large carnivorous dinosaurs that roamed North America and Asia during the last part of the Cretaceous, 85 to 65 million years ago. The most famous tyrannosaur is *Tyrannosaurus rex*, known to every schoolchild, and one of the last dinosaurs to walk the earth before the great extinction.

About thirty good specimens of these animals have been found from highly restricted areas in Western North America. Henry Fairfield Osborn first described *Tyrannosaurus rex* in 1905 and skeletons of a close relative of *T. rex*, *Tarbosaurus*, have been found in Mongolia.

Clearly this animal was imposing in size and stature. In fact, *T. rex* was one of the largest terrestrial carnivores of all time. It stood approximately 15 feet high and was about 40 feet in length, roughly six tons in weight. In its large mouth were six-inch long, sharp, serrated teeth. Good *T. rex* specimens, however, are hard to come by, one of the best specimens found to date is only 90% complete. Some 15–20 other specimens around the USA range from about 10% to 80% complete; missing ribs and tail bones are common.

Palaeontologist Jack Horner has proposed that *T.rex* could not have been a predator because it had small eyes (making it difficult to see prey), small arms (making it difficult to hold prey), huge legs (making it difficult it travelled quickly). Also, he says there is no evidence for predation because though bones have been found with tyrannosaur teeth embedded in them or scratched by them, but so far no study has shown that tyrannosaurs killed other dinosaurs for food. A bone showing tyrannosaur tooth marks that had healed would be strong evidence for predation.

Horner's evidence supporting scavenging include *T.rex*'s large olfactory lobes (part of the brain used for smell), and that its legs were built for walking long distances (the thigh was about the size of the calf, as in humans). Vultures have large olfactory lobes and are good at soaring to cover long distances.

Arguments against scavenging include comparisons to living animals. Most large predators (such as lions and hyenas) scavenge meat happily when it is available, but prefer fresh meat. Horner argued that *T.rex*'s arms were too weak to grab prey, but wolves, snakes, lizards and birds are successful predators without using their forelimbs. Whether *T.rex* was a slow animal is tough to tell, you will see in the Dinosaur Speed Activity.

What is the public to think of all this? Make up your own mind; the fact is that reconstructing the behaviour of extinct animals is difficult, especially when there are no close modern relatives with which to compare them. *Tyrannosaurus* may have been scavengers, predators or both.

Classroom Activities

Activities described in this section can all be done in the classroom, using equipment normally found in schools. Some of the activities may need photocopied sheets for the students. A copy of these sheets is included alongside the description of each activity. Other background information that may be useful for the activities can be found in the Resource section. Curriculum links are provided next to the description of each activity, as well as the age suitability of activities and the equipment needed.

1. Sand to Stone

Concept
This experiment shows how fossilisation occurs. It can be done by the students or as a demonstration be the teacher.

Curriculum Links
KS3, KS4 & Sc3 Materials and their properties. 2d, 2e, 2f, 2r

Materials & Equipment
- Shoe box or milk carton
- Plastic spoon
- Cling film
- Sand, gravel or fine soil
- 6 heaped tablespoons of Plaster of Paris
- 500ml of water

Instructions
- ✓ Line the inside of the box with cling film and fill it 2/3 full of sand, gravel or soil.
- ✓ Add the plaster of Paris and water and stir quickly.
- ✓ Place the box where it won't be disturbed for several days.
- ✓ When the mixture is dry, turn the box over and remove the cling film.

- ✓ Compare your rock model with classmates' and with samples of sedimentary rocks.
- ✓ What kind of sedimentary rock did you make?
- ✓ What kinds of sediment make what type of rock? Eg. To make sandstone use sand; for a conglomerate, use gravel; for shale, use soil.
- ✓ Observe the necessary 3 steps to make real sedimentary rocks: deposition, drying, and pressure.
- ✓ Which step didn't play a part in making the model rocks?
- ✓ What do you think would happen if water constantly ran over your rock models?

2. Classifying Dinosaurs

Concept
Living things, including dinosaurs are all related. Students will learn how to group dinosaurs together based on common features.

Curriculum Links
KS3 & Sc2 Life processes and living things 4b

Materials & Equipment
- Pictures of a range of dinosaurs from books and the Internet

Instructions
- ✓ Group dinosaurs into different 'families', based on their characteristics e.g. herbivore, omnivore, carnivore; bipedal, quadrupedal; overall shape etc.
- ✓ Make a display of the dinosaur pictures, placed in groups.
- ✓ Write a short section to go with each group explaining what special features each group has.
- ✓ Compare grouping dinosaurs with grouping living things.
- ✓ What features do you look for when classifying living animals?
- ✓ Can we use the same things when classifying dinosaurs?

3. Transition from Birds to Dinosaurs

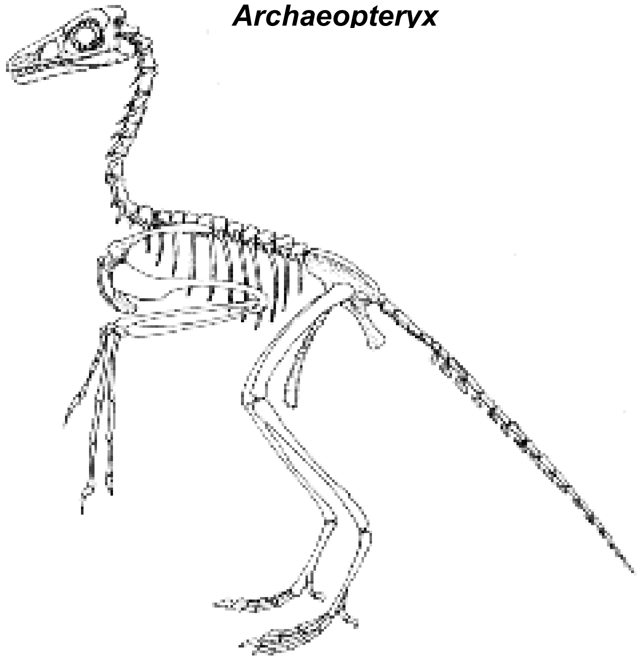
Concept
Palaeontologists now know that birds evolved from dinosaurs. This realization came by the discovery of many fossils that share bird and dinosaur characteristics. Students will learn more about this important evolutionary transition.

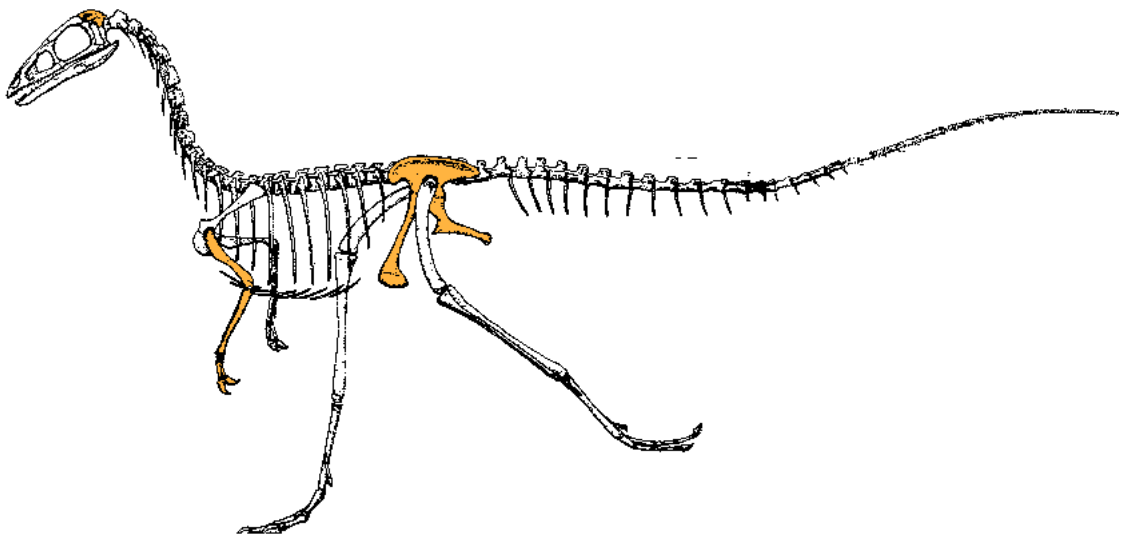
Curriculum Links
KS4 & Sc2 Life processes and living things 3h and 4i

Materials & Equipment
✏ Illustrations of *Archaeopteryx* and *Compsognathus*.

Instructions
✓ Using the illustrations of *Archaeopteryx* and *Compsognathus*, classify the two animals using their physical characteristics.
✓ Compare their likenesses and differences.
✓ This activity can also be used alongside the Bird Evolution Debate.

Archaeopteryx





Compsognathus

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4. Rock Studies

Concept
Rocks record the history of Earth's past. In order to understand more about this, students will learn to identify and classify different types of rocks.

Curriculum Links
KS3, KS4 & Sc3 Materials and their properties. 2d, 2e, 2f, 2r

Materials & Equipment
✎ Rock Collection (School science labs, libraries and museums are sources for borrowing rock collections).

Instructions
- ✓ Look carefully at samples of sedimentary rocks and note how they are different.
- ✓ Draw and label sketches of these rocks and write a brief description of how the rocks are formed.
- ✓ Students may own their own rock collection; get them to bring them in to share with the class.
- ✓ Compare sedimentary rocks to other rocks (igneous and metamorphic):
- ✓ Name the two other types of rock.
- ✓ How are the other types of rocks formed?
- ✓ How are igneous and metamorphic rocks the same as sedimentary rocks?
- ✓ How are they different?

5. Fossilisation in a Sponge

Concept
This experiment helps explain the chemical processes of fossilisation.

Curriculum Links
KS4 & Sc3 Materials and their properties 2r

Materials & Equipment
- Large beaker
- Bunsen burner
- $2cm^2$ piece of sponge
- 500ml sugar
- 250ml water

Instructions
- ✓ Dissolve the sugar and water in a beaker over a bunsen burner.
- ✓ Allow the solution to cool for 15 minutes.
- ✓ Drop the sponge into the solution.
- ✓ Place the beaker in a safe place where it will not be disturbed.

- ✓ After one week, remove the sponge.
- ✓ Talk about what happened to the sponge.
- ✓ Compare what happened to the sponge to what happens to bones buried in sediment.

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6. Tracking Stories

Concept
Scientists can learn a lot about an animal's behaviour by trace fossils that they leave behind, such as footprints and trackways.

Curriculum Links
KS4 & Sc2 Life processes and living things 4a and 5a

Materials & Equipment
✏ Photocopied picture of dinosaur trackways (see next page)
✏ Calculator

Instructions
✓ Look carefully at the dinosaur trackways. Footprints and trails like these are called trace fossils and they can tell scientists lots of information about dinosaur behaviour. Answer the questions below:
✓ On the trackway diagram, label which dinosaur made which tracks.
✓ How many dinosaurs made the tracks?
✓ How big were the dinosaurs?
✓ What do you think they were doing?

✓ As a challenge calculate how fast each of the dinosaurs were going. We cannot use the normal calculation for speed (speed = distance/time) as we don't know how long it took the dinosaurs to make each trackway. Instead scientists have worked out another mathematical formula for calculating speed from trackways:

$\mu = 0.25g^{0.5} \times \text{stride length}^{1.67}\ h^{-1.17}$

μ = relative speed
g = acceleration due to gravity = 10m/s
h = hip height = 4 x footprint length

The answer is in m/s.
Conversion factors:
M/s x 3.6 = kph
M/s x 2.2369 = mph

Palaeontology – Keystages 3 & 4

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Tracking footprints