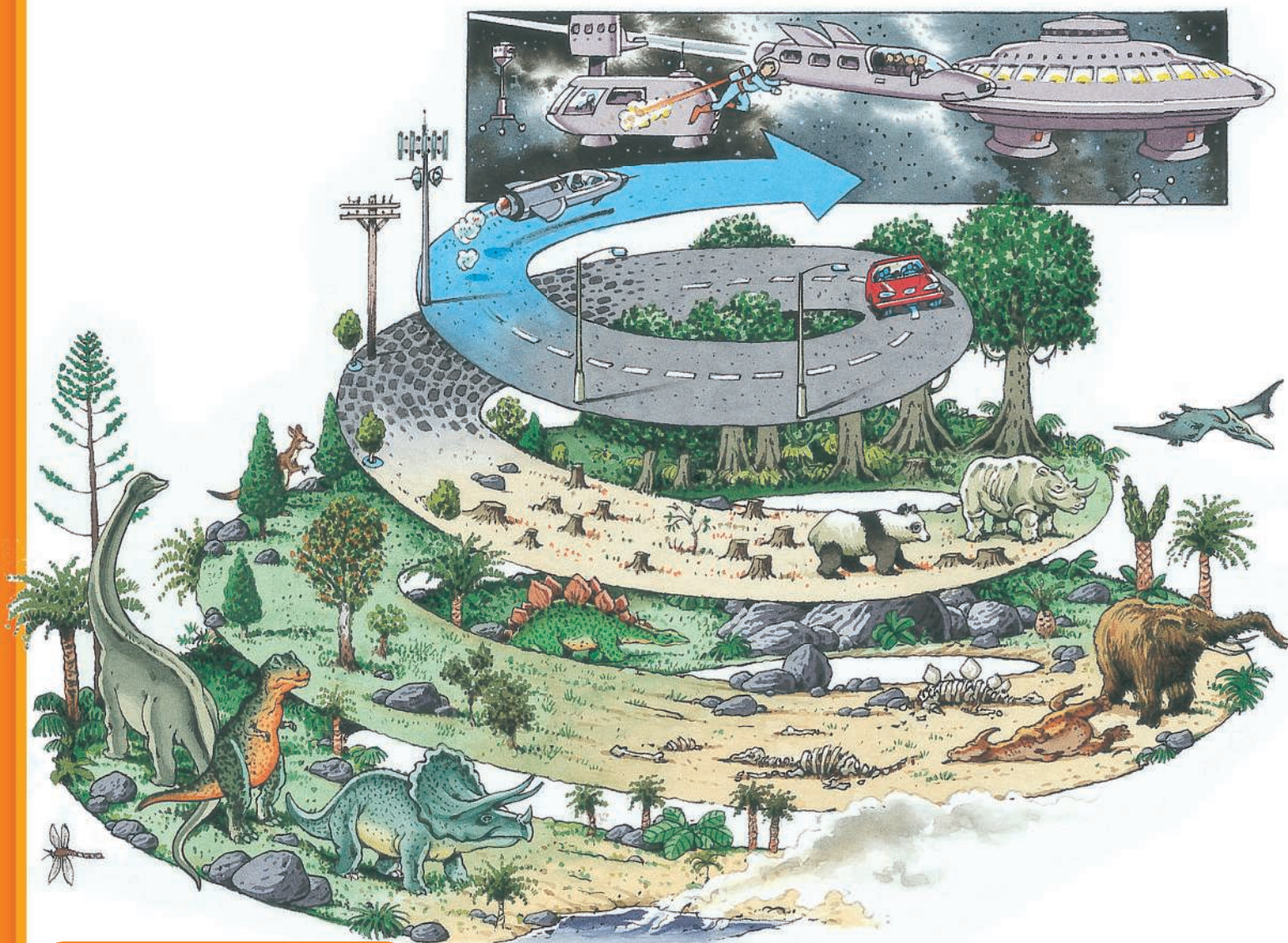


Life goes on

9



Think about these

Who was Linnaeus and does he belong to your family?

Will Melbourne ever experience tropical conditions?

How old is the Earth?

What has dating got to do with rocks?

Who on earth is Denis Crawford?

Can you swim in a gene pool?

How can one species become two?

How many species become extinct every hour?

Key outcomes

Evaluate theories concerning the evolution of organisms.

Describe the genetic basis of inheritance.

Relate concepts of adaptation, biodiversity and evolution to the survival of species.

Explain implications of crustal movements of the Earth.

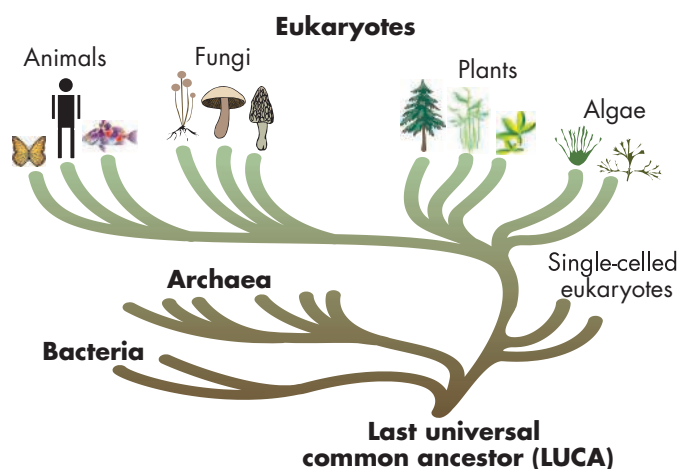
Describe regulation and coordination mechanisms in plants and animals.

Demonstrate the link between natural selection and evolution.

Apply concepts of geological time to help explain both natural selection and evolution.

YourQuest

LUCA — Your ancestor?



Every living thing on Earth is thought to have descended from one single entity. This was a sort of primitive cell that floated around in the primordial soup over three billion years ago. It has been named the **last universal common ancestor** or **LUCA**. There is considerable controversy surrounding this ancestor, as it has left no fossil remains or any other physical clues of its identity. Researchers, however, are comparing the genes from all forms of life and have put together a portrait of this cell that could be the ‘mother of us all’.

THINK AND INVESTIGATE

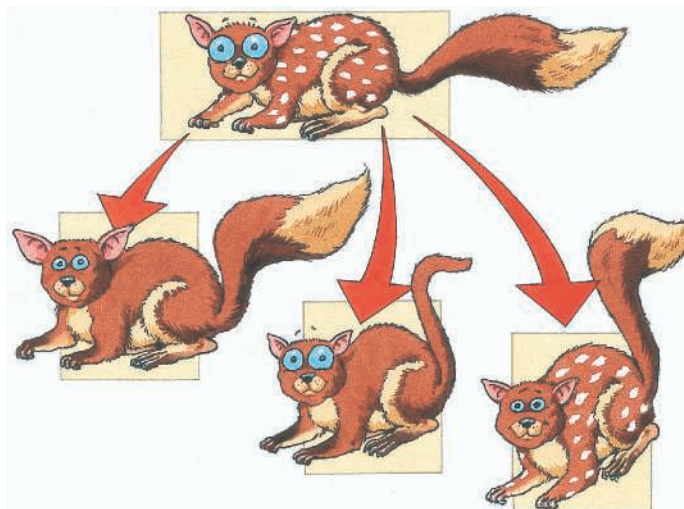
- (a) Suggest reasons why all forms of life are coded by nucleic acids (DNA or RNA).
(b) Although nucleic acids are all made up of nucleotides, how can they differ?
- What do you think Earth was like three billion years ago? Find out if your hypothesis was correct.
- (a) Suggest the features of organisms that could survive on Earth three billion years ago.
(b) Suggest processes or features that may have increased the chance of organisms passing on their traits to their offspring at this time.
- Design an organism that could survive these conditions. Describe its features, including those that are present in organisms living today.

Five minutes to midnight

If we compressed the Earth’s 4.5 billion year history into a single year, Earth would have formed on January 1 and the present time would be represented by the stroke of midnight on December 31. Using this timescale, the first primitive microbial life forms appeared in late March, followed by more complex photosynthetic micro-organisms towards the end of May. Land plants and animals emerged from the seas in mid-November. Dinosaurs arrived early on the morning of December 13 and then disappeared forever in the evening of December 25. Although human-like creatures appeared in Africa during the evening of December 31, it was not until about five minutes before the New Year that our species, *Homo sapiens* appeared on Earth.



The common ancestor



How common can you get?

- Carefully observe the features of the possums in the figure above.
- Make lists of how they are similar and how they are different.
- Suggest reasons for the differences.
- Suggest how they may have become different.

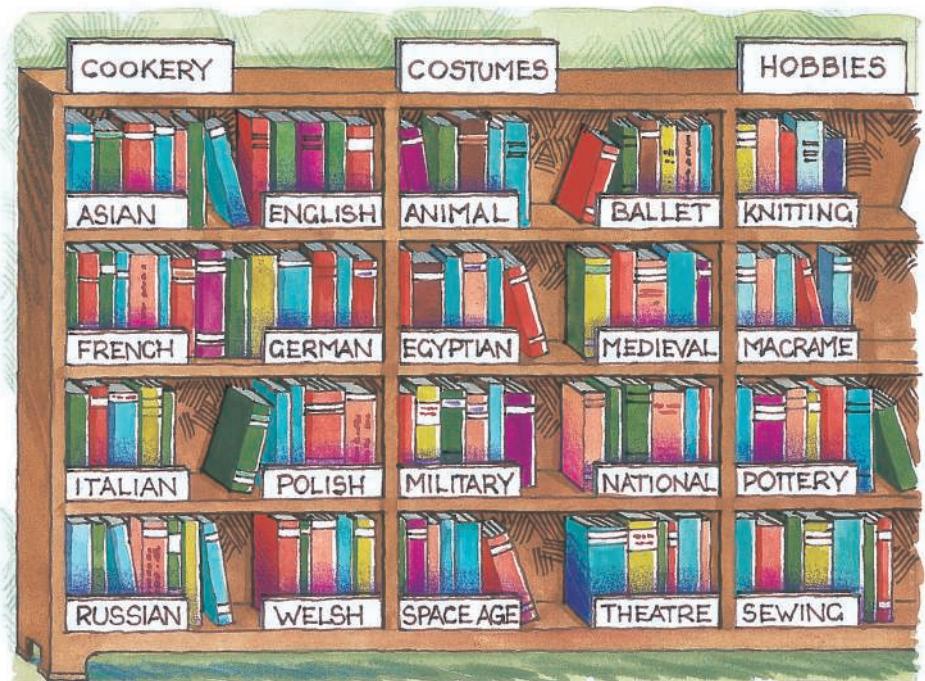
Sorting things out



There are not only a lot of fish in our world, but birds, trees, worms, spiders, frogs . . . How do we tell them apart? How could we ever know all their names? Why would we ever want to?

Have you read any good books lately?

There are millions of different books. How do you go about finding the book you want to read? If you go into a library, you will find that books are sorted into sections. All the children's books are together, as are the reference books, the fiction books, the foreign language books and the biographies. These are again sorted either into alphabetical order or, in the case of reference books, into subjects (for example, history, geography, science, cookery, etc.). The aim of this sorting process is to make it easy for everyone using the library to find the book they want. The reason we use a sorting process for books also applies to living things — it makes them easier to locate and identify. There are approximately 1.5 million different types of living things on Earth that have been studied in some way. There are probably three times this amount that we don't know about.



Books in a library are sorted to make them easier to find. How many levels of sorting can you see here?

Why classify?

As there is such a vast number of different types of living things, scientists find it useful to sort or classify them into groups. Each group is then given a name. **Classification** of living things enables scientists to put some order on the natural world. In this way, all scientists are able to communicate with each other, and know that they are talking about the same kind of organism.

Classification is useful, for example, when dealing with diseases, disease-carrying organisms and disease control. There are 3000 different types of mosquito, but only a small number of these can transmit malaria. Instead of spraying all mosquito populations, scientists are able to identify those populations known to transmit malaria and then take steps to control them.

What's in a name? What is a species?

The Swedish naturalist Carl von Linné developed a naming system that could be used for all living organisms (see the diagram on page 238). It involved placing all living organisms into small groupings based on their similarities. He called the small groupings **species**. Species showing similar characteristics were placed into a larger grouping called a **genus**; similar genera (plural of genus) were placed into an even larger grouping called a **family**.

The idea of grouping similar organisms was extended further, with similar families grouped into **orders**, similar orders grouped into **classes**, similar classes grouped into **phyla** (the plural of phylum), and similar phyla placed into the largest grouping of all, a **kingdom**. There are many ways of remembering the order of the levels, such as the mnemonic:

Kingdom	Kooky
Phylum	Professors
Class	Care
Order	Only
Family	For
Genus	Great
Species	Science.

How are organisms grouped?

The three main characteristics used to classify organisms are their internal and external structures, their cell structure and their chemical composition. Organisms classified together in the smaller groupings (such as genus and species) are very similar; those in the larger groupings such as kingdom and phylum have a large number of differences.

Organisms that belong to the same species closely resemble each other. Organisms within the same species can freely breed with other members of the same species to produce **fertile** offspring; that is, their offspring can eventually reproduce. In their natural habitat, members of one species usually do not breed with members of other species.

An organism's species name is made up of the name of the genus to which it belongs, followed by its descriptive or specific name. The descriptive name usually tells us something about the organism; for example, *Petroica rosea* is the scientific name for the rose robin. The genus name is *Petroica* and the descriptive name is *rosea*, which describes the colour of the robin's breast.

The scientific names of organisms have usually been Latinised, the generic name beginning with a capital letter and the descriptive or specific name beginning with a lower case letter. If typewritten, Latin names are usually shown in *italics*; if handwritten, they are underlined.

Carl von Linné outlined this system of giving organisms two names (called the **Binomial System of Nomenclature**) in his paper *Systema Naturae*, published in 1735. He eventually Latinised his own name and is now referred to as **Carolus Linnaeus**.

Remember the following rules for writing an organism's scientific name.

1. The name is made up of two words — the genus name and the descriptive or specific name.
2. The genus name comes first, and the descriptive or specific name comes second.
3. The genus name starts with a capital letter and the descriptive or specific name with a lower case letter.
4. The species name should be set in italics if typed, and underlined if handwritten.

Some examples of scientific names

Common name	Genus name	A descriptive or specific name
lion	<i>Felis</i>	<i>leo</i>
dog	<i>Canis</i>	<i>familiaris</i>
saltwater crocodile (the one that can eat humans)	<i>Crocodylus</i>	<i>porosus</i>
freshwater crocodile (a less dangerous species)	<i>Crocodylus</i>	<i>johnstoni</i>
pink cockatoo	<i>Cacatua</i>	<i>leadbeateri</i>
galah	<i>Cacatua</i>	<i>roseicapilla</i>
river redgum	<i>Eucalyptus</i>	<i>camaldulensis</i>
blue bell	<i>Scilla</i>	<i>nonscripta</i>

Kingdom



Phylum



Class



Class

Order



Order

Family



Genus



Species



Macropus giganteus

Eastern grey kangaroo

Species

Animalia

Chordata

Mammalia

Diprotodonta

Macropodidae

Macropus



This diagram shows the various groupings used to classify living organisms. Examples of organisms are shown at each level. It also shows how the Eastern grey kangaroo (*Macropus giganteus*) can be classified in the Kingdom Animalia (heterotrophic, eukaryotic, multicellular), Phylum Chordata (dorsal hollow nerve chord, may possess pharyngeal slits or pouches at some stages), Class Mammalia (hair, mammary glands and four-chambered heart), Order Diprotodonta (one pair of lower incisors, mostly herbivores) and family Macropodidae (12 or more teeth each side of jaw, powerful large feet).

ANALYSE AND EVALUATE

Levels of classification	Definition of word in first column: a group of similar . . .	Equivalent scientific grouping	Your address
kingdom	phyla	Animalia	Your planet is . . .
phylum	classes	Chordata	Your hemisphere is . . .
class	orders	Mammalia	Your country is . . .
order	families	Primates	Your State/Territory is . . .
family	genera	Hominoidea	Your suburb is . . .
genus	species	<i>Homo</i>	Your street is . . .
species	organisms which can interbreed under natural conditions to produce fertile offspring	<i>Homo sapiens</i>	Your house or flat number is . . .

1 Use the information in the table above to answer the questions that follow:

- To which kingdom do humans belong?
- Complete the column headed 'Your address' in your workbook.
- Explain how this information would enable someone to find you.
- How is the address column in the above table similar to using the seven levels of classification?
- Write out definitions of the seven levels of classification.
- What happens to:
 - the similarity between organisms, and
 - the number of organisms as you move down the levels of classification from kingdom to species?

REMEMBER

- Why do scientists sort living things into groups? Give an example of where this would be useful.
- Who developed the naming system for all living things?
- What are the names of the groupings, from largest to smallest, into which all living things are placed?
- What are the characteristics that scientists use to classify organisms into groupings?
- What is a species?
- What is the Binomial System of Nomenclature?
- The scientific name for the lemon-scented gum is *Eucalyptus citriodora*. What conclusions can you make about this tree from its scientific name?

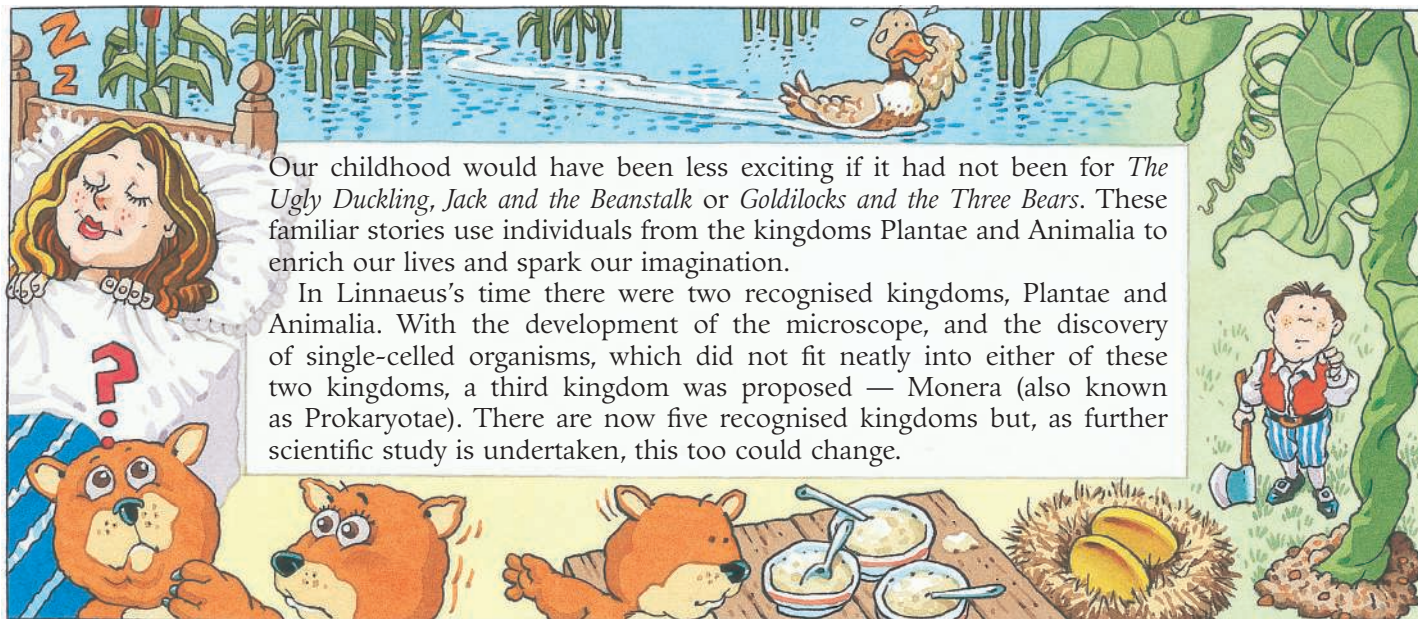
THINK AND DISCUSS

9 Refer to the table below to answer the questions that follow:

- Name one pair of animals which are in the same phylum. What does this suggest?
- Which two animals are in the same class? What does this suggest?
- Which pair of animals has more in common:
 - marine crayfish and honey bee?
 - domestic cat and red kangaroo?
 Give a reason for your answer.
- To which of the four animals in the table would (i) *Jasus macropus* and (ii) *Felis leo* be most similar? Give reasons for your answer.

Level of classification	Marine crayfish	Honey bee	Domestic cat	Red kangaroo
kingdom	Animalia	Animalia	Animalia	Animalia
phylum	Arthropoda	Arthropoda	Chordata	Chordata
class	Crustacea	Insecta	Mammalia	Mammalia
order	Decapoda	Hymenoptera	Carnivora	Diprotodonta
family	Palinuridae	Apidae	Felidae	Macropodidae
genus	<i>Jasus</i>	<i>Apis</i>	<i>Felis</i>	<i>Macropus</i>
species	<i>Jasus lalandei</i>	<i>Apis mellifera</i>	<i>Felis catus</i>	<i>Macropus rufus</i>

The magic kingdoms

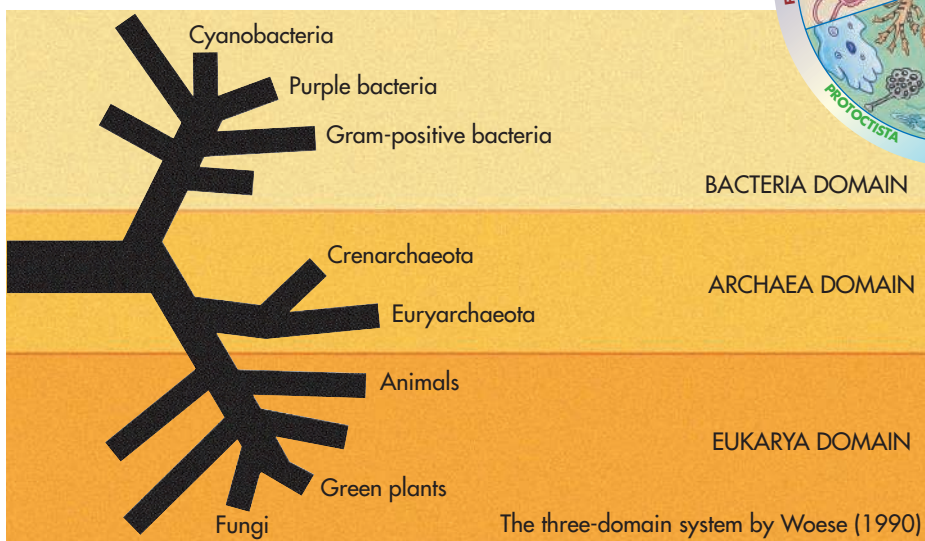


Our childhood would have been less exciting if it had not been for *The Ugly Duckling*, *Jack and the Beanstalk* or *Goldilocks and the Three Bears*. These familiar stories use individuals from the kingdoms Plantae and Animalia to enrich our lives and spark our imagination.

In Linnaeus's time there were two recognised kingdoms, Plantae and Animalia. With the development of the microscope, and the discovery of single-celled organisms, which did not fit neatly into either of these two kingdoms, a third kingdom was proposed — Monera (also known as Prokaryotae). There are now five recognised kingdoms but, as further scientific study is undertaken, this too could change.

Changing tides of classification

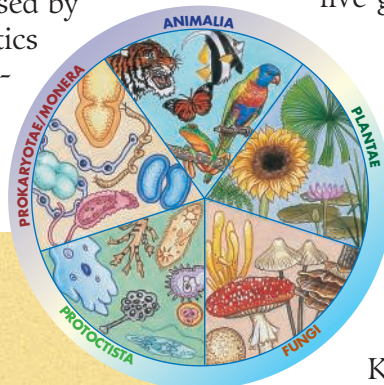
Classification is not fixed! As scientists make new discoveries, new information can result in new groupings and classifications. In 1969, a five-kingdom classification scheme was proposed by Whittaker. In recent years, however, alternatives to the five-kingdom classification have been suggested. In 1990, a new classification scheme was proposed by Woese, which, rather than using the physical characteristics of organisms, used their genetic make-up. This new classification scheme divided organisms into three main groups called **domains** (*Bacteria*, *Archaea* and *Eukarya*), which were then subdivided into many kingdoms.



Classification is not fixed and new models based on new information can replace old models: the five-kingdom system (above right) and the three-domain system (above).

The biggest group — kingdoms

Using the five-kingdom system, living things are classified into five groups: Prokaryotae (or Monera), Protocista, Fungi, Plantae and Animalia.



Kingdom Prokaryotae

Kingdom Prokaryotae is made up of single-celled organisms and contains all blue-green algae, bacteria and cyanobacteria. None of the cells in the Kingdom Prokaryotae contain a nucleus, and are therefore called prokaryotic (meaning 'before a nucleus'). The cells in this kingdom contain a very large range of chemicals and their function is very diverse.

The cells can survive in a large variety of habitats from Antarctic pools through to hot, thermal springs. Some members of this kingdom are photosynthetic, and some are chemosynthetic (that is, they can use chemicals to produce their own nutrients). Others cause decay and subsequently absorb the products of decay. Reproduction is primarily asexual, either by fission (splitting in two) or by budding (where a bud forms on the surface of the cell and breaks off to form a new cell).

Kingdom Protocista

Kingdom Protocista contains all brown, red, and green algae, protozoans, water moulds and slime moulds. The members of this kingdom range in size from the giant kelp *Macrocystis*, which can grow up to 60 metres in length, to the microscopic protozoans that cause malaria. Their cells are eukaryotic (that is, they contain a nucleus) and are arranged simply to form a multicellular organism. They do not have a complex transport system, but instead rely on **diffusion** to transport materials around the body. They all live in moist habitats ranging from the oceans to inside the bloodstreams of other organisms. Reproductive cycles can include both asexual and sexual processes.

Kingdom Fungi

Members of this kingdom show some plant-like characteristics. They have eukaryotic cells arranged to form a multicellular organism. They have strengthened cell walls made up of **cellulose** and/or **chitin**, and are **non-motile** (non-moving). They do not photosynthesise. Instead, they obtain nutrients by

firstly producing and releasing enzymes over the surface of their food source, and then directly absorbing the substances that are broken down by the chemical reaction that involves these enzymes. Fungi are important in the ecosystem because they cause dead material to break down and decay. This kingdom includes all mushrooms, toadstools, moulds, yeasts, smuts and rusts. Reproductive cycles can include both asexual and sexual processes.

sciFacts

Viruses do not fit into the existing classification of living things because they are not made up of cells.

Kingdom Plantae

All the individuals in the Kingdom Plantae are multicellular and made up of eukaryotic cells. Each cell is surrounded by a cell membrane, but also has an additional strengthening layer of cellulose, known as a **cell wall**. Microscopic examination of plant cells reveals that most of the cells possess large **vacuoles**, and some possess **chloroplasts** containing **chlorophyll**. Chlorophyll is a green pigment that enables plants to use light energy to produce simple sugars, using the process of **photosynthesis**. As plants are able to produce most of their own nutrients, they are referred to as **autotrophs** or self-feeders. Reproduction includes both asexual and sexual processes.

Kingdom Animalia

All the members of the Kingdom Animalia have eukaryotic cells

which are arranged to form a multicellular organism. Their cells lack large vacuoles, chloroplasts and a cell wall, being surrounded only by a cell membrane. Animals largely gain their nutrition by eating other organisms, but some animals absorb nutrients from their environment.

Animals are usually motile, in that they can move around from place to place, and some possess very highly developed muscular and sensory systems. Reproduction is primarily sexual. There is a large number of phyla in the Kingdom Animalia. These phyla represent animals as diverse as sponges, flatworms, jellyfish, insects, cats, birds and humans.

activities

REMEMBER

- 1 Why has the number of kingdoms changed from two to five?
- 2 What characteristics do members of the Kingdom Fungi have in common with members of the Kingdom Plantae?
- 3 At the cellular level, how do the members of the Kingdom Plantae differ from the members of the Kingdom Animalia?

INVESTIGATE

- 4 Use the Internet to find out the major differences between prokaryotic and eukaryotic cells.

CREATE

- 5 Using magazines and journals, cut out all the pictures of living things and classify them into kingdoms. Make a poster showing representatives from different kingdoms.

Long, long ago

Long before humans inhabited the Earth, the continents are thought to have been joined together. Animals were able to roam freely across this landmass.

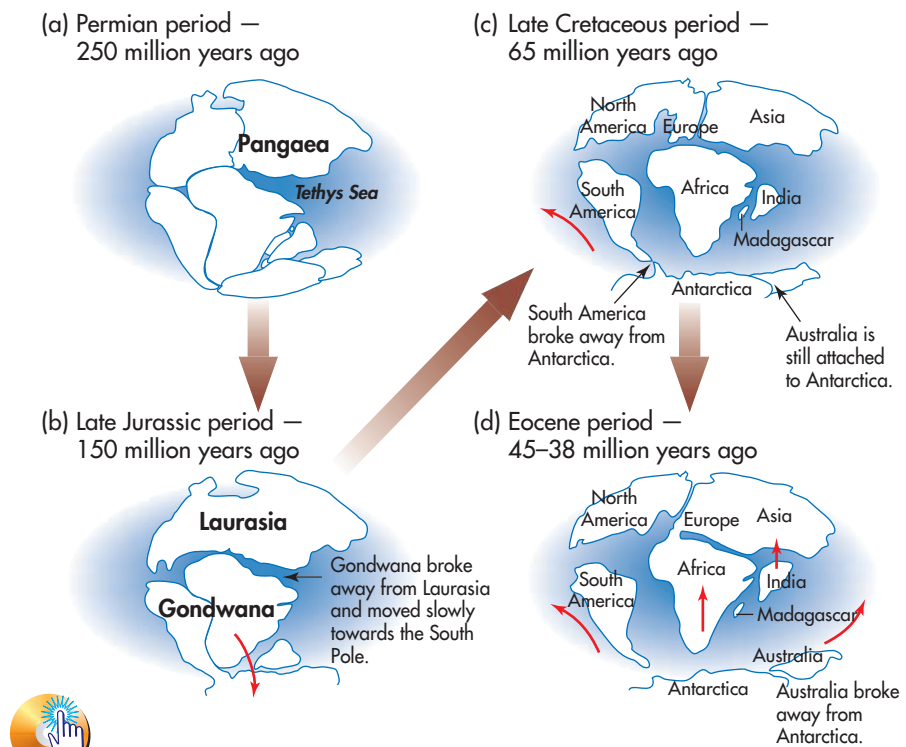
Today, fossils of closely related species can be found in South America, Australia, Europe and Africa.

Moving apart

The **Theory of Plate Tectonics** suggests that the Earth's crust is not a single surface. It is divided into about 30 plates, each about 120 kilometres thick. These plates move very slowly, only several centimetres each year, either sliding past each other, pushing against each other or moving away from each other. Over millions of years, some of these plates have moved further and further apart, separating what was once a single landmass into the continents we know today.



The destruction caused by this Los Angeles earthquake is evidence that the plates are still moving.



Scientists believe that Australia was once part of **Pangaea**, a giant landmass that comprised all the land on Earth. About 200 million years ago, Pangaea moved apart to form two **supercontinents**. **Laurasia** in the Northern Hemisphere consisted of North America, Greenland, Europe and Asia, and **Gondwana** in the Southern Hemisphere consisted of South America, Africa, India, Antarctica and Australia.

Evidence to support the view that the continents we know today were once part of two supercontinents includes:

- the fact that the continents are still moving apart; for example, Australia is moving northwards at the rate of about seven centimetres every year. It is predicted that in about 70 million years time Australia will collide with South-East Asia and form a

new mountain range in the Northern Territory.

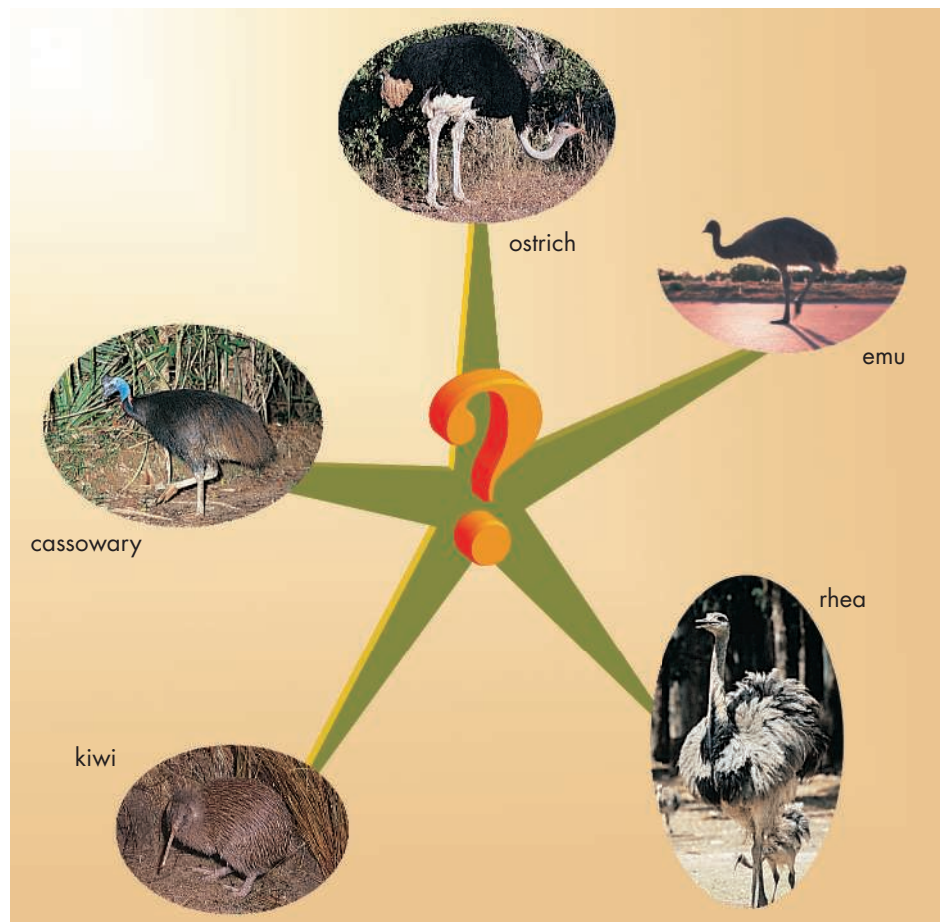
- the physical fit between the continents (see the diagram above.)
- the remarkable similarity between rock and crystal structures at the edges of continents
- fossil evidence, which suggests that marsupials originated in South America. Today, Australia, not South America, is home to the greatest range of marsupials (e.g. the platypus, echidna, kangaroo and wallaby). But how did they migrate from South America to Australia?
- the discovery of fossils of the land-dwelling dinosaur *Mesosaurus* (which lived about 270 million years ago) in only two places in the world — the eastern side of South America and the western side of South Africa. There are

now 6600 kilometres of ocean between these two places.

- the distribution of closely related animals and plants across the continents. This pattern is best explained by the existence of a southern supercontinent. Giant flightless birds can be found in South America (the rhea), Africa (the ostrich), Australia (the emu and the cassowary) and in New Zealand (the kiwi). Did these birds evolve from one common ancestor that inhabited Gondwana?

sciFacts

In 1492, Christopher Columbus sailed for 70 days to cross the Atlantic Ocean. If he were to make the same journey today, it would take a little longer. The Atlantic Ocean is 10 metres wider than it was in 1492.



Did the rhea, ostrich, emu, cassowary and kiwi descend from one common ancestor?

activities

ANALYSE AND EVALUATE

- Read the article on the right and then answer the questions that follow.
 - Using an atlas and the diagrams on the opposite page, locate Chile, Tasmania and Antarctica. Does their position on the supercontinent support the claims made by the researchers in the article? Explain.
 - Why aren't *Fitzroya* found on the Antarctic continent today?

REMEMBER

- What names were given to the two supercontinents? What present day continents did each consist of?
- Briefly summarise the evidence that supports the theory that the continents were once joined together into supercontinents.

THINK AND DISCUSS

- If marsupials did originate in South America, how did they migrate to Australia?
- Explain why giant flightless birds are now found on all the continents of the Southern Hemisphere, but not on those of the Northern Hemisphere.
- If Australia is moving northwards at a rate of seven centimetres every year, how far will it have moved in:
 - 150 years?
 - one million years?

Fossil find joins continents

A team of researchers from the University of Tasmania has found fossils of a tree in the north-west of the state, estimated to be 35 million years old. At this time, Tasmania was supposedly moving away from Antarctica.

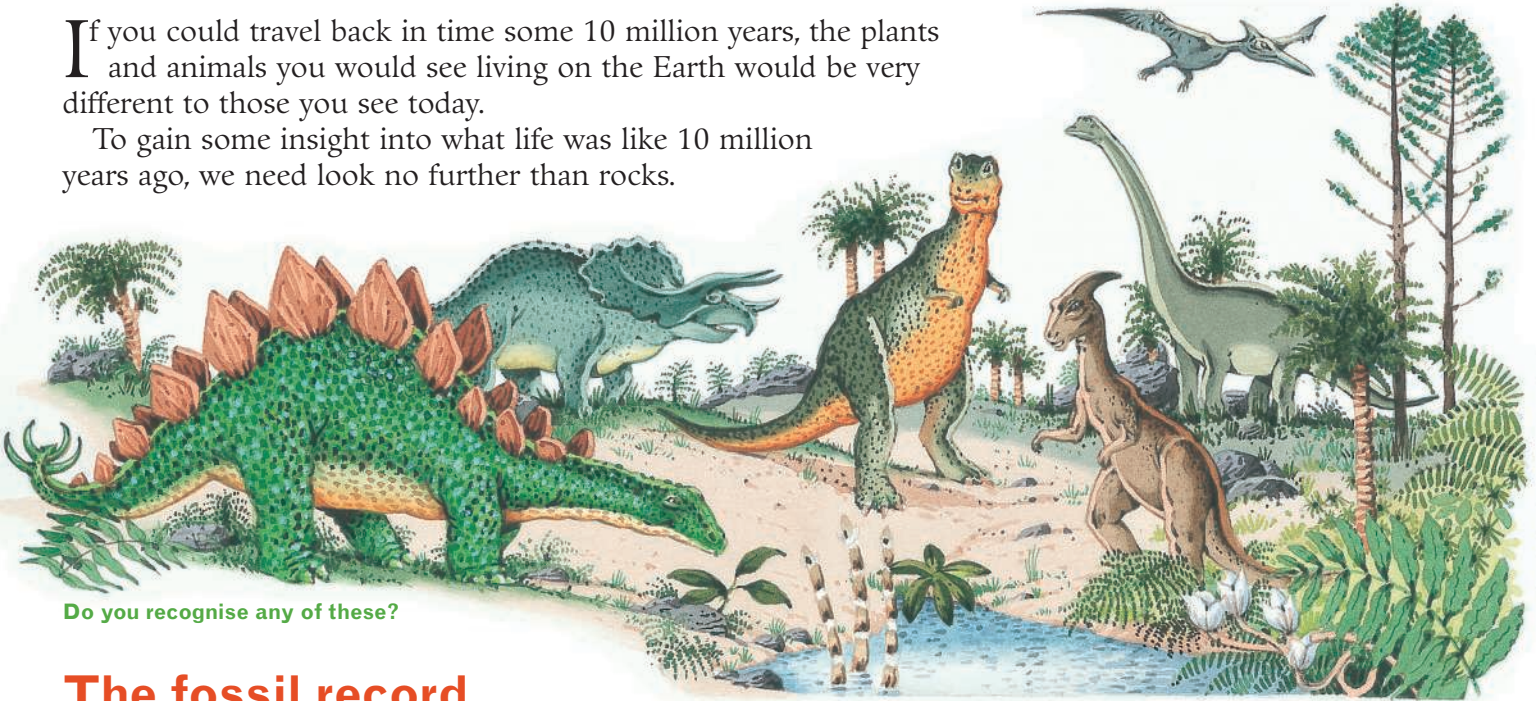
The tree, *Fitzroya*, is a giant conifer that can grow up to 50 metres high. Today, it is found only in Chile. The discovery is just one more piece of evidence to support the hypothesis that the continents in the Southern Hemisphere were once joined together as the supercontinent Gondwana.

Together with other discoveries made over the last decade, this find also lends weight to the view that there were once forests growing in places of high latitude where today there is often nothing but pack-ice. It would seem that forests containing a large number of species once thrived in Gondwana.

Times are a changin'

If you could travel back in time some 10 million years, the plants and animals you would see living on the Earth would be very different to those you see today.

To gain some insight into what life was like 10 million years ago, we need look no further than rocks.



Do you recognise any of these?

The fossil record

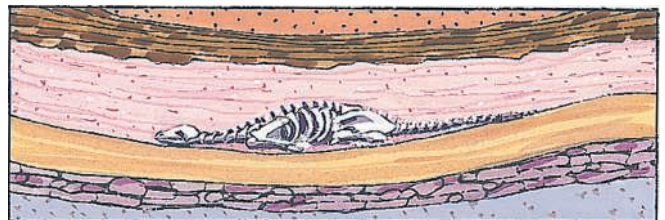
A **fossil** is evidence of past life. Fossils can be parts of an organism, such as its bones, teeth, feathers, scales, branches or leaves. Usually when an organism dies, micro-organisms cause so much decay that eventually no part of it remains. However, if an organism is covered shortly after its death by dirt, mud, silt or lava (as can happen, for example, if it becomes trapped in a mudslide or in the silt at the bottom of the ocean), the micro-organisms that cause the decay cannot work. This is because there is no

oxygen. Over millions of years, the material covering the dead organism is compressed and turned into rock, preserving the fossil within it.

Fossils can also be footprints, burrows and other evidence that an organism existed in the area. For example, a dinosaur track has been discovered in the Otway Range in southern Victoria. By observing the footprints in the track, **palaeontologists**, who study fossils, can work out the size, weight and speed of the dinosaur that made them.



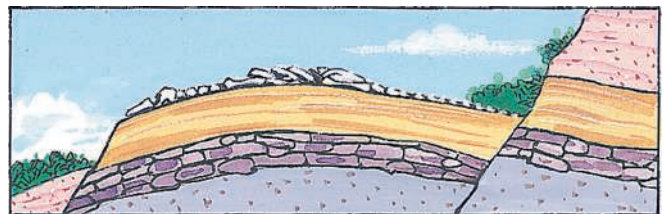
1. A dinosaur dies and is quickly covered by sediment.



2. Over time, the sediment turns into rock. The remains of the dinosaur turn into a fossil.



3. The fossil is flattened by the layers of rock.



4. The rock is folded and eroded and the fossil can be seen on the surface.

Fossil formation

sciFacts

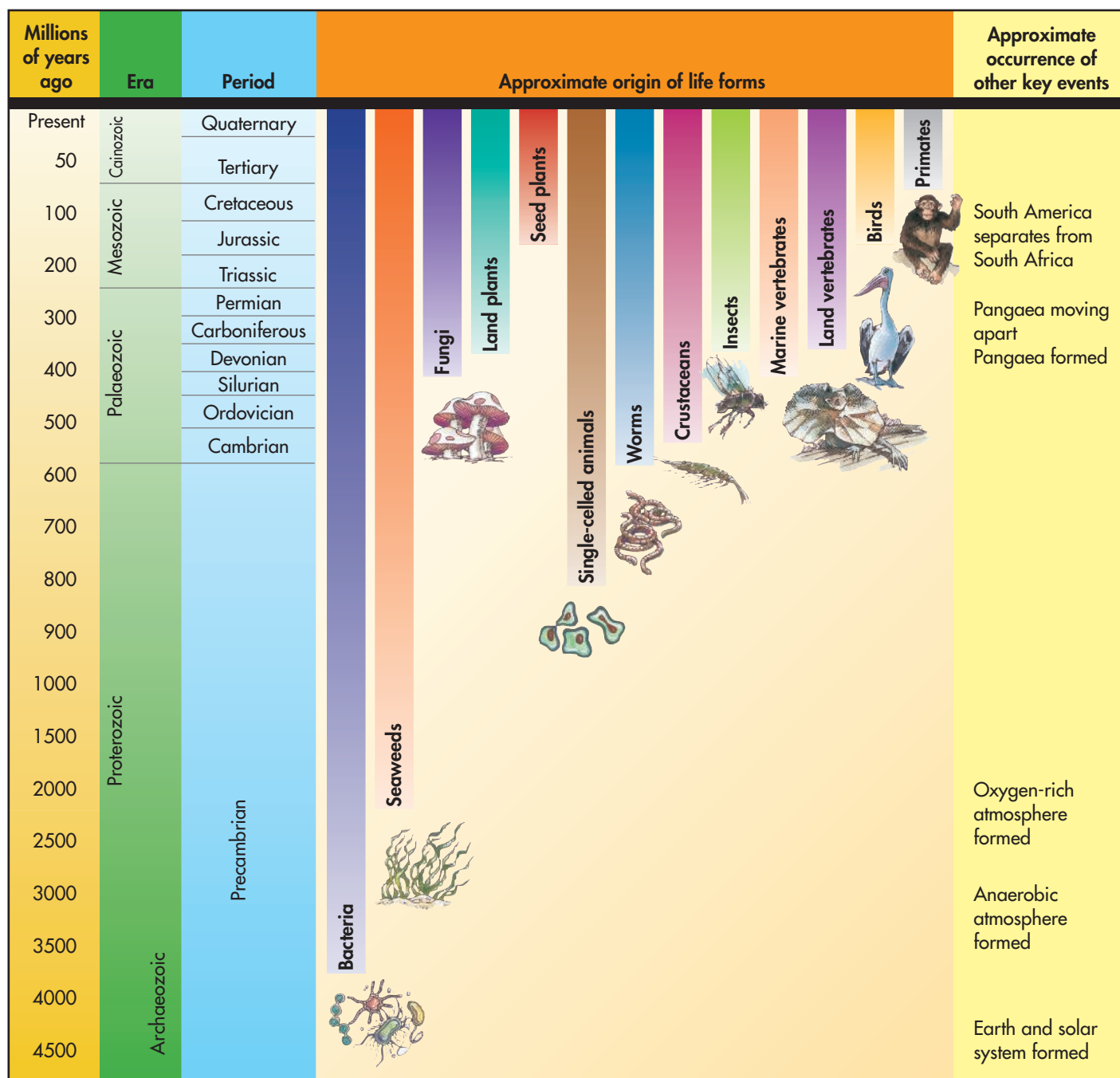
It is thought that over 4 000 000 000 000 different kinds of living things have, at one time, inhabited the Earth; however, only 250 000 of these organisms have been discovered as fossils.

Dating fossils

Radioactive carbon dioxide is naturally present in air, and living things are constantly incorporating a small amount of carbon into their body tissue. This intake stops at death, after which the radioactive carbon in the organism begins to slowly break down into its non-radioactive form. By calculating the amount of radioactive carbon left in the body remains,

it is possible to work out when the organism died. This type of dating, called **absolute dating**, can be used to calculate the age of fossils that died thousands of years ago.

There is also another method scientists can use to calculate the age of fossils. Rocks are laid down in layers; therefore, it is reasonable to assume that the lower layers of



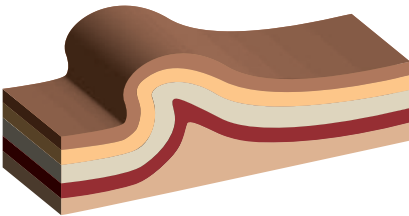
The fossil record provides an incomplete picture of life as it existed on Earth.

rock were laid down first and are older than the layers above them. If any living thing was trapped in the rock layer at the time it was laid down, there is a chance it may have been fossilised. It would therefore be approximately the same age as the rock that surrounds it. This method of dating is called **relative dating**.

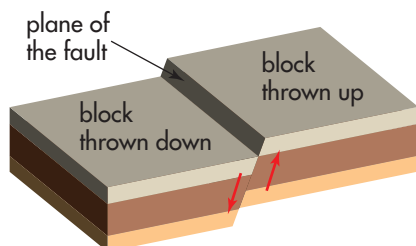


Fossils can be dated by observing their position in the rock layers.

(a) Folds



(b) Faults



The formation of folds and faults can cause changes in the rock layers.

The relative dating method does need to be used with care, however, as the plates in which the rocks lie are still moving. It is possible that a layer (or layers) containing fossils could have been thrust upwards by a sideways force to form a **fold**, or broken and moved apart in opposite vertical directions to form a **fault**.

The oldest rocks discovered so far have been found in Canada and are thought to be around 4550 million years old. The Earth is thought to be about 4600 million years old.

Recording change

The **fossil record** also gives evidence that species have changed over time, and may show how new species arose.

The fossilised skeleton of a bird (*Archaeopteryx*) shown below was found in Bavaria and has been dated at 150 million years. It clearly shows feathers, which are a feature of all modern birds; however, it also has

dinosaur characteristics such as teeth, claws on its wings and a long, jointed bony tail. From this, scientists have deduced that birds **evolved** from a dinosaur ancestor. The evolution, or change over time, of other species can also be followed by studying the fossil record.

Evidence that life may once have existed on Mars has been found inside a meteorite that landed in Antarctica. The meteorite has been dated at about 13 000 years old. Examination of thin slices of the meteorite under an electron microscope has suggested the presence of **microfossils** of single cells. This is significant because it is thought that life on Earth also started out as single cells; however, these single cells on Earth then evolved into complex and diverse organisms. The earliest known fossils on Earth have been found in Greenland. They contain carbon from organisms that once lived, and have been dated at 3800 million years.



The fossilised skeleton of *Archaeopteryx*

ANALYSE AND EVALUATE

- Examine the picture of the fossilised dinosaur below. Then write a brief description of the animal, including what it may have eaten and how it may have moved. Why do you think it had so many large openings in its skull?



Fossilised skeleton of the Saurischian dinosaur

- Examine the dinosaur track below to decide:
 - which dinosaur walked along this track first, and which walked here last
 - which dinosaurs most probably walked on two legs, and which most probably walked on four
 - which dinosaur hopped
 - which dinosaur was the heaviest.
 (Identify the dinosaur(s) in your answers to the above questions as A, B, C or D.)



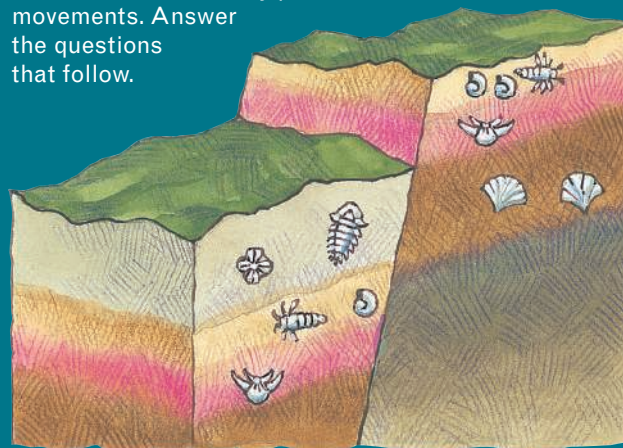
REMEMBER

- What is a fossil?
- List the conditions that need to be present to ensure that fossilisation occurs.
- What does the fossil record tell us?
- Why is the fossil record incomplete?
- Describe two techniques that scientists use to date rocks. What does each method tell us?
- Why do scientists believe that dinosaurs may have been the ancestors of modern birds?

- Use the fossil record diagram on page 245 to:
 - list the order of appearance of different groups of organisms on Earth
 - determine the era in which Pangaea was formed.

THINK AND DISCUSS

- Why are so few organisms preserved as fossils?
- Why did land-dwelling plants appear in the fossil record before land-dwelling animals?
- The layers of rock shown in the illustration below have been disturbed by plate movements. Answer the questions that follow.



- Was the plate movement caused by folding or faulting?
- Which layer of rock is the youngest? Explain your answer.
- Which layer of rock is the oldest? Explain your answer.

INVESTIGATE

- What do geologists and palaeontologists do?
- Investigate the claims of 'life' on Mars (for example, information on the rock sample labelled ALH84001) through newspaper reports and websites. For an example, go to the website for this book and click on the Center for Mars Exploration link (see 'Weblinks', page 305). Are you convinced that life once existed on Mars?
- Research and prepare a report on carbon dating.

CREATE

- Create a dinosaur track using modelling clay.
- Make a cast of a leaf fossil using modelling clay or plasticine. To do this, firstly roll out a rectangular piece of clay and cover it with petroleum jelly. Then press a ribbed leaf into the clay to make an impression. Remove the leaf and build some clay walls about 1 cm high at the edge of the rectangle. Cover the walls with petroleum jelly and pour in some mixed plaster. When the plaster has set, remove the clay and examine the cast for the leaf impression.
- Make a model or draw a picture to show what a common ancestor of both mammals and birds may have looked like.

Science at work: Zooming in

Science is full of wonder, just waiting to be explored. More than in any other career, the scientist can be both an adventurer and an explorer. The opportunities to discover new things are almost endless, with the journey of discovery full of many twists and turns along the way.

The life of scientist Denis Crawford is one such adventure. He asks questions, makes observations and experiences new challenges as he tries to make sense of the world around him.



Denis Crawford photographing the Sorsdal Glacier

Chemical colours

Educated in West Essendon, Victoria, Denis studied a mix of humanities and sciences. After completing Year 12, he spent 18 months at Dookie Agricultural College. From there he moved to the Organic Chemical Research Section of ICI, experimenting with 'colourful chemistry'. His job was to discover new colours of pigments, paints and inks, and then think up names to describe them.

Caring for 'crawlies'

In 1977, the 'call of the wild' beckoned Denis. For the next 10 years he was involved in *entomological* research with the Department of Agriculture. He immersed himself in the world of insects. During the day he collected caterpillars and maintained breeding colonies in his laboratory. Here he could study not only the insect's reproductive cycle but also the best way to control insect populations. Over two billion dollars worth of pesticide is used annually in Australia to rid crops of agricultural pests; Denis's caterpillars were responsible for half of this use. During this time he was often referred to as 'the caterpillar chef'. He found that the best food for the caterpillars was a blend of baked beans and agar, which he set into blocks and cut up into insect 'bite size' pieces.



One of Denis's creeping, crawling specimens

Snappy travels

Denis became more and more interested in the challenges involved in 'capturing' the wonders of the world around him. At the end of his time at the Department of Agriculture, he travelled overseas, taking photographs of the natural world around him. On his return to Australia, over 500 of his photographs were placed in a photographic library. This library acted like an agent and sold Denis's photographs to magazines, journals and other parties.

Getting a closer look

Denis's dual interests in natural science and photography led him to enrol in the RMIT's Applied Science (Photography) degree course in 1991. His third-year project was on close-up insect photomicrography, that is, taking photographs using a scanning electron microscope. His aim was to produce a series of photographs in which dead insects were made to look alive. Denis successfully met the challenge he set himself, and at the end of 1993 his work on the project earned him the Chris Hales Imaging Award.

Strange looking . . .

Denis was increasingly seen to be 'staring at bushes, waiting for insects to move into the right spot'. He remembers the reactions of other people when they saw him lying 'fully stretched out on the footpath photographing harlequin bugs going about their daily business'. As Denis recalls, 'People stared at me, gave me strange looks and then crossed the street to avoid me. To "shoot" a bug properly you have to get down to their level . . . I had no choice!'



Denis's *Backyard Insects* book cover photograph

Backyard insects

Denis's insect photographs caught the attention of Paul Horne, an entomologist. He approached Denis with the idea of creating an informative and colourful book on everyday insects. Over the next two years, Denis produced over 100 'insect images' and Paul wrote the accompanying text.



One of Denis's insect images

Living in a freezer

The wilds of Antarctica had always held a fascination for Denis. Since he was young, he had loved to hear about Antarctic adventurers like Sir Ernest Shackleton, Captain Scott and Sir Douglas Mawson.

In 1994, he approached the Antarctic Division to offer his services as a photographer. Two years later, in January, he was on a ship travelling through rough seas and pack-ice. His mission was to photograph small fossils in the Vestfold hills, in eastern Antarctica.

Fifteen of the 70 expeditioners disembarked with Denis at Davis Station. They included a palaeontologist, a meteorologist, an astrophysical engineer, a space plasma physicist and a zoologist.

Denis's first impressions of Davis Station were interesting: '... a Legoland on Mars ... a colourful blockscape of buildings ... all colour coded'. The Antarctic environment is, in fact, so unusual that NASA has used one of the ice-free regions as a training ground for astronauts in extraterrestrial living.

Finding frozen fossils

Denis was very excited about what he found, 'Fossils were sitting on the surface of what used to be a seabed four million years ago. After the last major glaciation, about 12 000 years ago, a glacier receded and exposed this seabed. Although most of the fossils were of shells, there were also fossils of ancient dolphins and whales. They were extraordinary!'



An Antarctic fossil

'As you walk across the Marine Plain, you disturb very fine dust. This dust is the remains of four-million-year-old diatoms (phytoplankton), and from time to time you have to stop to wipe the diatoms out of your eyes.'

'Sitting on the surface of this flat plain are many unique rocks which have been moved from other areas and deposited here by the glacier. There is a two-metre high "turtle skull" rock which has strange holes in it caused by the eroding winds.'

Life at the bottom of the world

Wind is an ever-present and important feature of Antarctica. The winds come off the great Antarctic plateau from the South Pole and fall downwards towards the sea. They are known as katabatic winds. When the wind hits the coast, it can be travelling at a speed of 200 kilometres per hour.

Denis's challenge was to photograph fossils in the field. 'It was so windy it was difficult to set up the tripod, and the camera kept shaking. As it was so cold, I had to wear thick gloves. This made it hard to operate the camera. I ended up photographing the fossils in the station lab.'

Sleeping arrangements on field excursions were also curious. 'Once I was outside in the field for five days. During this time, the research team stayed in round fibreglass huts. These huts were named on the basis of their shape and size. I slept in a "melon" but there were also "apples" and "Smarties". The "melons" slept two people, whereas the "apple" slept only one. Although we had torches, we didn't really need them, as in summer there were 20 hours of full sunlight. The rest of the time was like a "weird dusk". We had no television but we didn't miss it because there was so much to learn and so many adventures to live ...'

Fire and ice

The Sorsdal Glacier lies at the end of Marine Plain. Denis was among a group of scientists who climbed it, starting at twilight and reaching the top at midnight. 'When we reached the top, we celebrated by eating a packet of TimTams and drinking Tang. It was the most stupendous sight. I'll never forget the colours ... the sky was on fire and the ice was purple.

'Wow! ... to capture the colour and feeling of the moment. Hand me my camera quickly!'

And now? At the moment Denis is writing a book on his adventures in Antarctica. What adventures await him once he's finished that journey?

activities

REMEMBER

- 1 Draw a flowchart of Denis's life. Include years where possible.
- 2 What is photomicrography?
- 3 What was Denis's job while he was in Antarctica?
- 4 How old were the fossils that Denis photographed in Antarctica?
- 5 What are diatoms and why did they get in Denis's eyes?
- 6 Why didn't Denis need to pack a torch for his Antarctic travels?

THINK AND DISCUSS

- 7 What is a photographic library? What types of people might use a photographic library?
- 8 What do palaeontologists, meteorologists, astrophysical engineers, space plasma physicists and zoologists do? What might they be doing in Antarctica?
- 9 Why would you expect to find fossils underneath a glacier?
- 10 The fossils that Denis photographed in Antarctica were four million years old. What types of organism might they have been?
- 11 Suggest the effect that the winds may have had on the Antarctic environment.
- 12 Suggest some features or characteristics that organisms living in Antarctica may have in order to cope with the weather conditions.

INVESTIGATE

- 13 Find out more about the lives and expeditions of Sir Ernest Shackleton, Captain Scott and Sir Douglas Mawson.
- 14 What is an entomologist?
- 15 Investigate some of the caterpillars that destroy Australian crops. How can farmers control them?
- 16 Investigate glaciers. Why are they able to move rocks from one place to another? Where are the nearest glaciers to Australia?
- 17 Find out about the lives and features of organisms which inhabit Antarctica. How are they suited to their environment?

IMAGINE

- 18 Imagine that you are going on an expedition to Antarctica. Suggest a scientific reason for your expedition. Carefully plan your trip including what types of scientist you would take. What two personal items would you take? Write an imaginary journal detailing your expedition.
- 19 Photograph some insects and use them to construct a class field guide to local insects. You will need to use reference books to find out about each insect.
- 20 Write a story about your future adventures. Include dates and key events. Your final story may take the form of a journal, biography, tape recording, video or play.

Adding variety to life

Ayla examined her son again, trying to remember the reflection of herself. My forehead bulges out like that, she thought, reaching up to touch her face. And that bone under his mouth, I've got one too. But, he's got brow ridges, and I don't. Clan people have brow ridges. If I'm different, why shouldn't my baby be different? He should look like me, shouldn't he? He does a little, but he looks a little like Clan babies, too. He looks like both. I wasn't born to the Clan, but my baby was, only he looks like me and them, like both mixed together.

(from *The Clan of the Cave Bear* by Jean M. Auel)

In the extract above, Ayla realised that her baby was a mixture of two races. The mixing of races is only one of the ways that variety is added to life.

Look at the dogs in the photograph below. What differences can you see? How did this variation come about when all the individuals belong to the same species?



Different breeds of the species *Canis familiaris*

Bringing in new genes

Migration of individuals of the same species into a new population can bring new genes into that population. The human species, for example, has until recently been split into small groups. The separate identity of these groups was maintained by geographical barriers, such as mountains and oceans, and by attitudinal and social barriers. With the advent of faster and more accessible means of transport and improved communications, these barriers are now starting to break down, and migration between human groups is common.

Sometimes the variation introduced into a population is not beneficial. An inherited anaemic disease, thalassaemia, is common among people living along the Mediterranean coast, particularly people of Greek origin. As people from this part of the world have migrated to Australia, they have brought with them the recessive gene responsible for thalassaemia, and some children born in Australia are now showing this disease. On the other hand, if the variation introduced into a population is beneficial to the population's survival, that characteristic may then become more frequent in that population.

The case of the English peppered moth

The English peppered moth, *Biston betularia*, rests on tree trunks during the day. Its speckled grey colouring provides a good camouflage on the lichen-covered trunks. In about 1850, a black English peppered moth was discovered in Manchester. It was disadvantageous for these moths to be black as they stood out against the white lichens and were therefore easily seen by predators. What could have happened to cause this drastic change, one that seemed to be exposing the moth to more danger?

With the spread of the Industrial Revolution and the expanding use of steam power, pollution became an everyday problem in large cities like Manchester. The once white lichen-covered tree trunks turned black. This change meant that it was no longer advantageous for the *Biston betularia* to be speckled grey, as this made the moth more visible to predators. The number of black moths increased dramatically, and by 1895 they made up about 98 per cent of English speckled moths. But how did they get to be black? Was it just because the tree trunks turned black? We will find out more later in this spread.



Which moth can you see?

Variety through sex

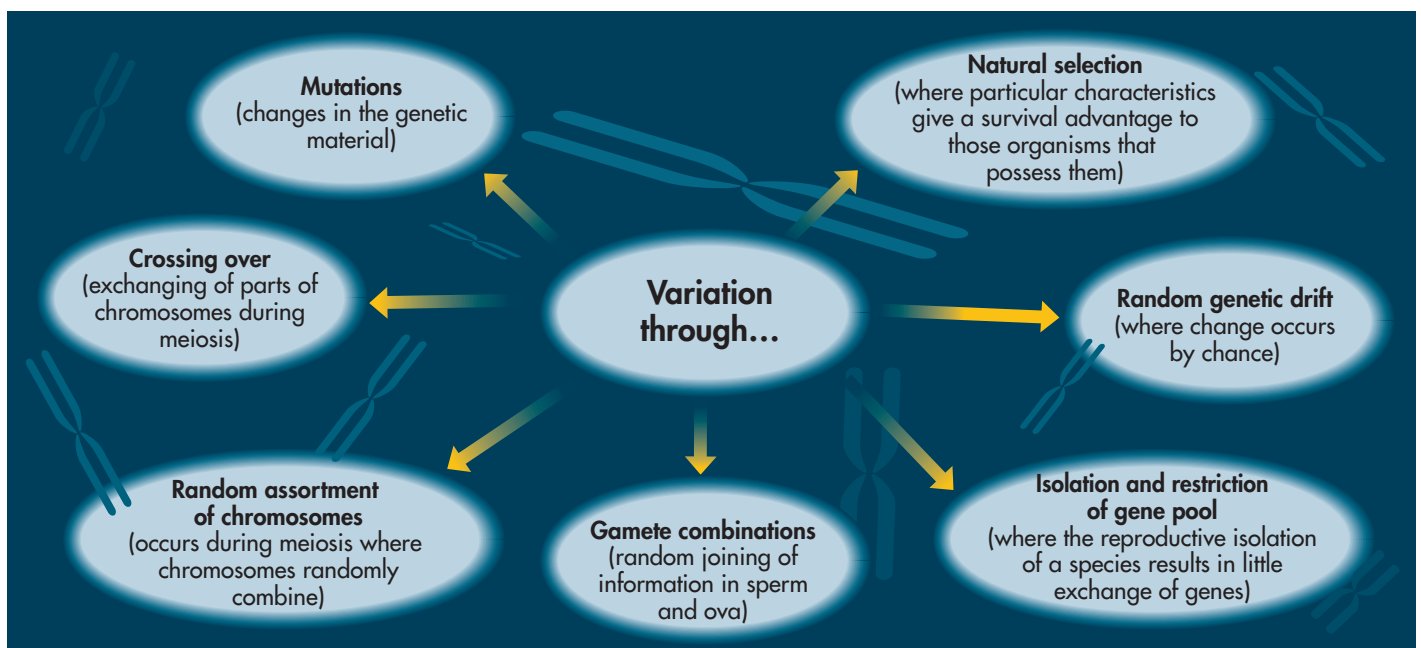
Each of the cells in your body contains 23 chromosomes from your mother (maternal chromosomes) and 23 chromosomes from your father (paternal chromosomes). When you start producing sex cells or gametes (sperm or ova) through the process of

meiosis, an opportunity is provided to mix up these paternal and maternal chromosomes. Further mixing occurs when maternal and paternal chromosomes exchange some of their genes in a process called **crossing over**.

Parents produce gametes by a process called meiosis. One of each chromosome pair goes into the gametes produced.

Baby contains both maternal and paternal chromosomes.

Our gametes contain a mixture of our maternal and paternal chromosomes.



Variation — the spice of life

There is very little genetic variation among the present-day cheetah population. Scientists believe that this is because at some time in the past, all cheetahs were wiped out except for one mating pair. The genes of this pair are now found in all cheetahs.

Sometimes making mistakes can be good

Chromosomes are found in the nuclei of cells. Chromosomes are made up of DNA (deoxyribonucleic acid), which provides the blueprint for the production of proteins. When cells divide, their chromosomes have to replicate and divide precisely to ensure that the new cells contain the correct number and type of chromosomes.

When gametes are produced, the meiotic division ensures that each new cell contains half the normal number of chromosomes of other types of cells. Random and spontaneous mistakes are sometimes made during this division process. If the mistake involves changing the DNA within the cell, it is called a mutation. This change could involve either the amount of DNA in the cell (a **chromosomal mutation**) or the information coded in the DNA strand (a **gene mutation**). This change may, in turn affect the protein or proteins that are produced.

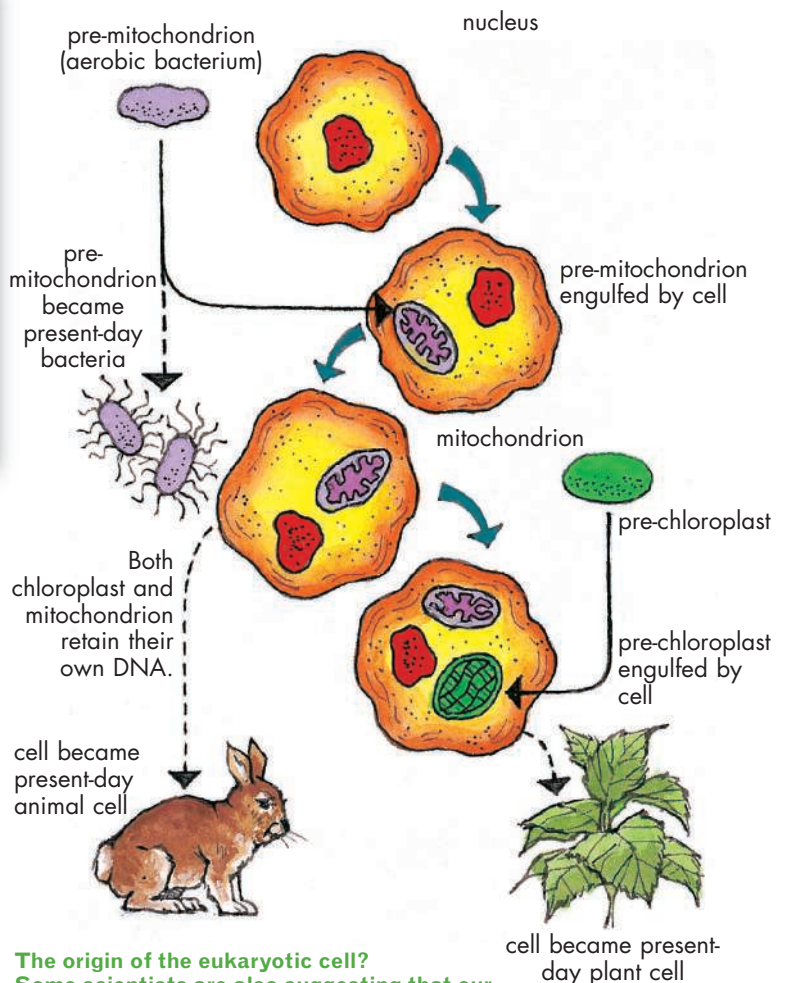


Native Australian budgerigars are blue in colour; however, mutations have produced a wide range of new colours.

Only very rarely does a mutational change assist an organism to survive. In the case of the *Biston betularia* moth, for example, it is thought that the black variety originally arose as a result of a mutation. This mutation proved to be beneficial for the moth, as its environment was changing at the same time. As the pollution in the air caused the lichen-covered tree trunks to blacken, those moths without the mutation (that is, with a speckled grey colour) decreased in number. Gene mutations are the only means by which new genes can be produced in a species.

Just visiting?

Can adding variety to life increase your chances of survival? The ancestors of the eukaryotic cells that make up your body may have thought so! There is a hypothesis that over a billion years ago, ancestors of complex cells like ours 'captured' some little aerobic bacteria. Supplying these prehistoric cells with energy, these 'house guests' were 'fed and looked after'. Over time, however, the independence and most of the genetic material and functions of these aerobic bacteria were lost. They became mitochondria — the organelles that supply our cells with energy using aerobic respiration. It is considered that chloroplasts, like those in plant cells, evolved in a similar way.



The origin of the eukaryotic cell?
Some scientists are also suggesting that our nucleus may have come from a giant viral ancestor.

Secret agent?

Whereas the nucleus of a human cell contains about 20 000 to 25 000 genes, each mitochondrion has only 37. The genetic instructions or genome in mitochondria is referred to as mtDNA. Research is suggesting that mtDNA may play an important role in reproduction and also affect our health after we are born. Some studies are currently investigating the possible relationship between particular base sequences in mitochondrial DNA and ageing.

In the ovaries of developing female embryos, about 80 per cent of the developing ovary's five million egg cells undergo programmed cell death by a process called atresia. Research is suggesting that mtDNA is involved in the selection of which of the egg cells survive. Recent studies also suggest that mitochondria in mammalian sperm are actively destroyed after a sperm fuses with an egg. This results in

mtDNA being passed only from the mother and not the father to the children. If you are a female, you will have inherited mtDNA from your mother, her mother and from all of the other mothers along your genetic line. If you are a male, you will have inherited your mtDNA from your mother, but it will not be passed on to your children.

Some scientists are involved in investigating genetic patterns in the mtDNA in various populations. There is a controversial theory which suggests that Earth's current human populations all have evolved from one female who lived in Africa 200 000 years ago, who has been named Mitochondrial or African Eve. There is also a theory that suggests that most Australians are descended from just seven (of the 22) 'daughters of Eve' on the basis of their mtDNA.

activities

REMEMBER

- 1 List the difference that you can see among the dog (*Canis familiaris*) breeds shown on page 252.
- 2 How can variation be added to a population?
- 3 What is the only way that new genes can be produced in a species?
- 4 Explain the difference between a chromosome mutation and a gene mutation.
- 5 Outline the hypothesis of the origin of the eukaryotic cell.
- 6 What is mtDNA and what is unusual about the way that it is inherited?

THINK AND DISCUSS

- 7 What sort of social and attitudinal behaviours could isolate human populations?
- 8 Describe two ways in which a change in the DNA could affect protein production.
- 9 How could any new variation occur in the cheetah population?
- 10 Comment on 'Variety is the spice of life' and 'Opposites attract' in terms of variation in a species.

INVESTIGATE

- 11 Investigate meiosis. What events occur during the meiotic division that can mix up the paternal and maternal chromosomes in the gamete? (*Hint*: Find out about independent assortment and crossing over.)
- 12 (a) Who was Mitochondrial Eve and why was she important?
(b) Do all scientists agree on her existence? Explain.
- 13 Find out more about research investigating mtDNA. Present your findings as a journal or newspaper article, web page or PowerPoint presentation.

USING DATA

- 14 Read the article and answer the questions that follow.

Bacteria don't sunbake!

The ozone layer helps to filter out many harmful UV rays. In Precambrian times, over 62 million years ago, there was, however, no ozone layer. How then did life survive? To answer this question, a team of biologists from NASA's Ames Research Centre in California has been studying microbial mats of bacteria and blue-green algae, the types of organisms that lived in Precambrian times.

The natural production of DNA in each organism was studied by placing some of the mat into a plastic bag that was transparent to UV light. Some radioactive phosphate was added into the bag. (Phosphate is used by cells to produce DNA.) Every few hours the amount of phosphate in the DNA of some of the cells was measured. The results for both bacteria and blue-green algae showed the same pattern of DNA production. At sunrise, the amount of phosphate in the DNA was high. DNA production then ceased at noon for three to six hours, resuming again just before sunset. Photosynthesis occurred throughout the whole day.

Head of the research team, Lynn Rothschild concluded that the cells cease DNA production at noon because of the harmful UV light. The cells use this time to repair any DNA damage before they begin to divide again. This mechanism might give some unicellular organisms a natural advantage if the Earth's ozone layer continues to be destroyed.

- (a) What question were the researchers trying to answer?
- (b) Describe the experiment they set up.
- (c) What were their results? What were their conclusions?
- (d) What implications do these conclusions have for life on Earth if the ozone layer continues to break down?

Science at work:

The evolution revolution

The theory of evolution

Do you and the apes that you see at the zoo share a common ancestor? This concept has caused much controversy between religion and science. Carolus Linnaeus (1708–1778), the founder of taxonomy, developed his classification system ‘for the greater glory of God’, rather than in the interests of scientific understanding. His ideas, however, were used as a basis for the development of the theory of evolution. The theory of evolution is usually credited to one man, **Charles Darwin** (1809–1882). In fact, the ideas behind the theory were a culmination of those from a number of different individuals both in Darwin’s time and before it. With technological advances, refinements have also been made to Darwin’s theory.



Darwin points out the similarities between humans and apes, by an unnamed artist in *The London Sketch Book*, 1874.

Evolution ownership?

In 1831, Charles Darwin sailed from Great Britain aboard the HMS *Beagle*. During this seven-year voyage his views on life were greatly changed. He noted the similarities and differences in the flora and fauna inhabiting different regions. He was particularly puzzled by the features of the animals on the Galapagos Islands near South America.

By the time he had sailed from Galapagos, his observations and his awareness of the ideas of a geologist named **Sir Charles Lyell** (1797–1875), who had been influenced by James Hutton (1726–1797), led him to doubt the church’s position that the Earth was static and had been created only a few thousand years ago. He had been greatly influenced by both Lyell and Hutton’s views that geological change resulted from slow, continuous actions rather than sudden events, and that very slow and subtle processes over a long period of time could cause substantial change.

After returning home in 1837, Darwin began his notebooks on the origin of different species and, in 1844, wrote his essay ‘On the origin of species’.

In 1858, British naturalist **Alfred Wallace** (1823–1913) is reported to have said: ‘It occurred to me to ask the question, why do some die and some live? And the answer was clearly that, on the whole, the best fitted lived...’. It was in July of this year that his theory of natural selection (almost identical

to Darwin’s theory) along with extracts of Darwin’s unpublished 1844 essay, was presented by Lyell to the Linnaean Society of London. Although it was Wallace who wrote up his ideas for publication first, Darwin is known as the theory’s main author because he developed and supported natural selection more extensively. In 1859, Darwin finally published his book *On the Origin of Species by Natural Selection*. Many people were outraged by the suggestion that humans could be related to apes. The scientific community, however, gradually came to accept Darwin’s theory, some even expressing embarrassment at not having thought of such a simple explanation before.

What did Darwin conclude?

Many theories of evolution had been proposed before Darwin’s theory. His theory was different in that it included a process by which evolution could have occurred. He called this process **natural selection**, commonly known as ‘survival of the fittest’. He believed that by this process a single species could have given rise to many new species, and that these new species were much better able to survive in the environment in which they lived.

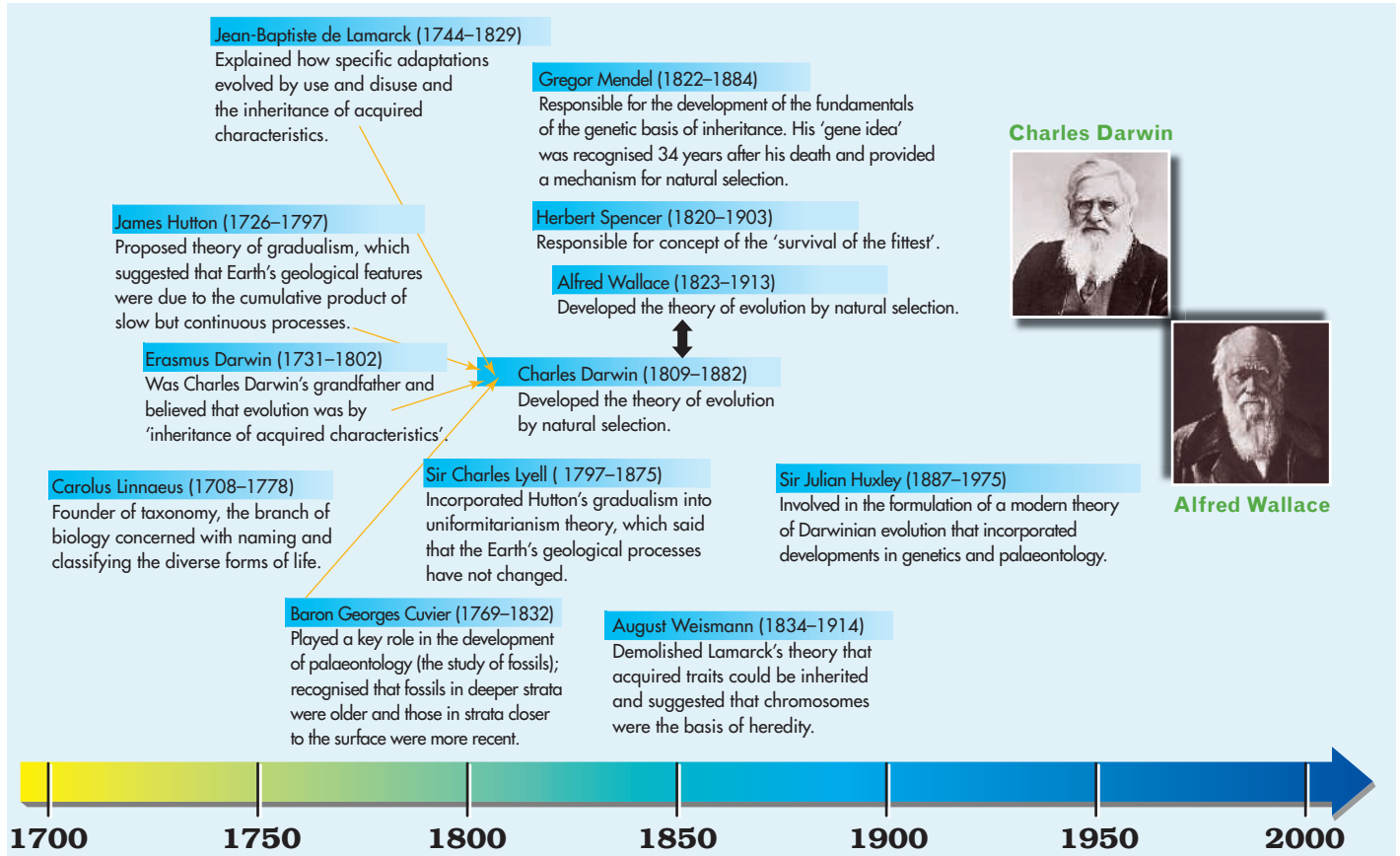
So, what is this theory all about? Natural selection proposes that:

- members of a single species show variation in their characteristics. Some of this variation is passed from parent to offspring (that is, it is inherited).

- in the struggle to survive, some members of a species will die before they reproduce
- the surviving members of a species possess the characteristics that best enable them to survive in their present environment. They pass these characteristics on to their offspring.
- over time, organisms become better suited to their current environment.

There were, however, many gaps in Darwin's theory. He did not have any understanding of genetics and therefore could not prove why variation existed in a species. He also did not know how this variation was inherited.

Scientists who contributed to the current theory of evolution. Where does the discovery of DNA fit into this theory?



activities

REMEMBER

- 1 Who are the two people jointly credited with developing the theory of evolution?
- 2 What did Darwin conclude from the observations he made during his voyage on the HMS *Beagle*?
- 3 Summarise the process of natural selection.
- 4 Outline the contributions of the following to the theory of evolution: Linnaeus, Darwin, Lyell, Hutton, Wallace and Mendel.

THINK, INVESTIGATE AND DISCUSS

- 5 (a) Use the timeline above to answer the following questions. Which of the scientists:
 - (i) was the first to be born?
 - (ii) lived the longest?
 - (iii) was born before Darwin?
 - (iv) was born after Darwin?

- (v) lived at the same time as Darwin?
 - (vi) is attributed with founding taxonomy?
 - (vii) played a key role in the development of palaeontology?
 - (viii) is responsible for the development of the fundamentals of genetics?
 - (ix) developed the theory of use and disuse and the inheritance of acquired characteristics?
 - (x) demolished Lamarck's theory and reasoned that chromosomes were the basis of heredity?
- (b) Add other social, cultural, religious, political or historical events to the timeline. Select one of the scientists and incorporate this information into what life must have been like for them. Comment on the influence that their contributions to the theory of evolution may have had on their personal lives.
- (c) Suggest where the discovery of DNA would fit into the timeline. Discuss the impact that this has had on the evolution theory.

The best, naturally

We are all different. Our differences increase the chance of survival of our species. If our environmental conditions were to change, some of us may have an increased chance of surviving. Those who survive may then pass on any genetically inherited advantage to their children who would also have an increased chance of survival, that is, unless the environment changed to their disadvantage. If this happened, then other variations may have increased chances of survival.

Who's the new kid in town?

Variation, struggle for survival, selective advantage and inheritance of variations formed the basis for

1 Variation of characteristics is present in a population.

2 The breeding population becomes isolated.

3 Different characteristics arise through random genetic drift, mutation and environmental pressures.

4 The environment changes. Because of selection, some characteristics are favoured over others. Those best suited to the environment survive.

5 Survivors reproduce and pass on favourable genes and features to offspring.

6 The frequency at which the genes for the new characteristics appear increases.

7 The isolated population is now quite different, producing a new species.

Speciation is a process by which a new species develops from another.

Charles Darwin's theory of evolution by natural selection. Darwin's theory also provided an explanation for how new species arise. The formation of new species is called **speciation**. New species can be formed if a population of organisms is divided into two or more new populations which are prevented from interbreeding with each other and different selection pressures act on each population.



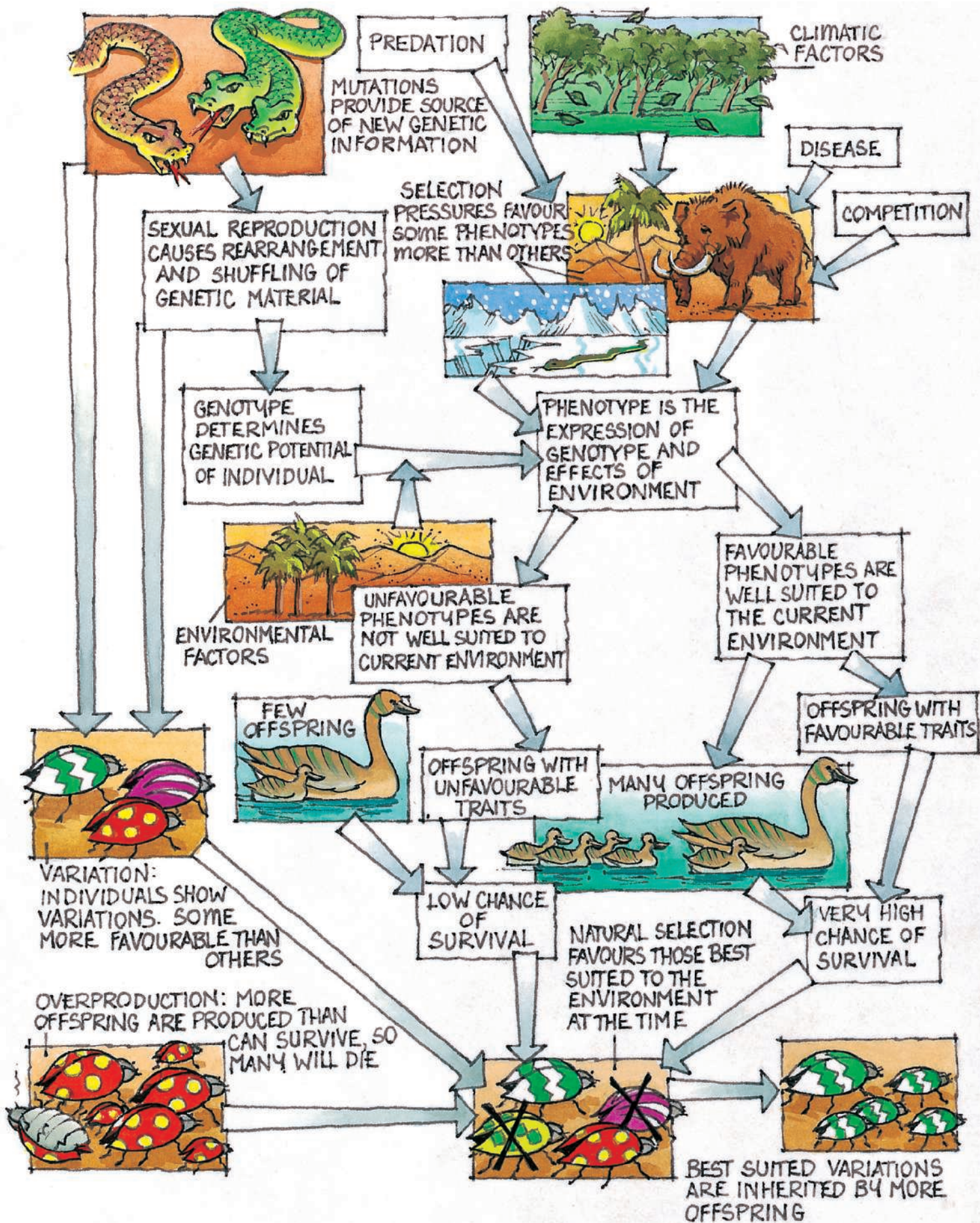
activities

REMEMBER

- 1 List the four principles that form the basis for Darwin's theory of natural selection.

INVESTIGATE AND CREATE

- 2 Use the *Evolution by natural selection* diagram on page 259 as a basis for a board game on natural selection.
 - (a) Use the Internet and a variety of other sources to find information that can be used for questions that are relevant to the natural selection game.
 - (b) Write these questions (and their answers) on cards.
 - (c) Discuss and design a rule book for your game.
 - (d) Play your team against another team in the class
- 3 Find out about Charles Darwin's life and adventures. Summarise your information into a journal, recording or play.
- 4 Design and construct your own organism.
 - (a) Give this organism a name and describe the environment in which it lives.
 - (b) Use this organism as the common ancestor for four other variations of the organism.
 - (c) Construct each variation, giving each a name and describing how the variation increases its chances of survival in its own environment.
- 5 Find out about, and report on, Jean-Baptiste de Lamarck's theory of evolution.



Science at work: 'Old' evidence

The theory of evolution by natural selection is now so well accepted by most scientists that it has almost become scientific fact. Since Darwin's time, evidence has been collected that supports this theory. This evidence is detailed below.

Biogeography

It was the geographical distribution of species (or **biogeography**) that first suggested the concept of evolution to Darwin. He observed that islands with similar environments in different parts of the world were not populated by closely related species but with species related to those of the nearest mainland. Hence, he concluded that species originate in given areas and may later disperse outwards. Parts of Australia and Africa, for example, share a similar hot and dry climate. Despite this, both countries are home to a great range of different plants and animals. Australia has the largest number of species of marsupials and monotremes, whereas there are none in Africa. Does this suggest that evolution has occurred independently in both places?

There are some unrelated organisms, however, which live in very similar environments in different parts of the world and have evolved similar structures. The tendency of unrelated organisms to acquire similar structures is known as **convergent evolution**. The fin of a dolphin and a shark, and the eye of an octopus and that of a human are examples. Structures that perform the same roles but have different evolutionary origins are called **analogous structures**.

The fossil record

The study of organisms of the geological past as represented by their fossil remains is called palaeontology. As the layers of sedimentary rock are arranged in the order they were deposited, the most recent layers are near the surface and the older layers are further down. The position or location of a fossil in the strata, or layers, of rock gives an indication of the time period in which it lived. It also provides us with information on which groups of species were living at the same time and in which order they appeared

on Earth. Fossils or the rocks in which they were located can also be dated by various **radiometric techniques**, which are based on the rate of decay or half-life of particular isotopes (refer to page 45).

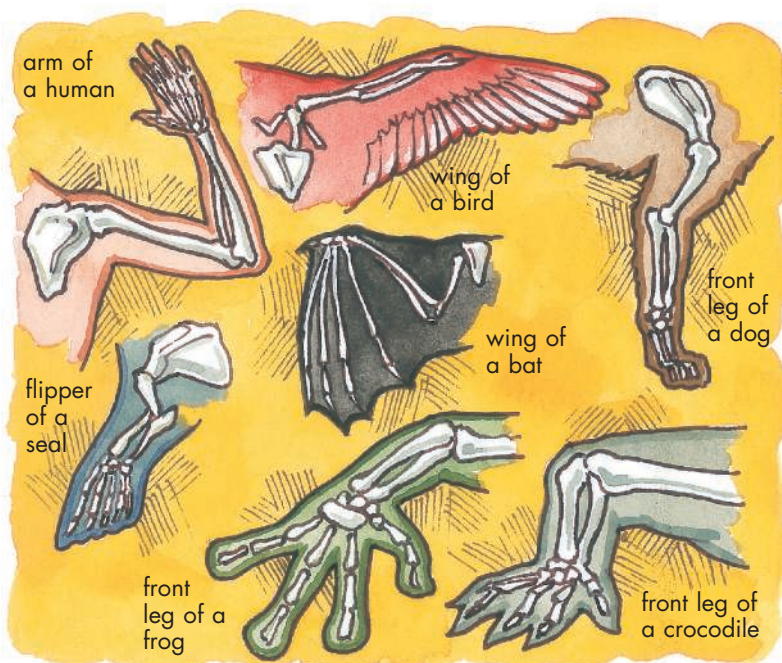
Comparative anatomy

The forearms of mammals, amphibians, reptiles and birds are remarkably similar in structure. Each, however, is used for a different function, such as swimming, walking or flying (see the diagram below). The structure of the forearm can be traced back to the fin of a fossilised fish from which amphibians are thought to have evolved.

Similarity in characteristics that result from common ancestry is known as **homology**. Anatomical signs of evolution such as the forearms of mammals are called **homologous structures**.

Comparative embryology

Organisms that are believed to be closely related go through similar stages in their embryonic development. During the early stages of development, the



The forearms of mammals, amphibians, reptiles and birds show remarkable similarity in structure. Does this suggest a common ancestor?

human embryo and the embryos of other animals appear to be quite similar. For example, the embryos of fish, amphibians, reptiles, birds and mammals all initially have gill slits. As the embryos develop further, the gill slits disappear in all but the fish. It is thought that gill slits were a characteristic that all these animals once shared with a common ancestor.

Molecular biology

The evolutionary relationships among species can also be reflected in their DNA and proteins. The closer the match in the DNA sequences, the more recent their common ancestor and hence the more closely they are related. For example, you are more closely related to your brothers or sisters than to your cousins, who in turn are more closely related to you than your classmates. Likewise, humans and chimpanzees have very similar DNA, compared to that of humans and ferns. **DNA hybridisation** is a technique that can be used to compare the DNA in different species to determine how closely related they are.

Artificial selection

Darwin found evidence that environmental factors can screen inheritable variations in each generation, favouring some variants over others. In **artificial selection** humans mimicked the process of natural selection by artificially selecting

certain desired characteristics in a population in their breeding of domesticated plants and animals. Horse breeders, for example, can crossbreed the fastest and strongest horses in order to produce those most capable of winning races.

activities

REMEMBER

- 1 List five types of evidence that support Darwin's theory.
- 2 What does 'biogeography' mean and why was it important to Darwin's development of his theory of evolution?
- 3 What is palaeontology and how is it important to ideas about the evolution of organisms?
- 4 Why are the embryos of the human, monkey, pig and chicken similar during early stages of development?
- 5 What is the difference between homologous structures and analogous structures?
- 6 What is DNA hybridisation and how is it useful?

- (b) Which species are most closely related to humans?
- (c) Which species are less likely to be closely related to humans?
- (d) Use the information in the table below to construct a flowchart, graph or diagram to show the likely relationship between the seven listed species.

INVESTIGATE AND CREATE

- 8 Australia's indigenous flora and fauna are unique. Find out the names of several of Australia's indigenous flora and fauna and the reason for their uniqueness.
- 9 Trace the pedigree of a horse, cat or dog. Explain reasons for some of the matings in the pedigree.
- 10 How is artificial selection different from natural selection?
- 11 Explain the significance of adaptations of organisms in relation to their survival.
- 12 Find out what the environment was like at some particular time in the past. Which traits or features would give an organism increased chances of survival? Would these features still be an advantage in modern times? Explain.
- 13 What will Earth be like in the year 3000? Brainstorm and then record your summary of the ideas. Design a human that would be best suited to this futuristic environment. Present your suggestion as a poster or web page with descriptive labels to explain the functions or advantages of your futuristic human's body.

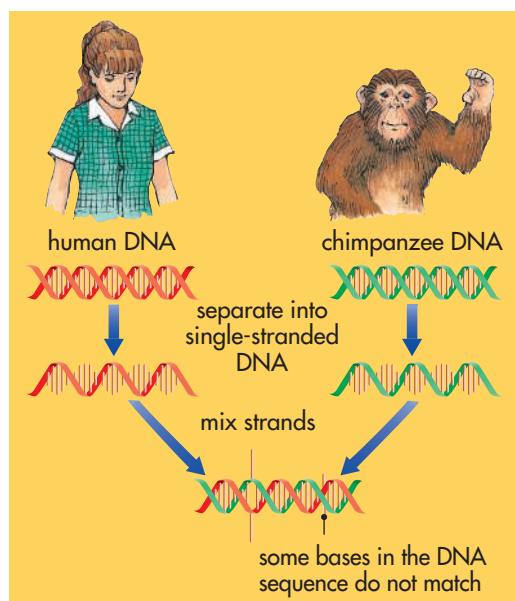
THINK AND DISCUSS

- 7 Examine the data in the following table and then answer the questions that follow.

DNA differences among closely related species

Species tested against human DNA	Percentage differences
human	–
gorilla	1.8
green monkey	9.5
orang-utan	3.6
chimpanzee	1.4
capuchin monkey	15.8
gibbon	5.3

- (a) Reorder the information so that the species are arranged from the most to the least related to humans.



DNA hybridisation. The more closely related organisms are, the more similar are their DNA sequences.

It's great to be different

Have a look at the people around you. Do you notice any differences? How would you explain your observations?



Desert community



Rainforest community

What is biodiversity?

Consider the two photographs shown above. There are two distinctly different communities shown. One is a desert community and the other is a rainforest community. These are only two of the many different communities that exist on Earth. Such **ecological biodiversity** is common across the globe. The organisms that inhabit each community are different because they have different requirements for survival.

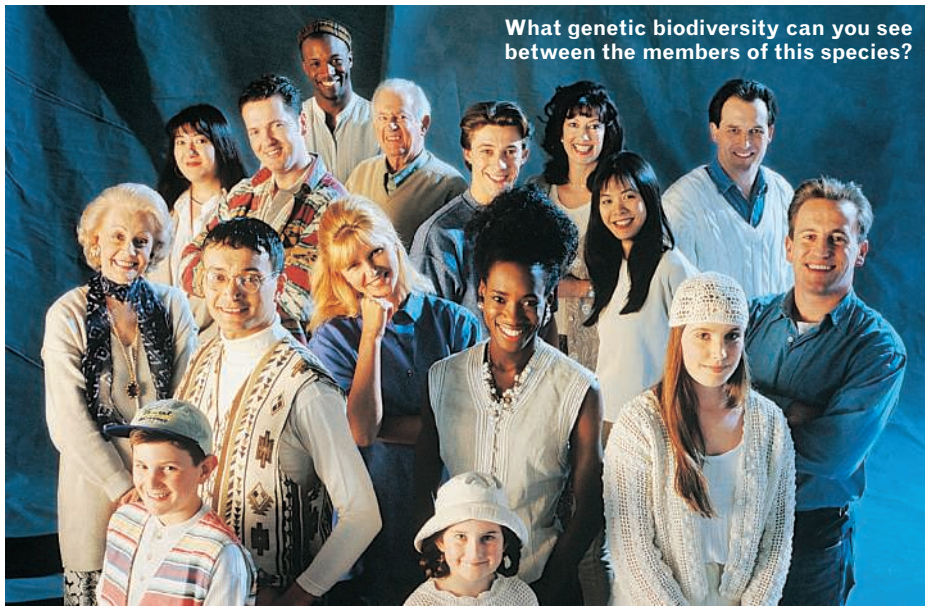
The large number of different species that inhabit rainforest communities is an example of **species biodiversity**. If you were to look closely at members of the same species, you would see that they, too, show a variety of characteristics. This is because each individual in a species has inherited a different set of genes from its parents. This is an example of **genetic biodiversity**.

Why is biodiversity important?

Imagine that someone collected all the individuals from one species of frog from the rainforest community shown on the left, and then extracted all the genetic information available for these individuals. This information would represent the **gene pool** for that species in this community.

Let's extend this example further. When individuals of this species of frog mate, they recombine their genetic material to produce offspring that show a wide variety of characteristics. Such variability within a species is important because it may enhance the chances of survival of the individual's offspring in a changing environment. Some of the individuals may have genes that will assist in their survival. They may then pass these genes on to their offspring. On the other hand, if a large number of frogs were removed from this rainforest area without mating, their genes would be removed from the gene pool. Once removed, they are gone forever.

All environments change over time. If they change too rapidly, however, and the genes required for survival in the changed environment are not present in the gene pool, the extinction of that species may occur. Over the last 100 years, the natural habitat of many species has been changed so significantly that the species could not adapt to the new conditions, and many have died out.





Once DNA is lost from the gene pool, it is gone forever.

Tropical rainforests provide a huge storage of genetic material, much of which could be useful to humans.

Did you know that one-quarter of the prescription and non-prescription drugs used by humans are obtained from tropical plants? So far, only one per cent of plants in tropical forests have been investigated for their medicinal properties. A cure for AIDS or cancer may be hiding in our tropical forests.



Many modern medicines were originally found in tropical rainforests.

activities

REMEMBER

- 1 Explain what is meant by ecological biodiversity, species biodiversity and genetic biodiversity.
- 2 Why is each of these important for the survival of life on our planet?
- 3 What is meant by a gene pool?
- 4 What happens if a species does not possess the genes that will allow members of that species to adapt to new conditions?

ANALYSE AND EVALUATE

- 5 Read the article below and then answer the questions that follow.
 - (a) What is the name of the substance that may hold the key to treating cancer in the future?
 - (b) What sort of studies were undertaken to obtain this information?

- (c) How does this substance go about limiting cancer growth?
- (d) From what plant did Mr Pezzuto originally obtain this substance?
- (e) Where else is this substance found?
- (f) How could this substance be used in the future?

THINK AND DISCUSS

- 6 Under what circumstances could genes be removed from a gene pool?

CREATE

- 7 Choose a familiar plant or animal species. Using magazines, calendars, journals, etc. collect pictures that show variation within that species. Paste the pictures onto poster paper. Label the poster with the name of the species and the types of variations that exist within that species.

Grapes may hold the key to cancer

ONE of humankind's lifelong struggles, to find a cure for cancer, may be sitting on our supermarket shelves — grapes.

Preliminary studies on mice and cell cultures indicate that the substance, resveratrol, found in grapes, could help prevent or treat cancer in humans.

'It's a very early observation but it's exciting that we found this compound,' said Mr John Pezzuto, a scientist at the University of Illinois in Chicago.

Mr Pezzuto's experiments showed that resveratrol can inhibit the formation of tumors at three stages: the initiation of DNA damage in a cell, a cell's transformation into a cancer cell, and the growth and spread of a tumor.

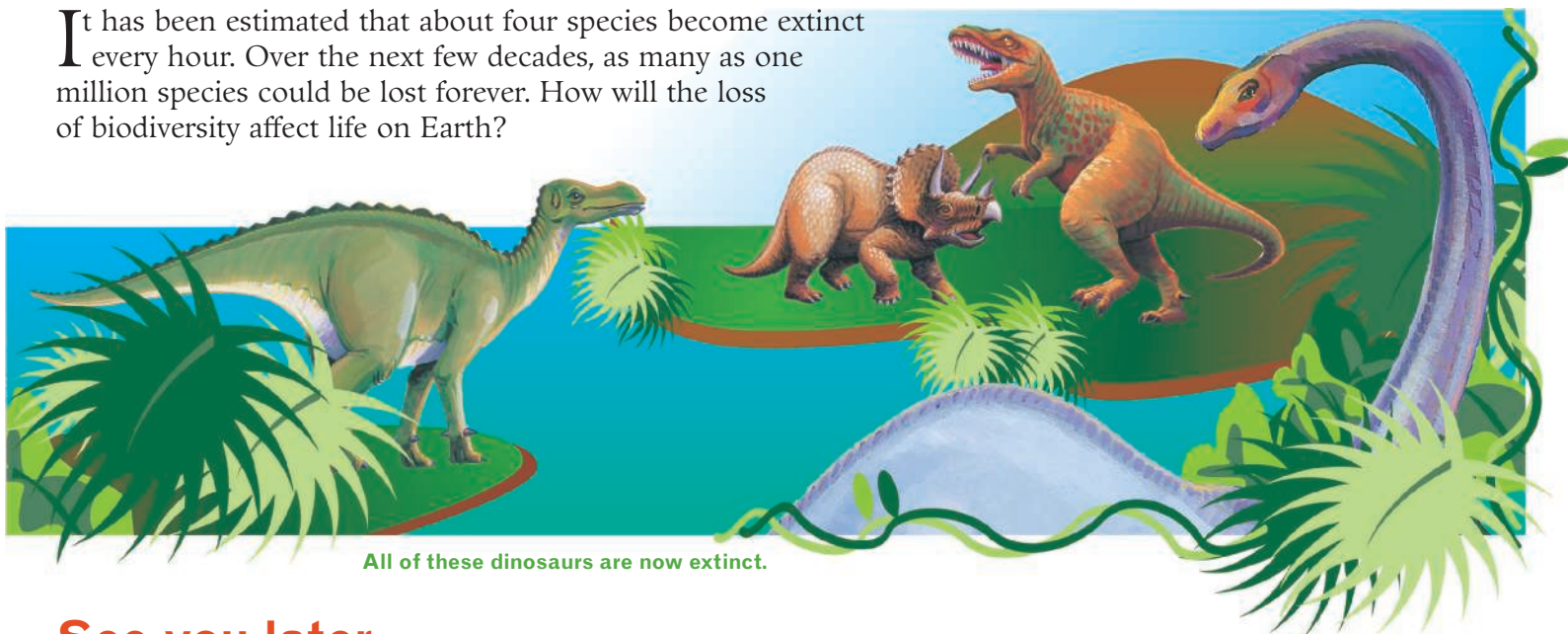
Mr Pezzuto carried out his experiments using a Peruvian legume, *Cassia quinquangulata*. This legume was found to contain resveratrol, which is also found in grapes, particularly red grapes, and

grape products such as wine. Resveratrol is also found in peanuts, mulberries and several dozen other plants.

It is not recommended that people start to eat large quantities of grapes or drink excessive amounts of red wine. Resveratrol could, however, be used as a dietary supplement in high-risk populations in an effort to limit their chance of getting cancer, or could even be used to treat cancer.

See you later alligator

It has been estimated that about four species become extinct every hour. Over the next few decades, as many as one million species could be lost forever. How will the loss of biodiversity affect life on Earth?



All of these dinosaurs are now extinct.

See you later

Extinction, or the disappearance of a species, and the resulting loss of genetic information from the gene pool is a natural occurrence. The fossil record shows several times when huge numbers of species became extinct. Species that cannot successfully reproduce under changed environmental conditions will cease to exist. It is estimated that 99 per cent of all the species that have ever lived are now extinct!

Mass extinction is the term used to describe the dying out of thousands of species all over the world at the same time. Suggested reasons for mass extinctions include gradual changes in the climate or meteor showers. The most devastating mass extinction of all occurred about 225 million years ago in which 96 per cent of all species died out. This included about 90 per cent of the marine life present at the time! Around 65 million years ago, more than

75 per cent of all species died out. This included more than half the marine species, many terrestrial plants and animals such as the dinosaur. About 10 000 years later another mass

extinction occurred, this time involving many species of giant mammals. During this extinction, many large marsupials in Australia and placental species in other countries became extinct.

Main event	Epoch	Mass extinction
Modern humankind	Quaternary 2 mya – present	Human activities threaten mass extinction in modern times
Early flowering plants; origin of birds	Cretaceous 146 – 65 mya	76% of species lost 47% of genera lost
Spread of dinosaurs, ammonites and cycads	Triassic 245 – 208 mya	Extinction of many marine species
Primitive reptiles and paramammals; appearance of beetles and conifers	Permian 286 – 245 mya	96% of species lost 84% of genera lost
Rise of mosses and ferns, ammonites and spiders	Devonian 410 – 360 mya	82% of species lost 55% of genera lost
Appearance of primitive fishes, trilobites, molluscs and crustacea	Ordovician 505 – 440 mya	85% of species lost 60% of genera lost

How do you think these mass extinctions affected the species that survived?
(mya = millions of years ago)

Why are species disappearing?

Over the last 100 years, the number of extinctions has dramatically increased. Some of the reasons why this is happening are listed below.

- Rainforests provide a home for a large number of the world's species. Over 60 000 species of spiders and insects live in the Amazonian rainforest. **Deforestation** over the past 30 years has removed half of the world's forests. This has been done to provide land for farming, woodchips, timber, fuel, sites for urban development as well as mine and dam sites. In the past 200 years, Australia has cleared two-thirds of its rainforests.
- **Introduced species**, such as rabbits, may be better able to hunt for food and living space than native species. In this event, there is an increase in the number of introduced species and a decrease in the number of native species.
- Some species are hunted by people for meat, hide, horns, feathers or eggs, or because they are a threat to domesticated species.

sciFacts

Melbourne Zoo and Healesville Sanctuary are actively involved in the breeding in captivity of endangered species. This program enables species to be returned to the wild, and some members of the species to be preserved in case wild populations die out. The long-footed potoroo, the leadbeater's possum, the helmeted honeyeater and the orange-bellied parrot have all been saved from extinction in this manner, and large breeding populations are now established in the wild.

Why worry? Be happy

The majority of Australians live in cities, far removed from forests. Would the reduction in the number of species and the resulting loss of biodiversity in those forests ever affect city dwellers?

Some of the ways in which wild species affect our lives are described below.

- Wild plant and animal species provide a source of wonder and beauty for large numbers of people.
- Rainforests provide a huge store of untapped genetic material, much of which may be useful to humans.
- Each organism in the food web holds a very important place. Removal of one species has a major effect on the rest of the organisms in that food web.

- Most of our modern crop plants were domesticated from wild plants. With the increase in the world's population, finding suitable food crops from wild species may well be an issue in the future.
- Wild species help to recycle nutrients in the soil, providing us with fertile soil for crop growth.
- Many wild species help to filter and remove poisonous substances from the air and soil.
- The greater the genetic diversity within a species, the better its chances are of surviving in changing environmental conditions. Research has found that if a species loses genetic diversity, it will eventually dwindle in numbers and perish.
- All species have a right to exist without human interference.



Deforestation destroys the habitat of many species.



The leadbeater's possum is an endangered animal.

What is being done about the loss of species?

We have at last realised the importance of genetic biodiversity on our planet. The following approaches in Australia and overseas attempt to save some of our endangered species from extinction.

- National parks are being established so that species numbers can be monitored. For example, Chinese giant panda numbers are increasing as more reserves are set up where pandas can breed free from human interference.
- Botanical gardens and zoos are being maintained so that plants and animals can be bred in captivity.
- Already existing areas are being protected by fencing off certain areas. For example, sand dunes at beaches are sometimes closed off to allow the growth of plants and the reintroduction of animal species.

Dead as a dodo?

The dodo bird had a large, hooked beak and a plume of white feathers on its rear. They were first sighted on Mauritius, an island in the Indian Ocean, in 1598. In 1681, only 83 years later, they were extinct!

Although dodo birds could not fly, they are believed to have evolved from an ancestor (similar to a pigeon) that could fly. At the time that this ancestor landed on Mauritius, over four million years ago, its new habitat had a plentiful food supply and contained no predators. Can you suggest a reason for the dodo bird's loss of the ability to fly? How could this

be advantageous to its survival? Scientists believe that with no natural predators, the dodo bird did not need to fly and so evolved into a flightless bird. The dodo's nests were on the ground since it was flightless.

A lack of natural predators made the dodo birds easy prey for the Dutch sailors who discovered them, and future Portuguese 'invaders' would club the birds to death for sport or food. However, one of the main causes of their extinction was the destruction of the forest in which they lived. This led to a reduced food supply. The other main cause was the introduction by humans of new species, such as cats, rats and pigs, which destroyed their nests.



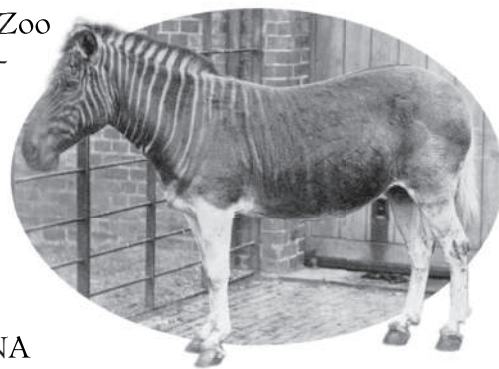
Dodo birds are now alive only in storybooks.

Losing more than your stripes?

Quaggas formerly lived in South Africa. They were a variety of zebra with a distinctive patch of stripes around their head, neck and front portion of their body. The unusual stripes, like those on zebras, may render the animal less visible and give some protection against predators. Can you suggest a reason for the variation of stripes in the quagga compared to other types of zebra?

Like other grazing mammals, it is considered that quaggas were ruthlessly hunted by settlers who saw them as competitors for the grazing of their sheep, goats and other livestock. It has been recorded that their flesh was eaten and their skin was used as 'grainbags' and 'leather'. Quaggas became extinct when the quagga mare at the Amsterdam Zoo died on 12 August 1883. This realisation did not register until many years later.

A project in South Africa involves an attempt to bring back the quagga from extinction and then reintroduce it into reserves in its former habitat. This project is possible because DNA analysis has shown that the quagga was actually a subspecies of a type of zebra that is still alive. It is hoped that some quagga genes still exist in the populations of these zebras. By selectively breeding zebra individuals to concentrate the quagga genes, they may be able to 'bring back' some of the features (e.g. colouration) of the extinct quagga.



Will quaggas make a reappearance?

Is extinction permanent?

The Tasmanian tiger or thylacine (*Thylacinus cynocephalus*) looked like a large, long dog with stripes, a heavy stiff tail and a large head. An adult thylacine was about 58 centimetres tall, about 180 centimetres long and could weigh up to 30 kilograms. It was carnivorous, had large powerful jaws, and fed on kangaroos and rodents. Although it looked like a dog, it was a marsupial with a pouch and was more closely related to kangaroos and koalas.

The introduction of sheep as livestock in 1824 resulted in conflict between the settlers and the thylacines. In 1830, thylacine bounties were introduced by Van Diemens Land Company and, by 1888, the Tasmanian parliament had placed a price of one pound per thylacine's head. It was not until 1909, after 2184 bounties

were paid, that the government bounty scheme was terminated. By 1910, thylacines were rare, and in 1933 the last thylacine to be captured was sold to the Hobart Zoo. This thylacine died on 7 September 1936 and it was in this year that thylacines were added to the list of protected wildlife. In 1986, thylacines were declared extinct by international standards.

On 4 May 2000, the first piece of DNA was extracted from a thylacine foetus that had been preserved in alcohol since 1866. These DNA fragments were then inserted into bacteria and multiplied to create a 'library' of DNA for research. It is the intention of Australian Museum scientists to determine the genome of the animal so that they can produce up to 50 thylacine clones using Tasmanian devils, quolls or numbats as surrogate mothers.



A preserved thylacine foetus at the Australian Museum. What are the implications of cloning extinct animals?

activities

REMEMBER

- 1 What are the three major factors leading to the extinction of species?
- 2 Why is it important to humans that genetic biodiversity be as great as possible?
- 3 List three ways in which humans are attempting to preserve endangered species.
- 4 Why is breeding in captivity being undertaken?
- 5 What is a mass extinction? Give three examples of mass extinctions.
- 6 What is a dodo bird and how is it thought to have become extinct?
- 7 Why did the dodo bird build its nests on the ground and lose its ability to fly?
- 8 Draw a timeline to show the history of the events that contributed to the extinction of thylacines.

- 9 Summarise ways in which humans are attempting to 'bring back' extinct animals.

THINK AND DISCUSS

- 10 Consider the reasons that deforestation occurs. What alternatives to deforestation are available that could help to preserve our tropical forests?
- 11 Which one of the three approaches to preserve genetic diversity would be preferred? Explain your choice.
- 12 Apart from the factors already mentioned, what other factors may be contributing to the extinction of our native animals and plants?
- 13 As a class or in groups, brainstorm other outcomes or effects on humans if genetic biodiversity is reduced.

INVESTIGATE

- 14 Evaluate theories about the causes of the extinction of the dodo bird, the quagga and the thylacine.
- 15 Investigate the rate of extinction of Australian animals or plants since European settlement and suggest causes and implications of this.
- 16 Choose one of the following and describe the animal, its lifestyle and the theory of the cause of its extinction: flightless ibis (AD 1000), giant lemur (AD 500), giant moa (AD 1500), aurochs (AD 1627) or an animal of your choice.

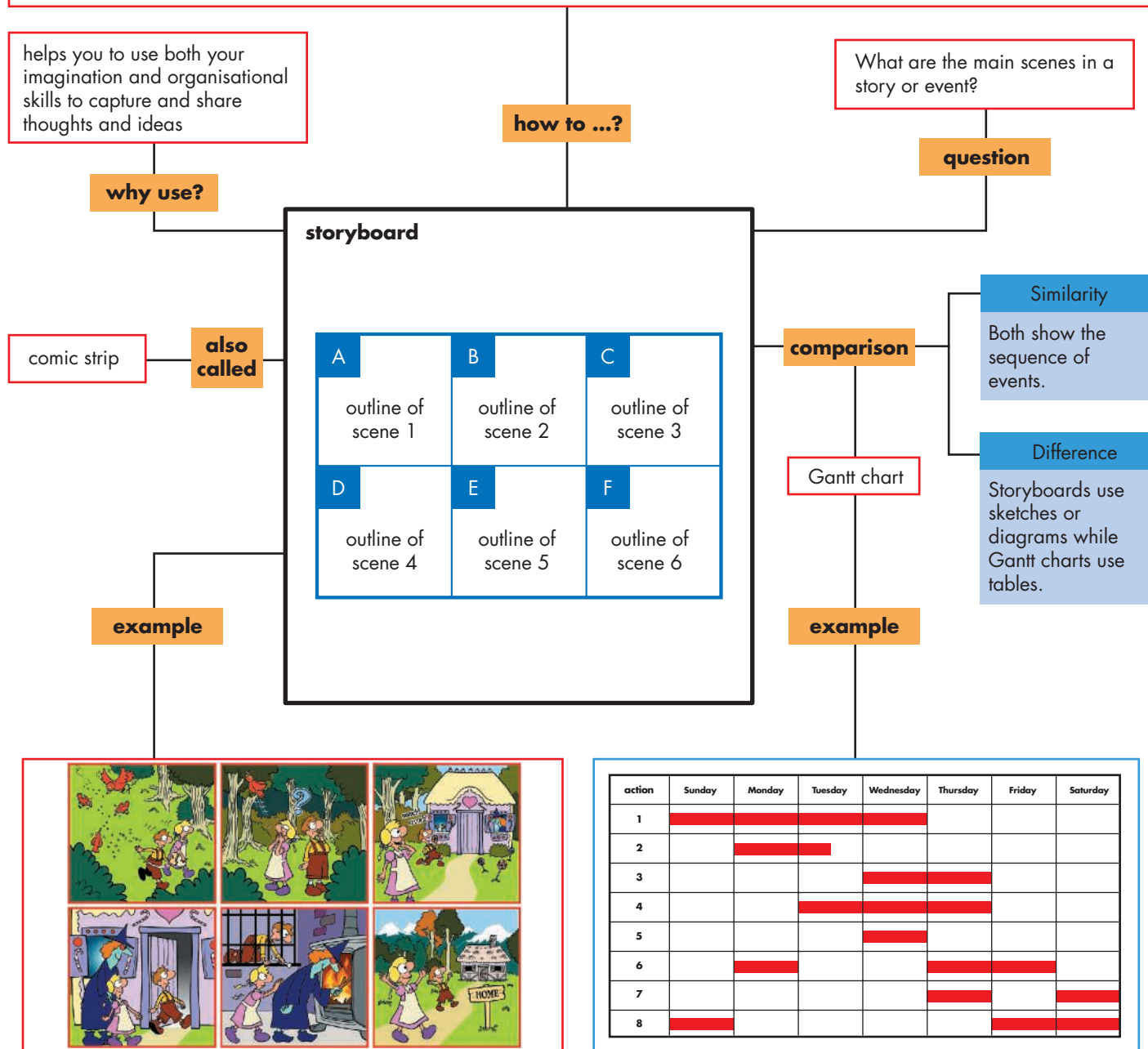
CREATE

- 17 Role-play a situation in which developers want to remove trees in a forest to provide land for housing. They have provided the home buyers with free seeds to revegetate the area. Conservationists disapprove of the plan.

Thinking tools: Storyboards and Gantt charts

1. Decide how many scenes you need in your story. Often, 6–8 is a good number. Divide your page into this number of equal sections.
2. Consider which will be the three main events in your story and draw them roughly in the first, middle and last sections of your page.

3. Brainstorm the scenes that fit between these. Select the most appropriate and add them as intermediate scenes.
4. Mentally stand back and examine your story outline; make any desired changes to enhance its dramatic impact.



Adapted with permission from Hawker Brownlow Education © 2005 modellearning.com *Thinking Skills and EyeQ: Visual Tools for Raising Intelligence* by Ian Harris, Oliver Caviglioli and Bill Tindall

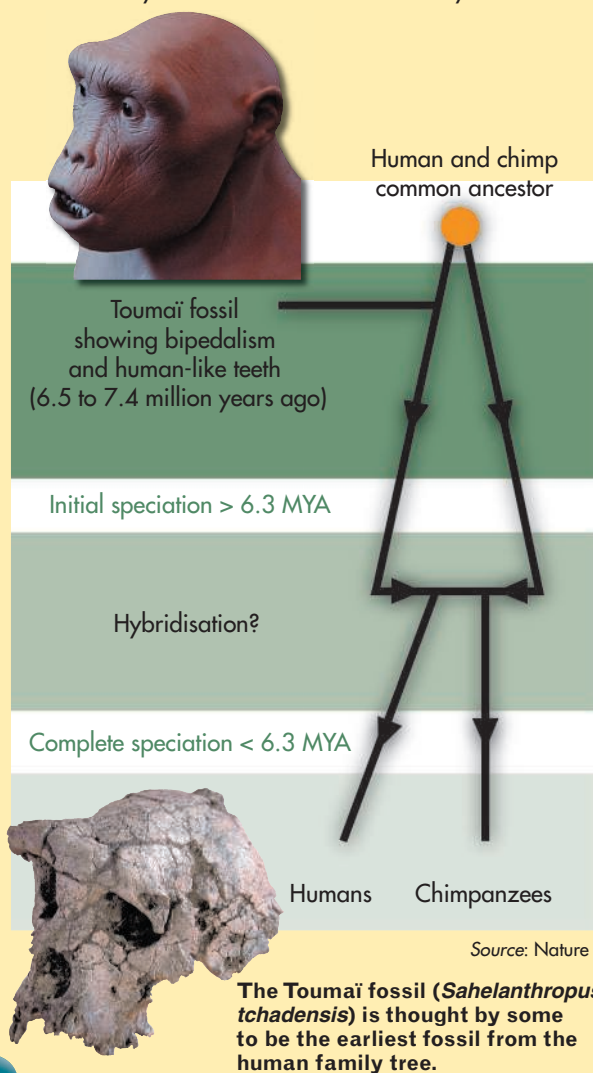
What a tangled family tree!

Shame and scandal in the family? A genetic study suggests that human and chimp ancestors may have been interbreeding for a long time after their two lineages began to evolutionally split apart. Patterns in the genes of the X chromosome suggest that the two lineages split sometime before the first proto-human fossils, but later rehybridised in a 'reverse speciation' event.

The genomes of humans, chimps and gorillas were compared using a 'molecular clock' to estimate how long ago the three groups diverged. Research from a recent study suggests that humans and chimps diverged between 5.4 and 6.3 million years ago. This is considerably more recent than the time previously suggested. What impact may these findings have on our current interpretations of fossils and theories of human evolution?

TANGLED FAMILY TREE

If chimps and early humans rehybridised, supposed early ancestors may in fact have been evolutionary dead ends.



THINK AND DISCUSS

- 1 Read through *What a tangled family tree!* then answer the following questions.
 - (a) Outline a possible implication of the findings of the genome comparisons on humans and chimps.
 - (b) If speciation is the creation of new species from existing ones, suggest a definition for 'reverse speciation'.
 - (c) Carefully study the image of the Toumaï fossil and the suggested reconstruction. List features that are chimp-like and features that are human-like. Do you think it more closely resembles a human or a chimp? Give reasons for your suggestion.
 - (d) How do we currently define a species? Suggest implications of these findings on our current definition. Suggest a definition that you think should be used in the future.

INVESTIGATE, CREATE AND DISCUSS

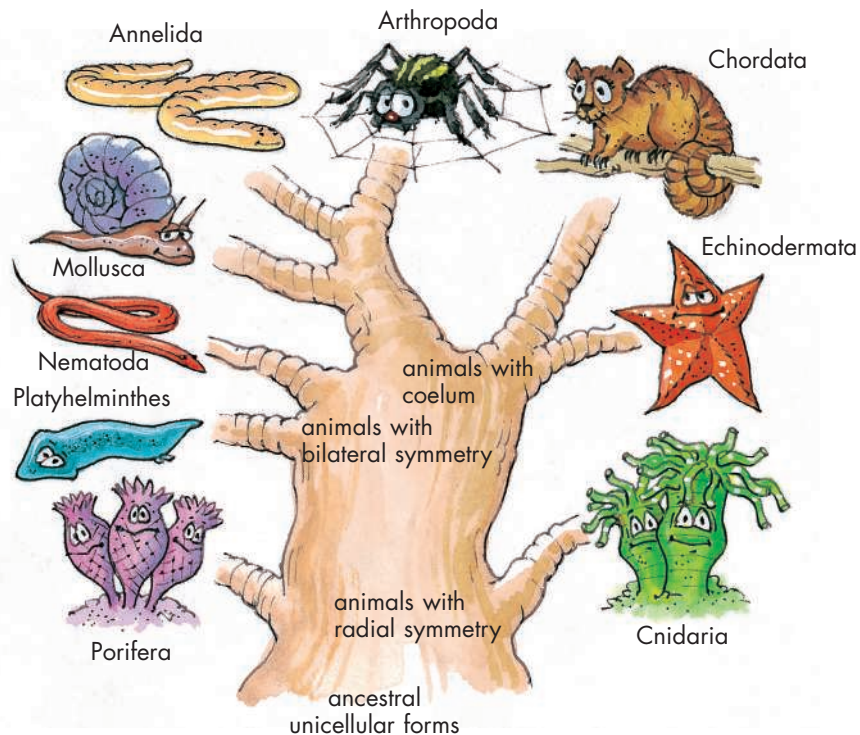
- 2 Find out more about the Toumaï fossil and the different interpretations that are being suggested about it. Construct a storyboard to outline two of these interpretations.
- 3 Research current theories on human evolution. Use a Gantt chart to summarise some of your findings.
- 4 Find out more about an aspect of human evolution that interests you and construct a storyboard to share what you have found out.
- 5
 - (a) Find out more about the 'hobbit-like human ancestor' (*Homo floresiensis*) and the various scientific discussions about their lineage.
 - (b) Use a Gantt chart to summarise your findings.
 - (c) Create a storyboard for a possible 'Day in the life of a *Homo floresiensis*'.
- 6 Find out more about one of the following topics and report back your findings using a thinking tool of your choice.
 - reverse speciation
 - how the X chromosome can be used in evolution studies
 - research on the human genome
 - the 'Piltdown man' hoax
 - the Laetoli footprints
 - an *Australopithecus afarensis* called Lucy
 - Mitochondrial Eve
 - Neanderthals
 - human cultural evolution

Looking back



1. Refer to the animal kingdom evolutionary tree at right to answer the following questions.

- Which animal group (or phyla) is most closely related to the chordata group?
- Which is more closely related to the mollusca, the arthropoda or nematoda?
- Which animals have radial symmetry?
- Do you think that platyhelminthes would have more or less in common with annelida compared to cnidaria? Explain.
- Suggest the significance of adaptations of organisms in relation to their survival.



The animal kingdom evolutionary tree based on genetic and structural information

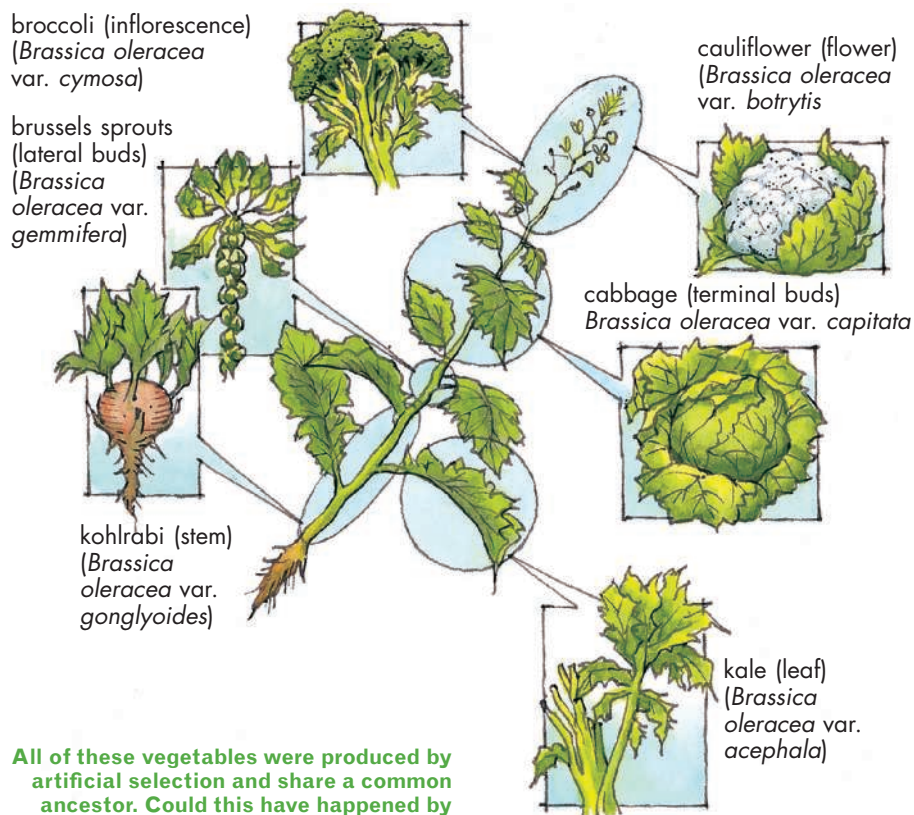
2. Find out difficulties that one of the following scientists had in being able to express their scientific opinions because of the society of their lifetime:

- Gregor Mendel
- Jean Baptiste de Lamarck
- Charles Darwin.

3. Are humans still evolving? Organise a class debate to discuss.

4. *Brassica oleracea* is a common ancestor to a number of vegetables.

- Suggest how these different vegetables came to be.
- Select three of these vegetables and find out ways in which they are similar to and different from each other.
- 'Create' a new descendant of *Brassica oleracea*, describe its features and why you have chosen them. Include a common and scientific name for your creation.



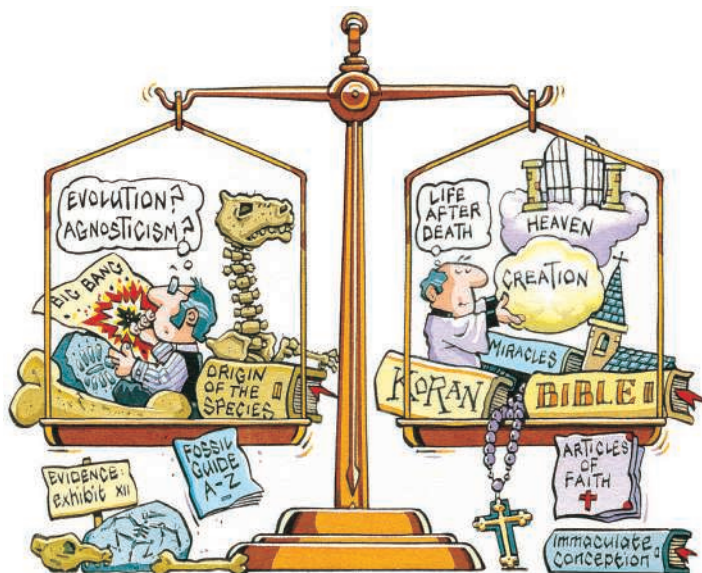
All of these vegetables were produced by artificial selection and share a common ancestor. Could this have happened by natural selection also?

5. Answer the following questions. (In most cases they are one word answers.)

- The biological name for humans
- Short for deoxyribonucleic acid
- The smallest level of classification
- The southern supercontinent
- _____ System of Nomenclature
- The process that forms gametes
- Common name for *Canis familiaris*
- The kingdom to which humans belong
- Another planet where evidence of life may have been found
- Over 30 of these make up the surface of the Earth
- This kingdom contains all the mushrooms
- The process of sorting living things into groups
- Non-moving (two words)
- Not prokaryotic
- The northern supercontinent
- Fossils that can be seen only under a microscope

6. Not all people accept the theory of evolution. Find out why they do not support this theory. What are some other theories? What do you believe? Why?

- When layers of rock are thrust upwards or sideways
- The total DNA of a species in a population (two words)
- Charles _____ put forward a theory of evolution.
- A permanent change in DNA
- The basic unit of living things is the _____.
- When layers of rock move apart in opposite vertical directions
- The type of dating that assumes the lower layers of rock are older than the ones above
- The type of biodiversity among the communities that exist on the Earth



7. Find and circle the answers to question 5 in the following word puzzle. The words may be spelt across, up, down, diagonally and even backwards. Letters can be used more than once. There will be letters left over; write these letters in the order that they occur to discover the 'Life Goes On' message.



T	L	A	C	I	G	O	L	O	C	E	H	S
L	M	G	E	N	E	P	O	O	L	E	E	E
A	I	A	E	D	O	G	D	N	A	R	F	T
U	C	F	U	N	G	I	T	H	S	B	A	A
R	R	A	K	E	L	O	F	N	S	D	U	L
A	O	N	A	B	I	N	O	M	I	A	L	P
S	F	I	R	N	G	N	L	S	F	R	T	S
I	O	M	Y	T	M	O	D	A	I	W	L	P
A	S	A	O	O	L	L	L	E	C	I	T	E
H	S	L	T	G	O	N	D	W	A	N	A	C
I	I	I	I	N	O	I	T	A	T	U	M	I
N	L	A	C	R	E	L	A	T	I	V	E	E
E	S	S	R	A	M	M	E	I	O	S	I	S
H	O	M	O	S	A	P	I	E	N	S	G	S