3 Evolution

The great diversity of living things may be explained by the theory of evolution by natural selection. Variations upon which natural selection acts may be determined by both genetic and environmental factors. The selection of some variations over others is related to their possible effects on increasing the chances of survival and reproduction of individuals that possess them. In this way, favourable variations may be passed from one generation to the next. But what is the evidence for this theory and how can it be evaluated and interpreted?

OVERARCHING IDEAS

- Patterns, order and organisation
- Form and function
- Stability and change
- Scale and measurement
- Systems

SCIENCE UNDERSTANDING

The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence.

Elaborations

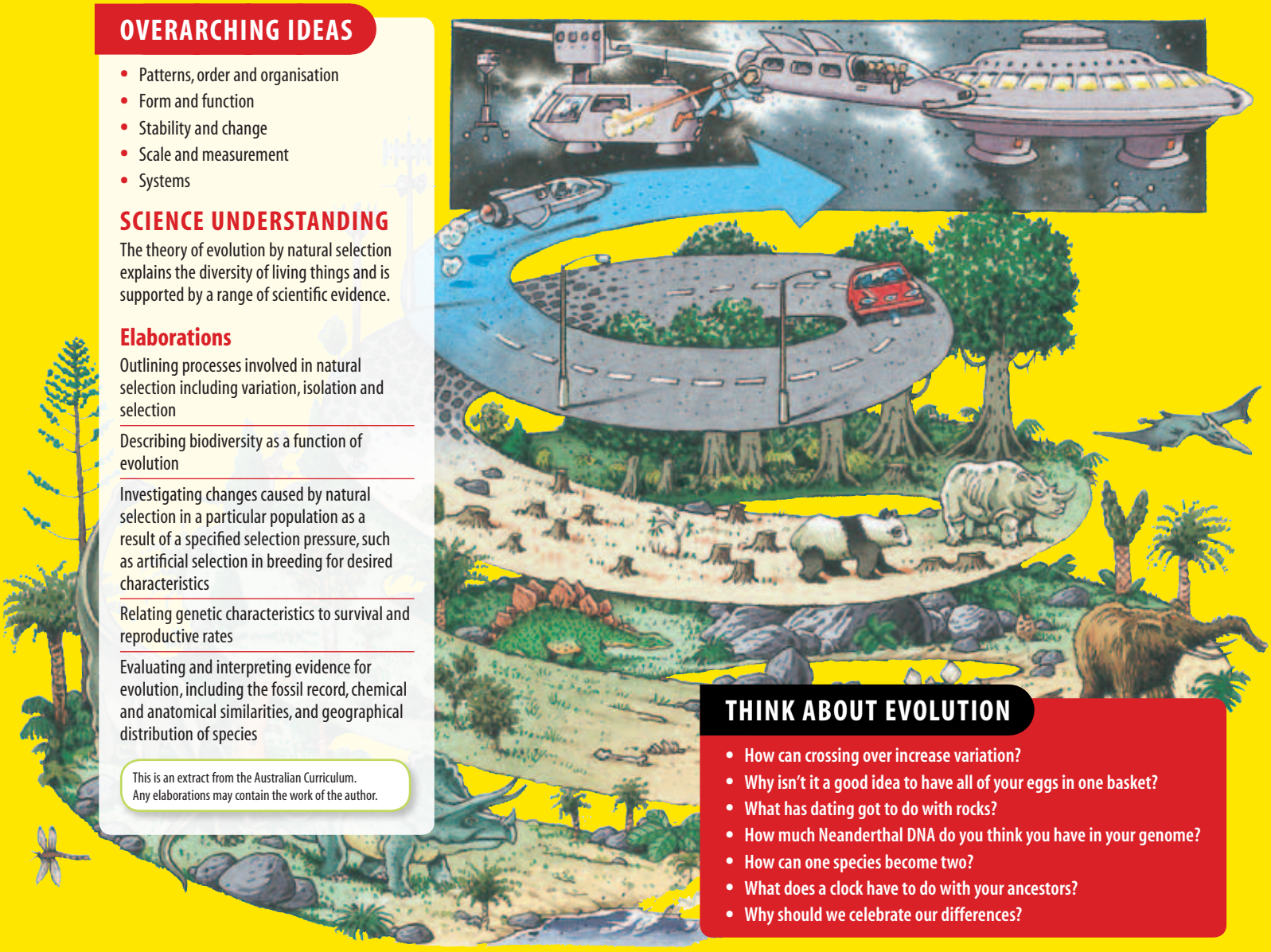
Outlining processes involved in natural selection including variation, isolation and selection

Describing biodiversity as a function of evolution

Investigating changes caused by natural selection in a particular population as a result of a specified selection pressure, such as artificial selection in breeding for desired characteristics

Relating genetic characteristics to survival and reproductive rates

Evaluating and interpreting evidence for evolution, including the fossil record, chemical and anatomical similarities, and geographical distribution of species

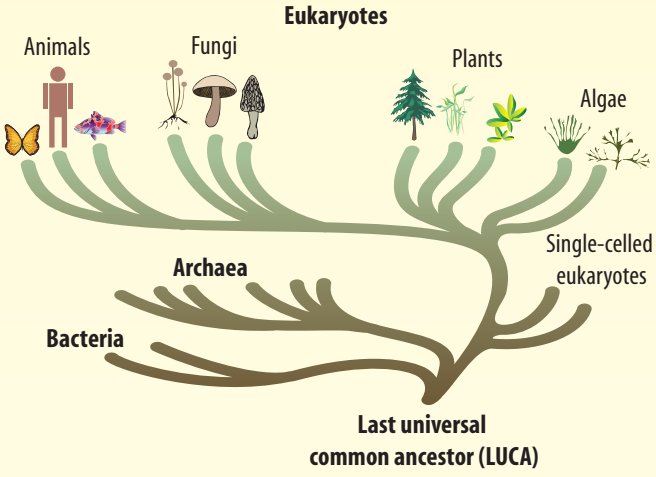


THINK ABOUT EVOLUTION

- How can crossing over increase variation?
- Why isn't it a good idea to have all of your eggs in one basket?
- What has dating got to do with rocks?
- How much Neanderthal DNA do you think you have in your genome?
- How can one species become two?
- What does a clock have to do with your ancestors?
- Why should we celebrate our differences?

YOUR QUEST

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 genes from all forms of life and have put together a portrait of this cell that could be the ancestor of us all.

THINK

1 (a) Suggest 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?

2 What do you think Earth was like three billion years ago? Find out whether your hypothesis agrees with current evidence.

3 (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.
(c) Design an organism that could survive these conditions. Describe its features, including those that are present in organisms living today.

FIVE MINUTES TO MIDNIGHT

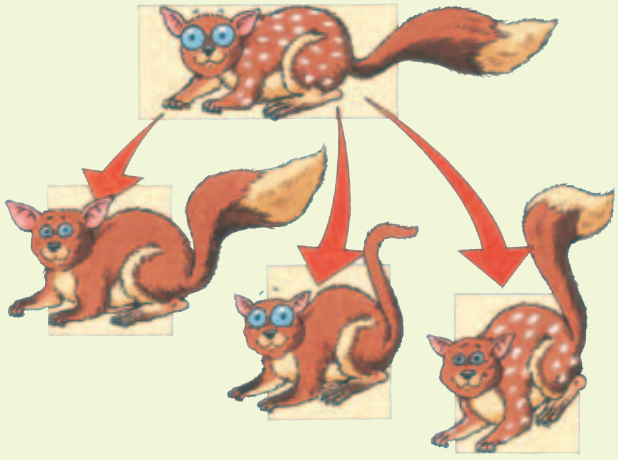
If we compressed the Earth's 4.5 billion year history into a single year, Earth would have formed on 1 January and the present time would be represented by the stroke of midnight on 31 December. Using this timescale, the first primitive microbial life forms appeared in late March, followed by more complex 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 13 December and then disappeared forever in the evening of 25 December. Although human-like creatures appeared in Africa during the evening of 31 December, it was not until about five minutes before the New Year that our species, *Homo sapiens*, appeared on Earth.

INQUIRY: INVESTIGATION 3.1

The common ancestor

KEY INQUIRY SKILL:

- processing and analysing data and information



- Carefully observe the features of the possums in the figure above.

DISCUSS AND EXPLAIN

1 Make lists of how the possums are similar and how they are different.

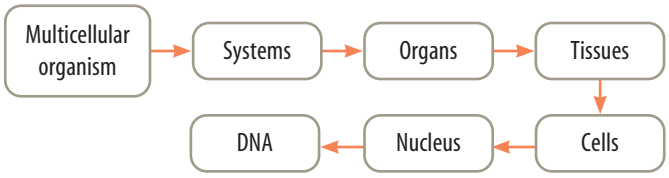
2 Suggest reasons for the differences.

3 Suggest how the possums may have become different.

Patterns, order and organisation: Classification

Classification is not fixed. With the wonders of new knowledge and understanding comes the excitement — and the frustration — of new theories and terminology.

There have been shifts from a model of two kingdoms, plants and animals, to a five-kingdom model and then a number of further variations. Initially, the main characteristics used to classify organisms into these groups were structures visible to the human eye, but with the development of microscopes, cell structure could be used as well. Now, due to new technologies, the chemical composition of organisms can be analysed at a molecular level.



Changing tides of classification

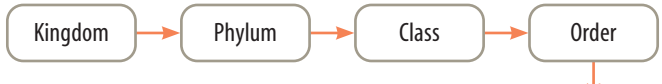
The five-kingdom classification was proposed by Whittaker in 1969. In 1990, Woese proposed a model that focused on genetic rather than physical characteristics to divide organisms into groups. This new grouping added broader levels of classification (domains) that were then divided into kingdoms. With new technologies, what other types of classification systems might be suggested?

Although classification systems are not fixed and can change when new information is discovered, they are very useful in the organisation of organisms into groups. Classification systems help us to see patterns and order in the natural world, so we can make sense and meaning of the world in which we live.

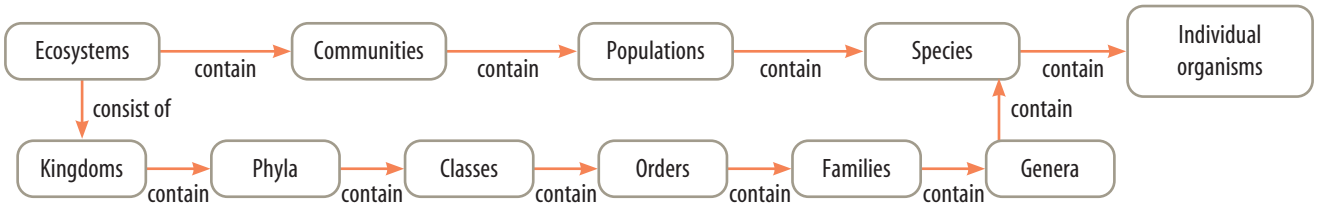
Binomial nomenclature

Classifying organisms into groups provides a framework that uses specific criteria and terminology

and improves our communication about organisms. The Swedish naturalist Carolus Linnaeus (also known as Carl von Linné) developed a naming system that could be used for all living organisms. It involved placing them into groupings based on their similarities. He called the smallest grouping *species*.



A painting of Carolus Linnaeus as a young man



Linnaeus' naming system was called the **binomial system of nomenclature** because it involved giving each species a particular name made up of two words. The scientific names given to organisms were often Latinised. In this system, the species name is made up of the genus name as the first word and the descriptive or specific name as the second word. A capital letter is used for the genus name and lower case for the descriptive name. If handwritten, the species name should be underlined; if typed, it should be in *italics*.

Species name	=	Genus	+	Descriptive name
e.g.				
Homo sapiens	=	*Homo*	+	*sapiens*

WHAT DOES IT MEAN?

The word *binomial* comes from the Latin terms ***bi-***, meaning 'two', and ***nomen***, meaning 'name'.

Species

There have also been changes in our definition of the term *species*. Although genetic technologies have blurred the lines of our classification system, our usual definition of *species* refers to individuals that can interbreed to produce fertile offspring.

Species also fit into another grouping in terms of where they belong within an ecosystem. Ecosystems consist of a number of different communities. Within these communities are populations of individual organisms of a species living together in a particular place at a particular time.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Suggest why classification of organisms is not fixed.

2 Select appropriate terms from the following list and use flowcharts to show their connections.

Populations	DNA	Multicellular
Ecosystems	Organism	Systems
Tissues	Species	Cells
Classes	Communities	Kingdoms
Families	Phyla	Orders
Genera	Nucleus	Organs

3 Suggest why scientists classify organisms into groups.

4 State the name of the person who developed the binomial system of nomenclature.

5 Outline the naming system used in the binomial system of nomenclature.

6 Outline a definition of *species*.

7 Outline the relationship between species and ecosystems.

THINK AND DISCUSS

8 Suggest criteria that are used to divide organisms into the five-kingdom classification system.

9 Explain why the number of kingdoms has changed from two to at least five.

10 State the relationships between the two terms in each of the following pairs.
(a) Genus and genera
(b) Phyla and phylum
(c) *Homo* and *sapiens*
(d) Genus and species
(e) Species and populations

INVESTIGATE

11 Use the internet to find out the latest classification systems and reasons for their differences from previous systems.

12 Research and report on Carolus Linnaeus.

CREATE

13 Using magazines, the internet and other resources, find pictures of living things and classify them into kingdoms. Make a poster showing members of the five kingdoms.

14 Construct a table showing the key similarities and differences between the five kingdoms at a cellular level, and then construct a model that demonstrates these for each kingdom.

Biodiversity

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

It's great to be different!

Have a look at the people around you. How many differences do you notice? How can you explain your observations? One part of your response might deal with genetics and inherited traits; another part might deal with the environment. The variation of characteristics or phenotypes within populations has contributed to the survival of our species.

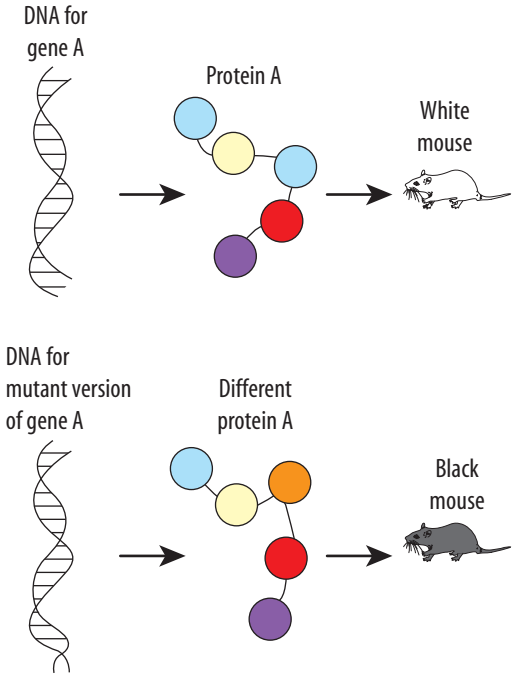
Genetic diversity

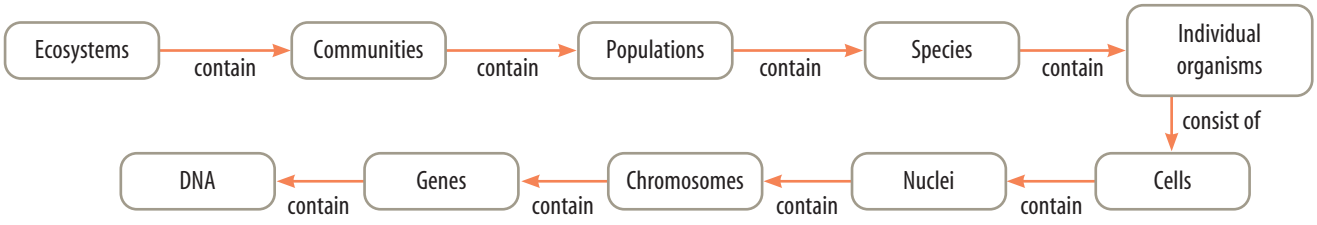
Biodiversity (or biological diversity) has to do with variation within living things. It can be described in terms of an ecosystem, at the level of species, or even at the level of individual genes. **Species diversity** is the number of different species within an ecosystem. In contrast, genetic diversity is the range of genetic characteristics within a single species. The most important level in terms of evolution is that of the gene.

Genetic diversity is important because it codes for variations of phenotypes, some of which may better suit the individual organism to a particular environment than others, giving it an increased chance of survival. If this individual survives, there is an increased chance of it reproducing to pass the advantageous gene to its offspring, also giving them an increased chance of surviving. Overall, this genetic advantage will increase the survival of the species within that particular environment.

MUTATION

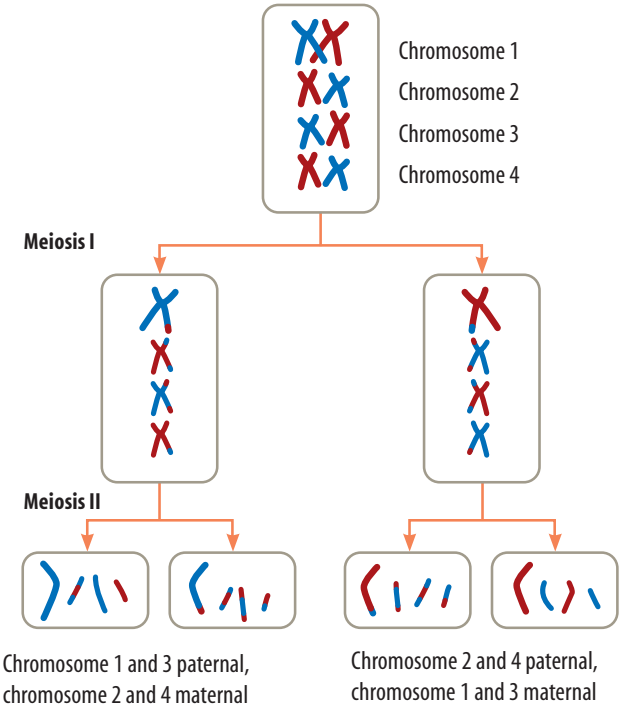
Mutation can occur in all organisms and is the source of new genetic variation. A change in the genetic code in DNA can lead to the production of a change in the protein that is coded for and produced by that segment of DNA. This can result in a change in the organism's characteristics. In the diagram below, for example, a change in DNA has led to the production of a protein that will result in a change in the colour of the mouse from white to black. Mutations that occur in germline cells (such as sperm and eggs) are the source of new alleles (alternative forms of genes) within populations.





Variation between individuals

Variation between individuals that reproduce sexually may also be the result of several other factors besides mutation. Variation can occur during **meiosis** due to crossing over of sections of maternal and paternal chromosomes, and also due to the independent assortment of the chromosomes into the **gametes** that are produced. The combination of gametes that fuse together during **fertilisation** provides another source of variation, as does the selection of a particular mate.



Independent assortment and crossing over during meiosis are two causes of variation between individuals.

Variation between individuals can be described in terms of **alleles** — the alternative forms of genes. The possible variation of alleles for a particular trait within an individual is called a **genotype**. Genotypes and the environment contribute to the variations in **phenotypes** or characteristics between organisms.

ADAPTATIONS

Variations that increase chances of survival may also be thought of as adaptations. An adaptation may be considered to be a special feature or characteristic that improves an organism's chance of survival in its environment. There are different types of adaptations; for example, structural adaptations (e.g. hair to keep warm), behavioural adaptations (e.g. courtship display to attract a mate) and physiological adaptations (e.g. ability to produce concentrated urine to conserve water). Can you think of adaptations that you possess that increase your chances of survival in your current environment?

Variation within populations

Variation can also be described within populations. Genetic variation within populations can be referred to in terms of the frequency of particular alleles within the population. While the genotype describes the variation of alleles for a particular trait within an individual, a gene pool describes the alleles for a particular trait within a population.

Genetic drift — changes due to chance events such as floods and fires — and **natural selection** can have an impact on allele frequencies and hence variation within populations.

FROGS AND GENE POOLS

When individuals of a 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 (or alleles) that will assist in their survival. They may then pass these favourable genes on to their offspring. On the other hand, if a large number of frogs emigrated or were removed from a particular habitat without mating, their genes (or alleles) would be removed from the gene pool. Once removed, they are gone forever.

GENE FLOW

Movement of individuals between populations provides another possible source of diversity. **Emigration** (moving out) may result in the loss of particular alleles; **immigration** (moving in) into a population may result in the addition of new alleles into the population.

Before advances in technology provided humans with relatively easy long-distance travel, our species was split into small groups. The separate identities 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 communication technologies, these barriers are now starting to break down, and migration and interbreeding between human groups is widespread.

A species of frog might show a wide variety of characteristics; this variability enhances the chances of survival.

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 among people of Greek origin. As people from this part of the world have migrated to Australia, they have brought with them the thalassaemia allele. Although this trait is recessive and requires two heterozygous parents to contribute it for their offspring to express it, there is an increasing number of people within the Australian population with this disease.

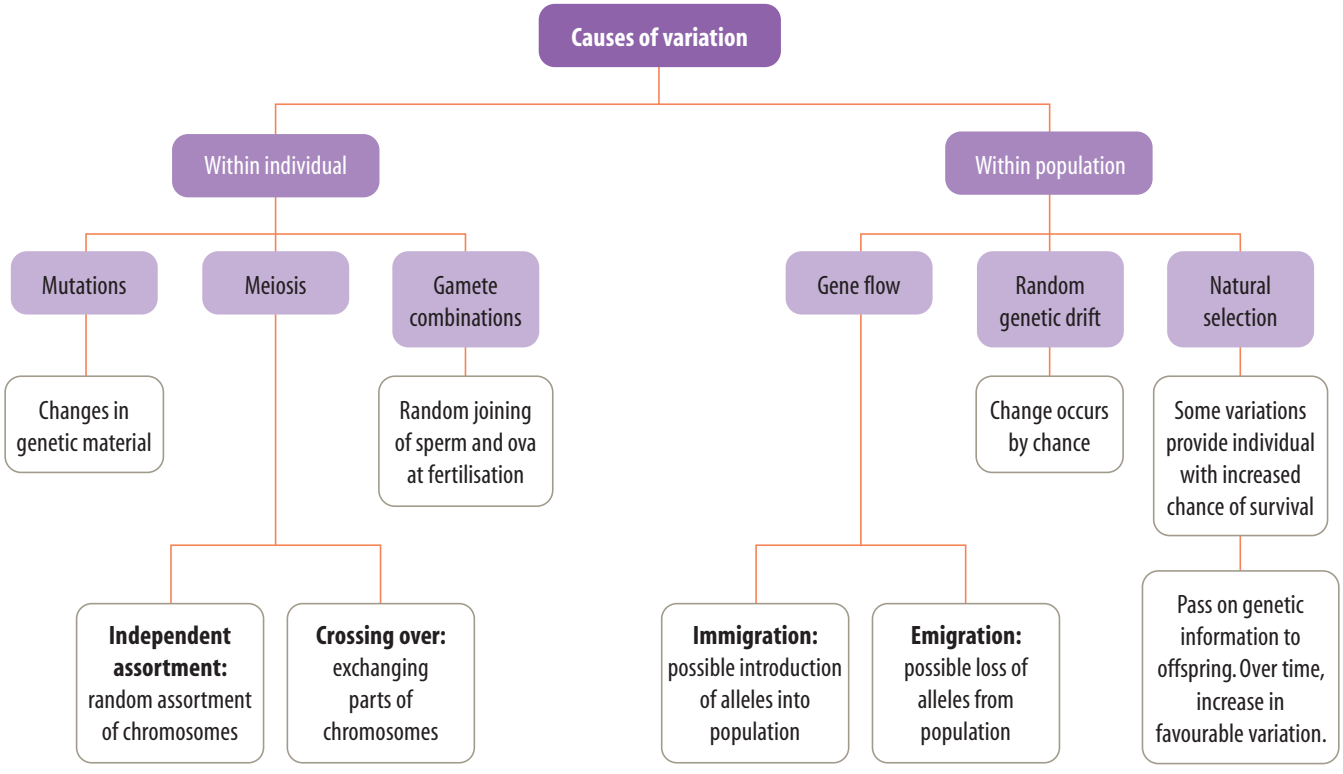
In other cases, the introduction of a genetic trait into a population may increase the chances of survival of individuals with the trait. This new variation may contribute to increasing the fitness of the population to the current or future environment.

Environments change

All environments change over time. If they change too rapidly, the genes required for survival in the changed environment may not be present in the gene pool and extinction of that species may occur. Over the last 100 years, the natural habitats of many species have been changed so significantly that those species may not have possessed the genetic variation to be able to adapt to the new conditions. Many species have therefore died out.

Reduced biodiversity

The use of reproductive technologies such as artificial selection, artificial insemination, IVF and cloning has the potential to unbalance natural levels of biodiversity. These technologies can be used in horticulture, agriculture and animal breeding to select which particular desired characteristics will be passed on to the next generation.



ARTIFICIAL SELECTION

For thousands of years, humans have used selective breeding techniques to breed domestic animals and plants. We have selected which parents will mate together based on their possession of particular features, to increase the chances that their offspring with have features that will suit our needs. This type of selective breeding is called artificial selection.

Because fewer individuals are selected for breeding, the genetic diversity is reduced and inbreeding may result. As well as decreasing variation in the traits of offspring, inbreeding can increase the chances of inherited diseases.

Artificial insemination

The sperm of a prize-winning racehorse may be used to inseminate many mares, increasing the chance of offspring that may also possess the race-winning features of its donor. This will lead to a larger contribution of alleles from this horse than would naturally be possible. It can also lead to reduced genetic diversity within the populations of horses in which this occurs.

IVF and embryo screening

In-vitro fertilisation (IVF) techniques allow the testing and selection of embryos for particular characteristics prior to their implantation. This can also have an impact on genetic diversity. Imagine the effect of implanting only female embryos or only those with a particular recessive trait.

Cloning

Imagine the production of a population of genetically identical individuals. Although they may be well suited to a particular environment, what might happen when the environment changes to one that they are not suited to?

CONSEQUENCES OF REDUCED BIODIVERSITY

Reducing variation in genetic diversity can lead to the eradication of populations or entire species. If the population or species is exposed to an environmental change or threat (for example disease, climate change or lack of a particular resource), the reduced variation may mean that there is less chance that some of the species will survive to reproduce.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Suggest why genetic diversity is important to the survival of a species.

2 Select appropriate terms from the following list and use flowcharts to show their connections.

Populations DNA Mutation Meiosis
Gamete combination Gene flow
Chromosomes Cells Ecosystems
Organisms Genes Species
Genetic drift Gene flow Natural selection
Communities Nucleus Variation
Crossing over Emigration Immigration
Fertilisation Independent assortment Alleles

3 Distinguish between:
(a) genetic diversity and species diversity
(b) gene and allele
(c) immigration and emigration
(d) genotype and gene pool.

4 Outline the relationship between mutation and genetic variation.

5 Explain why mutations are important to asexually reproducing organisms.

6 Are all mutations bad? Justify your response.

7 Suggest causes or sources of genetic variation for:
(a) an individual (b) a population.

8 (a) Outline how humans have achieved artificial selection.
(b) State the desired outcome of artificial selection.
(c) Suggest possible consequences of artificial selection on genetic diversity.

9 Outline the advantages and disadvantages of artificial insemination.

10 Suggest how IVF and related technologies could reduce human genetic diversity.

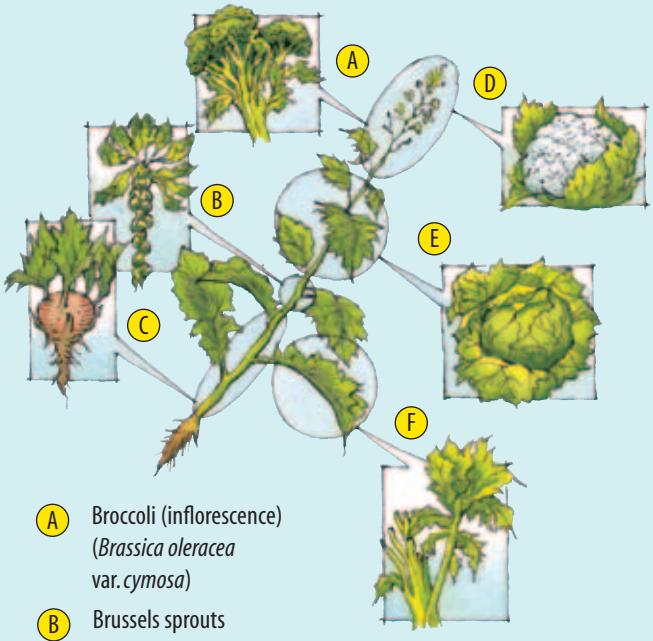
11 Outline the consequences of reduced genetic diversity to the survival of a species.

THINK AND DISCUSS

12 (a) List the differences you can see among the dogs (*Canis familiaris*) at the beginning of this section.
(b) Suggest how these variations came about.
(c) Find out more about artificial selection and how it is currently being used in Australia.

13 Discuss the implications on human populations of allowing the selective implantation of embryos that:
(a) are male
(b) possess recessive traits such as red hair or blue eyes
(c) have a potential for a higher IQ
(d) have a potential for paler skin.

14 *Brassica oleracea* is a common ancestor to a number of vegetables.
(a) Identify differences between *Brassica oleracea* and each of the species in the figure below.
(b) Suggest how these differences came about.



A Broccoli (inflorescence) (*Brassica oleracea* var. *cymosa*)

B Brussels sprouts (lateral buds) (*Brassica oleracea* var. *gemmifera*)

C Kohlrabi (stem) (*Brassica oleracea* var. *gonglyoides*)

D Cauliflower (flower) (*Brassica oleracea* var. *botrytis*)

E Cabbage (terminal buds) (*Brassica oleracea* var. *capitata*)

F Kale (leaf) (*Brassica oleracea* var. *acephala*)

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

15 Suggest what will happen if a species does not possess the genes that allow it to adapt to new environmental conditions.

INVESTIGATE AND CREATE

16 Choose a species. Using the internet, magazines or other resources, collect pictures that show variation within the species. Paste these onto a poster and label the types of variations that exist within the species.

17 Investigate meiosis and its involvement in generating genetic variation. Construct a model that shows independent assortment and crossing over.

18 Construct a model that shows possible variations of outcome from the fertilisation of gametes.

19 Find out more about genotypes and gene pools and create your own animation or cartoon to teach other students the difference between the two.

INVESTIGATE, THINK AND REPORT

20 Read the article below 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 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?
(e) Use internet research to identify relevant questions that could be investigated scientifically.
(f) Research and report on Australian research on the ozone layer.

21 Unscramble the following terms.
(a) vteydioirsib
(b) gmtimiranio
(c) egsatem
(d) seosimi

3.3 SCIENCE UNDERSTANDING

Natural selection

Survival of the fittest is more than having muscles, being tough or working out at the gym. It's about being better suited to a particular environment and having an increased chance of surviving long enough to be able to have offspring that will take your genes into the next generation.

Can you see the butterfly in this image?

Vive la différence!

We are all different! Our differences increase the chance of survival of our species. If our environmental conditions were to change, some of us might have an increased chance of surviving over others. Those who survive might then pass on any genetically inherited advantage to their children, who would also have an increased chance of survival; at least unless the environment changed to their disadvantage. If this happened, then other variations may have increased chances of survival. This is what the theory of evolution and natural selection is all about.

The mechanism for evolution

Darwin and Wallace's theory of evolution included the suggestion that the mechanism for evolution was natural selection. The three key terms that will help you to understand this idea are variation, competition and selection.

VARIATION

The theory of natural selection starts with the observations that more individuals are produced than their environment can support and that individuals within populations are usually different from each other in some way — they show variations. (Some causes of these variations are outlined in section 3.2.) According to this theory, some of these variations will provide the individual with an increased chance of survival over individuals with other variations within a particular environment. In other words, some variations will provide individuals with a competitive advantage.

Individuals that possess a favourable variation (or phenotype) will have an increased chance of reproducing and passing on this variation (through their genes) to their offspring. Inheritance of this variation (or phenotype) will also increase the chances of survival of the offspring and hence the possibility that they will also contribute their genes into the next generation. Over time and many generations, if this variation continues to provide a selective advantage, the number of individuals within a population that show the favourable variation will increase.

Individuals that have less favourable variations or that are not as well suited to their environment will not be able to compete as effectively. They may die young or produce few or no offspring. Therefore they will have a limited contribution to the gene pool of the next generation. This will lead to a decrease in the number of individuals with that particular variation within the population.

Can you suggest features that provide the individuals with increased chances of survival?

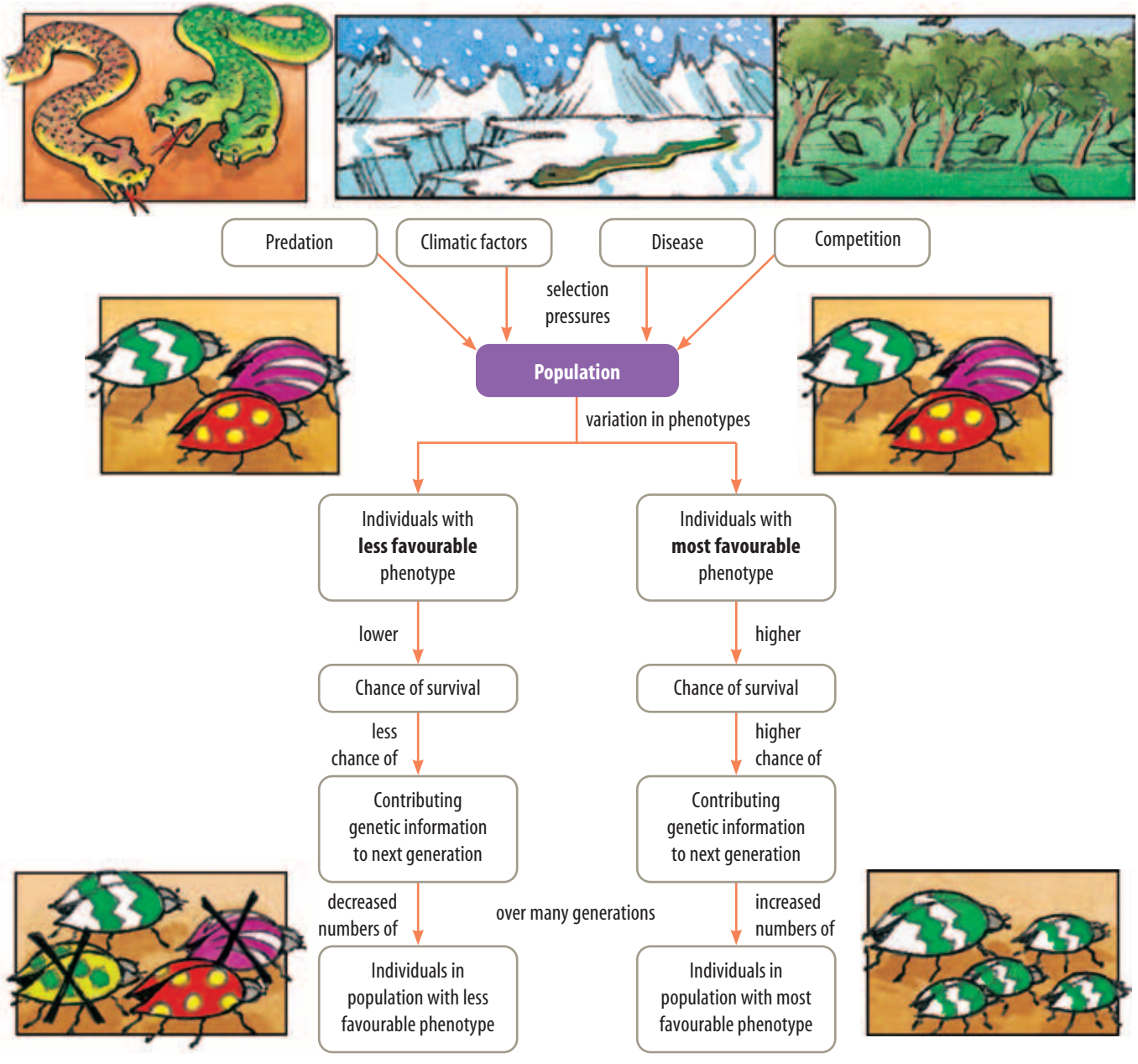
SELECTION

Organisms live within ecosystems. These ecosystems are made up of various living (biotic) and non-living (abiotic) factors. It is these factors that contribute to selecting which variations will provide the individual with an increased chance of surviving over others. It is for this reason that these factors may be referred to as **selective pressures** or **selective agents**. Biotic factors that may act as selective agents include predators, disease, competitors, prey and mating partners. Examples of abiotic factors include temperature, shelter, sunlight, water and nutrients.

COMPETITION

Individuals within a population compete with each other for resources. They may be competing for resources such as food, shelter or mates. Those with a selective advantage over other individuals will be better able to compete against them for the resource.

There may be situations in which competing may not be about resources, but about competing to not be eaten by a predator or killed by a particular disease. In this case, individuals with a particular variation that reduces their chance of being eaten or killed by the disease will have a higher chance of survival. Can you think of examples in which variations in phenotype might provide an individual with an increased chance of avoiding being eaten by a predator or dying from a disease?



Tales of resistance

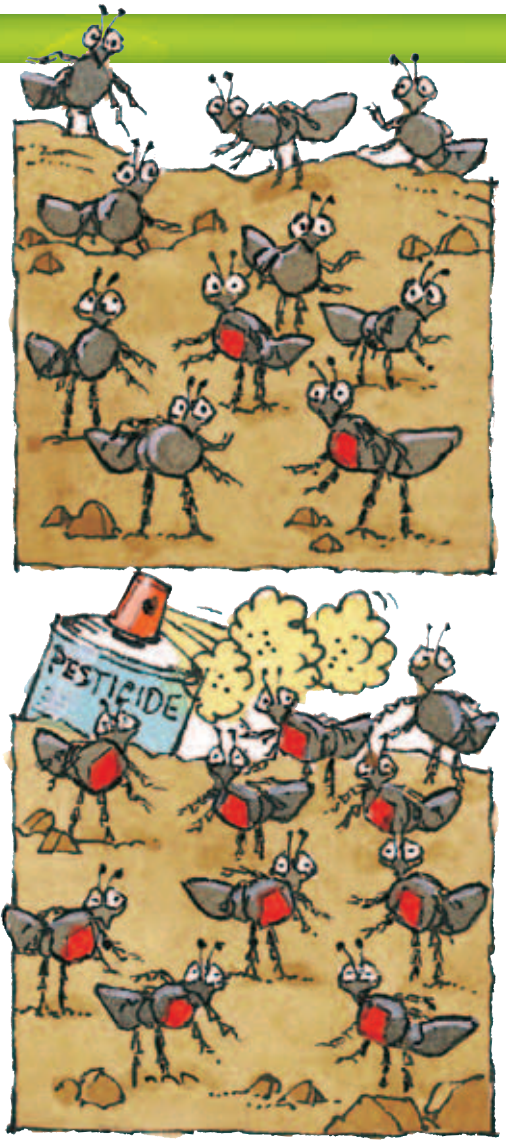
Most mutations are harmful to the organism and decrease its chances of survival. Some, however, may actually increase chances of survival. If a mutation results in a characteristic that gives the organism an increased chance of survival, then it is more likely that the organism will survive long enough to reproduce. If the organism's offspring inherit the genetic information for this new 'increased survival' trait, then over time an increased proportion of the population may possess this trait.

This is the way in which populations of organisms can become resistant to methods that humans have used to kill them or control their population sizes. Those individuals within the population with the mutation that confers resistance to the control method live long enough to produce offspring who also possess the resistant characteristic. Over time, future generations are likely to contain increased numbers of individuals within the population with resistance against the control method, making it no longer effective.

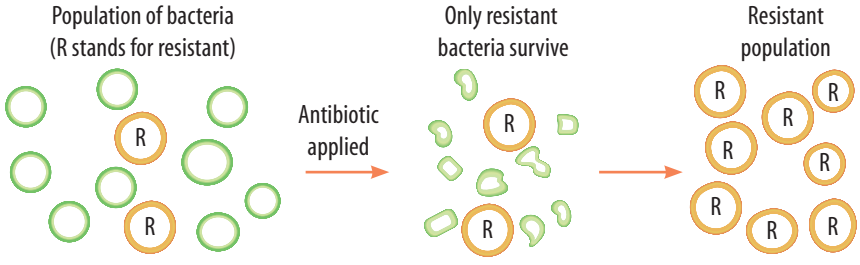
RESISTANT BACTERIA

Mutation is the key source of genetic variation in asexually reproducing organisms. Unless a mutation occurs, organisms that reproduce asexually produce clones of each other — they are genetically identical. Errors or changed sequences in their DNA during cell division can be the source of new alleles.

Prior to the discovery and use of penicillin, many people died from a variety of infections that can currently be treated with antibiotics. Penicillin and other antibiotics are drugs that can kill or slow the growth of bacteria. Referred to as 'magic bullets', these drugs revolutionised medicine. Although still widely used today, they are not as effective as they once were. Many bacteria have evolved to be resistant to them.



Mutations in flies can result in some individuals having resistance against a particular pesticide. When these flies reproduce, their offspring also show pesticide resistance.



Mutations in bacteria can result in some individuals having resistance against antibiotics. When these bacteria reproduce, their offspring also show antibiotic resistance.

RESISTANT BUGS AND BUNNIES

Variations due to mutation can also be advantageous in sexually reproducing organisms. The mutation may lead to a resistance to a particular pesticide, such as insects developing resistance to the pesticide DDT, or resistance to a particular viral disease, as in the case of some rabbits being resistant to the myxomatosis virus that was used to try to control their populations. If some individuals within the population have a mutation that enables them to survive and reproduce, they may pass this trait on to their offspring, who will also be resistant. An increase in the number of organisms within the population that are resistant to the pesticide or virus makes it a less effective agent of control.

INQUIRY: INVESTIGATION 3.2

Modelling natural selection

KEY INQUIRY SKILLS:

- evaluating
- planning and conducting

Equipment:

100 green toothpicks (or rubber bands)

100 red toothpicks (or rubber bands)

- Scatter 50 green toothpicks and 50 red toothpicks over an area of grass measuring at least 10 m × 10 m. The toothpicks represent caterpillars.
- One student will be the caterpillar-eating bird (CEB). Allow the CEB 15 seconds to 'eat' (pick up) as many of the caterpillars as she or he can.
- Count how many caterpillars of each colour were eaten. That will tell you how many caterpillars of each colour are left in the grass. Record these figures in a result table similar to the one shown at right.
- Allow the caterpillars to 'breed'. For every pair of caterpillars of a particular colour, add a third caterpillar of the same colour (e.g. if you have 15 green toothpicks [7 pairs] and 10 red toothpicks [5 pairs] left in the grass you should scatter an additional 7 green and 5 red toothpicks in the grass). Record the number of each type of caterpillar after breeding in your result table.
- The CEB will now have two further 15-second feeding frenzies. After each feeding frenzy, record the number of each type of caterpillar left in the grass, and allow the caterpillars to 'breed'.

DISCUSS AND EXPLAIN

1 Copy and complete the table below.

2 By the end of the experiment were there more green or red caterpillars? Explain why.

Time	Number of caterpillars	
	Red	Green
Start	50	50
After first feeding frenzy		
After first mating		
After 2nd feeding frenzy		
After 2nd mating		
After 3rd feeding frenzy		
After 3rd mating		

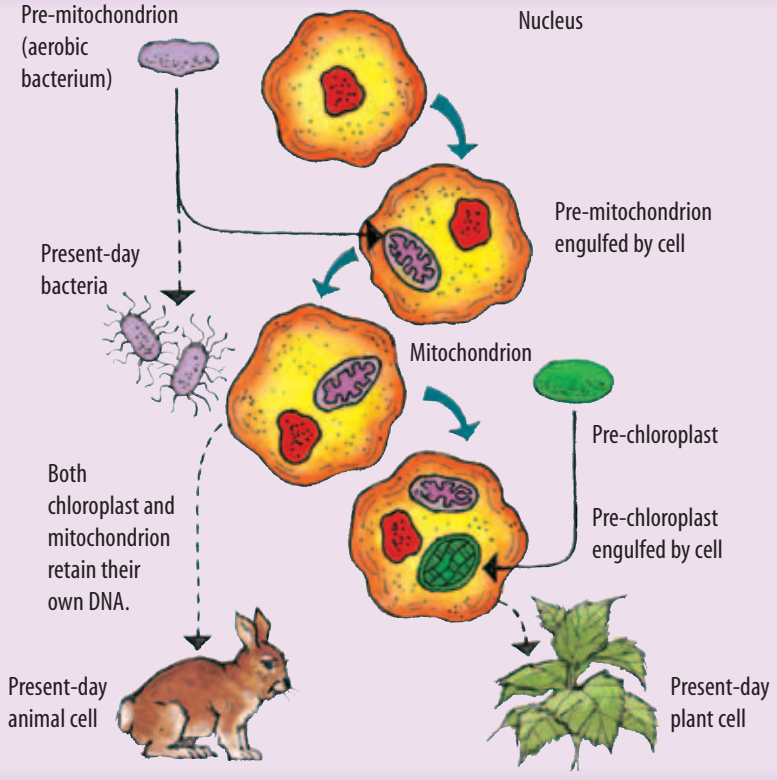
3 Suggest why one colour of caterpillar may eventually disappear or become less abundant in the population.

4 Explain how this experiment models natural selection.

HOW ABOUT THAT!

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. Their descendants are 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.



UNDERSTANDING AND INQUIRING

REMEMBER

1 Suggest how variation within populations increases the chances of survival of the species.

2 Construct a flowchart to describe natural selection using the following terms.

> Predation Competition
> Variation in phenotypes Selection pressures
> Climatic factors Population
> Less favourable Most favourable
> Disease Lower chance Higher chance
> Over many generations Survival Phenotype
> Genetic contribution to next generation
> Decreased numbers Individuals
> Increased numbers

3 Suggest the link between natural selection and evolution.

4 Describe what is meant by the term *natural selection*.

5 Identify three examples of (a) biotic and (b) abiotic selective pressures or selective agents.

6 Identify three resources for which individuals within a population may compete.

7 Describe a link between mutation, variation and resistance to a pesticide or antibiotic.

8 Using diagrams, explain how bacteria may become resistant to a particular antibiotic.

9 Myxomatosis virus was used as a method to control rabbit populations in Australia. However, it is no longer effective. Suggest reasons for the ineffectiveness of a previously effective method of control.

INVESTIGATE, THINK AND DISCUSS

10 DDT was a pesticide used to kill mosquitoes. It is no longer effective and has caused some unexpected environmental and ecological issues.
- (a) Find out more about the pesticide DDT and its history and use.
- (b) Identify ecological and environmental concerns about the use of DDT.
- (c) Suggest reasons for the gradual decrease in DDT's effectiveness as a pesticide.
- (d) Link the story about DDT to natural selection.

11 Penicillin was a very effective antibiotic against a number of different types of bacteria.
- (a) Find out more about the penicillin and its history and use.
- (b) Suggest reasons why some bacteria are now resistant against penicillin.
- (c) Link the story of penicillin to natural selection.

INVESTIGATE AND CREATE

12 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.

INVESTIGATE, THINK AND REPORT

13 The English peppered moth, *Biston betularia*, rests on tree trunks during the day. Prior to 1850, this species had a speckled pale grey colour that effectively camouflaged from predators as it rested on the pale lichen-covered trunks. In about 1850, a black version of this moth appeared. By 1895, these black moths made up about 98 per cent of the population.
- (a) Find out more about this species of moth.
- (b) Suggest the source of the new variation.
- (c) Find out what was happening in England between 1850 and 1895 that may have had an impact on the survival of these moths.
- (d) Suggest why and how the number of black moths in the population increased so dramatically.

Which moth is most easily seen?

14 Search the internet for cartoons and simulations on natural selection. Then use the best ideas to create your own cartoon, comic strip, picture story book or animation. Click on the **Sneakermales** weblink in your eBookPLUS to see a cartoon about how a cricket manages to mate.

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work sheets
- 3.1 Struggling to survive
- 3.2 Isolation and new species

Patterns, order and organisation: Evolution

Variation, struggle for survival, selective advantage and inheritance of advantageous variations formed the basis for Charles Darwin's theory of evolution by natural selection. It also provided an explanation for how new species arise.

The formation of new species is called **speciation**. There are two ways in which speciation can occur. **Phyletic evolution** occurs when a population of a species progressively changes over time to become a new species. **Branching evolution** or **divergent evolution** is more common; in this case, a population is divided into two or more new populations that are prevented from interbreeding. When different selection pressures act on each population, different characteristics are selected for. Over generations, these new populations may become so different from each other that they can no longer interbreed and produce fertile offspring. At this point, they have become two different species.

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.

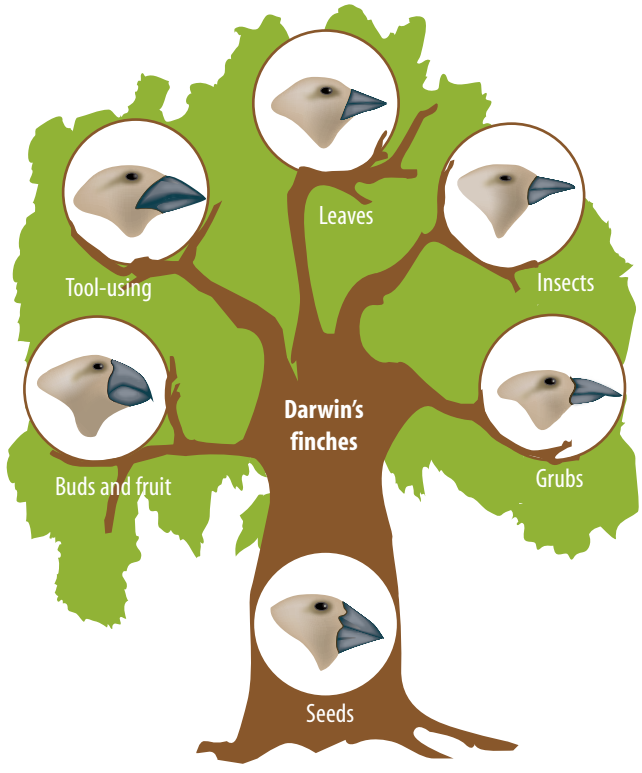
7 The isolated population is now quite different, producing a new species.

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

Divergent evolution

Divergent evolution is a type of evolution in which new species evolve from a shared ancestral species. That is, two or more new species share a common ancestor. At some point in history there has been a barrier (such as a geographical barrier, for example a mountain or ocean) that has divided the population into two or more populations and has also interfered with interbreeding between the populations.

Exposure of these populations to different selection pressures will result in the selection of different variations or phenotypes. Over time, the populations may be so different that even if they were brought back together they would be unable to produce fertile

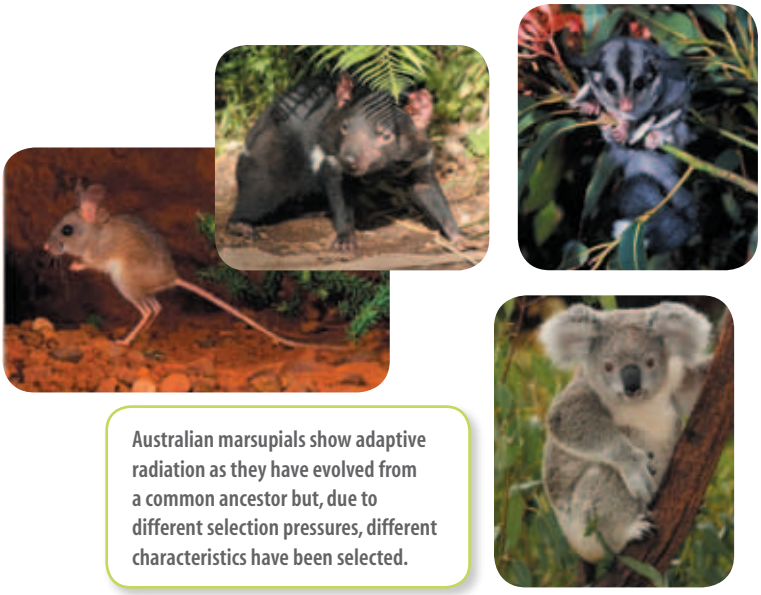


Darwin's finches are examples of divergent evolution. They share a common ancestor, but over time and generations, different selective pressures have led to the selection of different variations that are most suited to a particular environment or available niche.

offspring. It is at this point that they are referred to as different species. Speciation has occurred.

Adaptive radiation

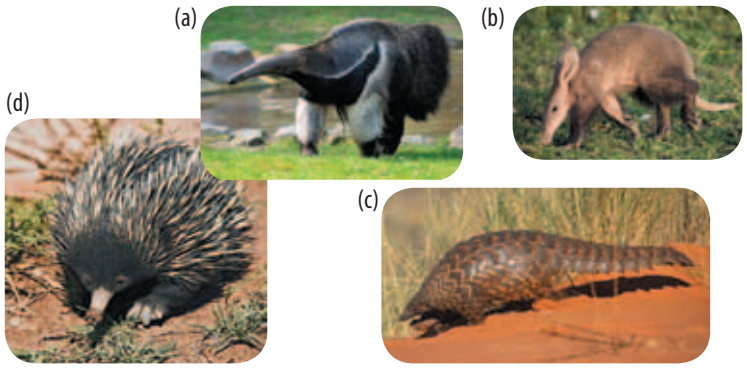
Adaptive radiation is said to have occurred when divergent evolution of one species has resulted in the formation of many species that are adapted to a variety of environments. Darwin's finches and Australian marsupials are two examples. Australian marsupials are thought to have evolved from a common possum-like ancestor. The photographs below shows examples of species that have arisen from a common ancestor.



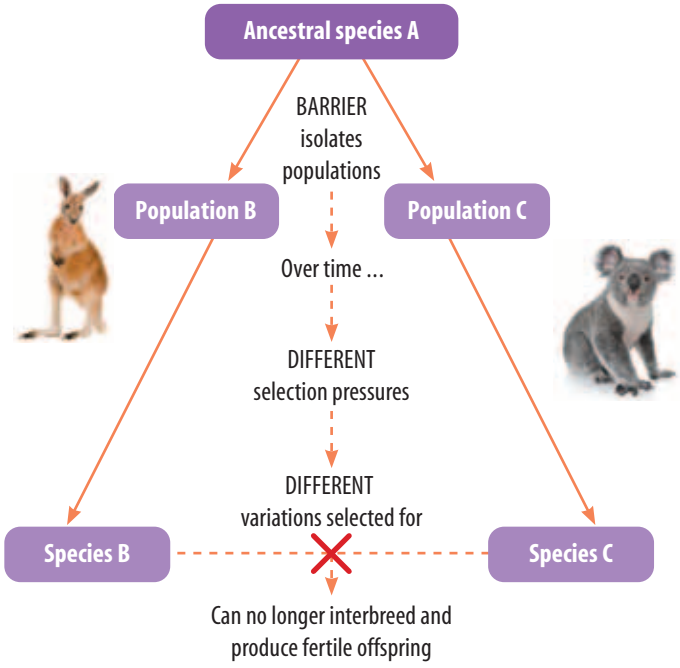
Australian marsupials show adaptive radiation as they have evolved from a common ancestor but, due to different selection pressures, different characteristics have been selected.

Convergent evolution

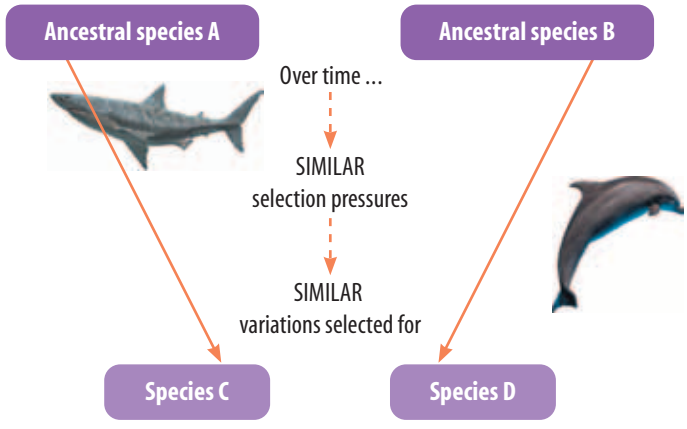
In divergent evolution, different selection pressures lead to the selection of different variations in evolution from a common ancestor. **Convergent evolution** is the opposite. Convergent evolution is the result of similar selection pressures in the environment selecting for similar features or adaptations. These adaptations have not been inherited from a common ancestor.



(a) The Australian echidna, (b) the African aardvark, (c) the South-East Asian pangolin and (d) the South American anteater share similar features. These features were selected for because they gave them a selective advantage in obtaining an available food supply within their environment, rather than because of a recent common ancestry.



Divergent evolution



Convergent evolution

Coevolution

The evolution of one organism can sometimes be in response to another organism. Examples of this coevolution include parasites and their hosts, or birds and plants. If you look at the features of birds

and the flowers that they pollinate, you may notice that some birds have evolved specialised features, such as beaks that are well suited for obtaining nectar for a flower with a particular shape. The plants have evolved flowers that may be of a particular colour that is attractive to its pollinator, and nectar that not only attracts but rewards the bird for its task of being involved in pollination.

EXTINCTION

Extinction is the loss or disappearance of a species on Earth. Extinction of a species may influence the evolution of another species, as it may provide the opportunity to move into the niche that the extinct species occupied. Extinctions and their effect on biological diversity are explored in section 3.10.

UNDERSTANDING AND INQUIRING

REMEMBER

1 State four key ideas that formed the basis of Darwin's theory of evolution by natural selection.
2 What is meant by the term *speciation*?
3 Describe how a new species can be formed.
4 Distinguish between (a) divergent evolution and (b) convergent evolution.
5 Describe an example of divergent evolution.
6 Outline the relationship between adaptive radiation and divergent evolution.
7 Describe an example of adaptive radiation.
8 Identify examples of organisms that show convergent evolution.
9 What is meant by the term *extinction*?
10 Select appropriate terms from the following list and use flowcharts to describe:
(a) divergent evolution
(b) convergent evolution.

Ancestral species A Similar selection pressures
Similar variations selected for Species C
Population B Different selection pressures
Over time Barrier isolates populations
Different variations selected for Species D
Population C Ancestral species B Species B
Can no longer interbreed and produce fertile offspring

ANALYSE, THINK AND DISCUSS

11 The figures at right show two species of North American hares that are closely related and share a common ancestor. The snowshoe hare, *Lepus americanus* (top), lives in northern parts of North America where it snows in winter. The black-tailed jack rabbit, *Lepus californicus* (bottom), lives in the desert areas.

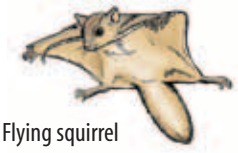
(a) Identify differences between these hares.
(b) Suggest reasons for these differences.
(c) Suggest how these differences came about.
(d) Is this an example of convergent or divergent evolution? Explain.

12 Identify where each of the figures shown belong in the convergent evolution table below.


Numbat


Bobcat


Spotted cuscus


Flying squirrel


Sugar glider


Anteater


Lemur


Spotted-tailed quoll

Niche	Placental mammal	Australian marsupial
Anteater		
Cat		
Climber		
Glider		

13 (a) Carefully examine each of the pairs of organisms shown below. Identify whether each pair is an example of convergent or divergent evolution.
(i) Dolphin and shark
(ii) Numbat and anteater
(iii) Sea dragon and seahorse
(iv) European goldfinch and pine siskin (finch)
(b) Provide a reason for your response.
(c) Use the internet to check the accuracy of your response.

(i)

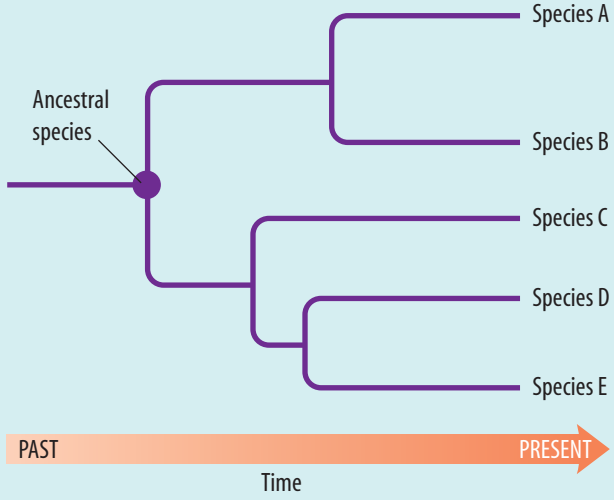

(ii)


(iii)

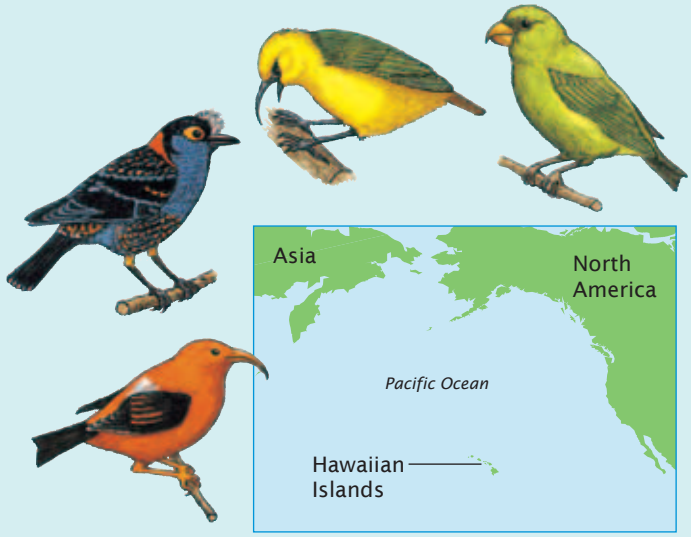

(iv)


INVESTIGATE, THINK AND CREATE

14 The figure above right shows how one ancestral species can undergo evolution and give rise to a number of new species.
(a) Select a species that is currently alive on Earth.
(b) Use the internet and other resources to find information that would enable you to construct a figure similar to the one given, showing your selected species and other species to which it is related.
(c) Write a play, story or documentary to tell the tale of the evolution of your selected species from its ancestral species.
(d) Using puppets, animations or multimedia, develop your tale into a presentation that can be shared with others.



15 Honeycreepers are found only in the Hawaiian Islands and share a common ancestry. Examples of four species of honeycreepers are shown in the figure below.
(a) Suggest reasons for their different appearance.
(b) Share your suggestions with others.
(c) Create a story to explain how and why these honeycreepers look so different.
(d) Collate the class's stories and read stories that others have written.



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How a new species evolves
Learn how a new species can form over time through the process of evolution.

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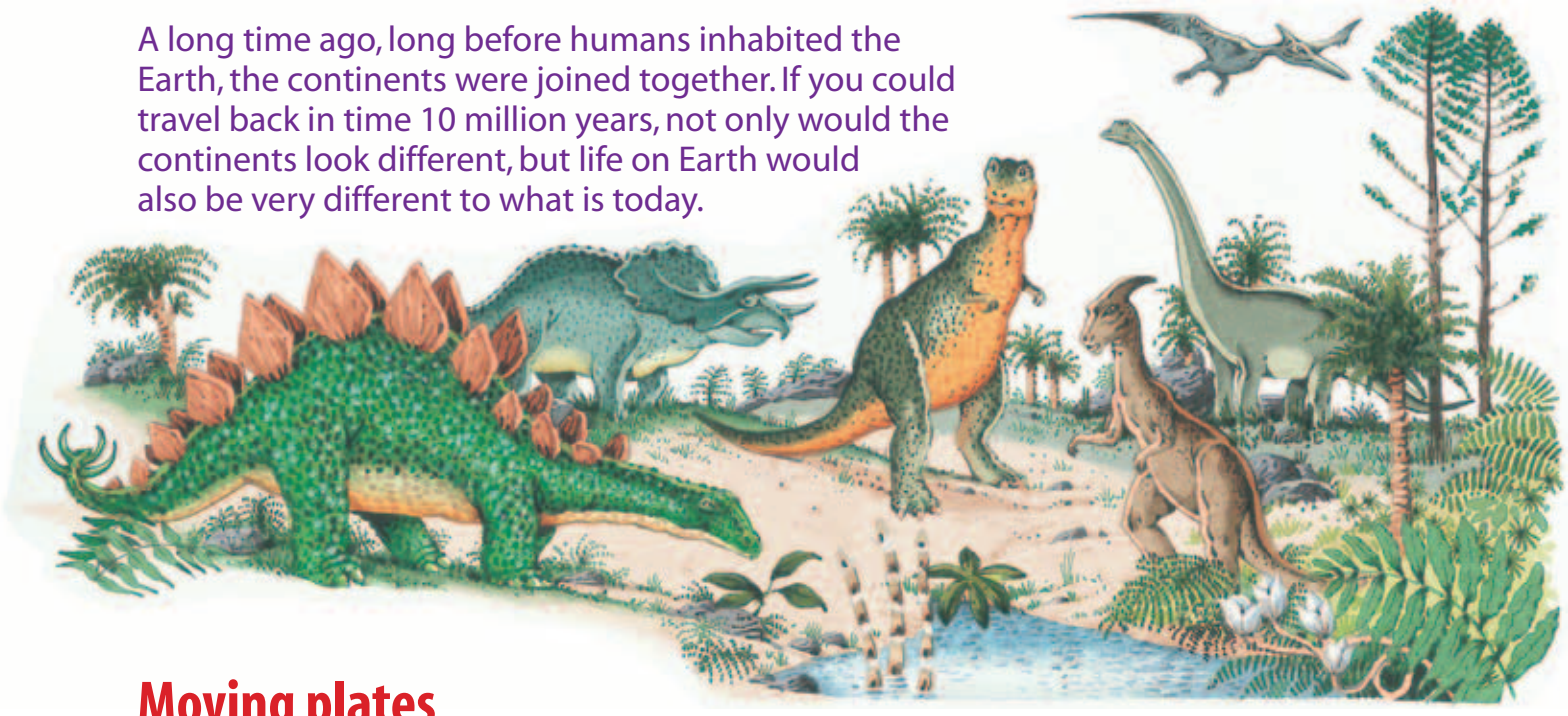
Long, long ago

A long time ago, long before humans inhabited the Earth, the continents were joined together. If you could travel back in time 10 million years, not only would the continents look different, but life on Earth would also be very different to what is today.



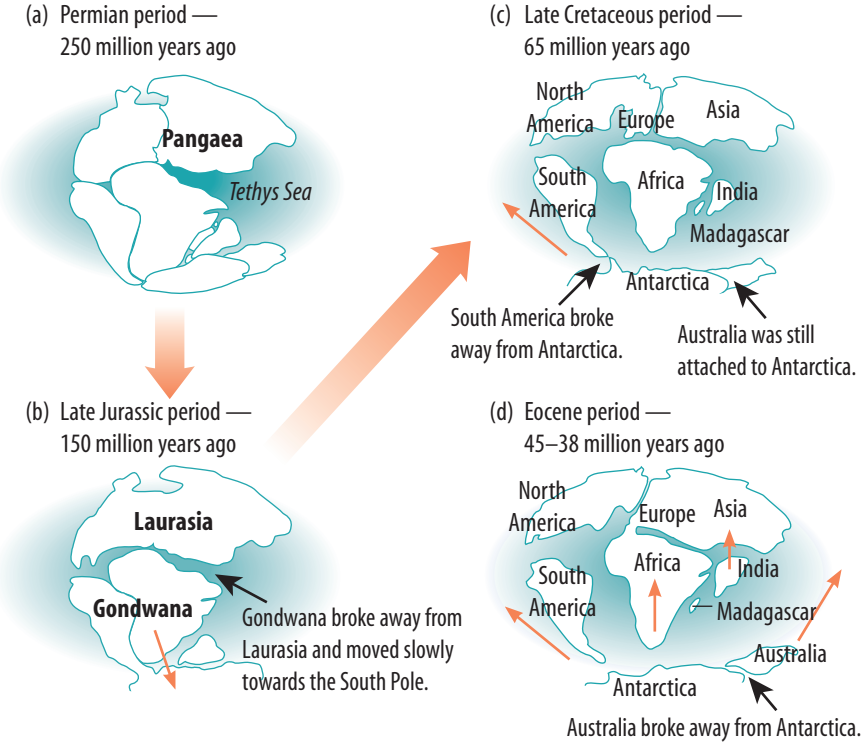
Moving plates

The theory of **plate tectonics** suggests that the Earth's crust is divided into about 30 plates, each about 120 kilometres thick. These plates move only several centimetres each year, sliding past, pushing against or moving away from each other.

Earthquakes are evidence that the tectonic plates are still moving.

From Pangaea to Gondwana

Over millions of years, some of these plates have moved further and further apart, separating what was once a single landmass into the continents that we know today. 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** and **Gondwana**.

Laurasia in the Northern Hemisphere consisted of the plates that would eventually become North America, Greenland, Europe and Asia. In the Southern Hemisphere, Gondwana consisted of the plates that would become South America, Africa, India, Antarctica and Australia.

Plate tectonics — the evidence

The evidence that supports the theory of plate tectonics includes:

- data showing that continents are still moving apart. Australia is moving northwards at the rate of about 7 cm every year.
- the physical fit between the continents
- the remarkable similarities between rock and crystal structures at the edges of continents
- fossil evidence suggesting that many of Australia's marsupials originated in South America
- 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, which are now separated by 6600 kilometres of ocean
- the distribution of closely related animals and plants across the continents.

Biogeography

Biogeography refers to the geographical distribution of species. Observations by Charles Darwin and Alfred Russel Wallace of this distribution contributed to their development of the theory of evolution. For example, Darwin 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. He concluded that the species originated in one area and then dispersed outwards.

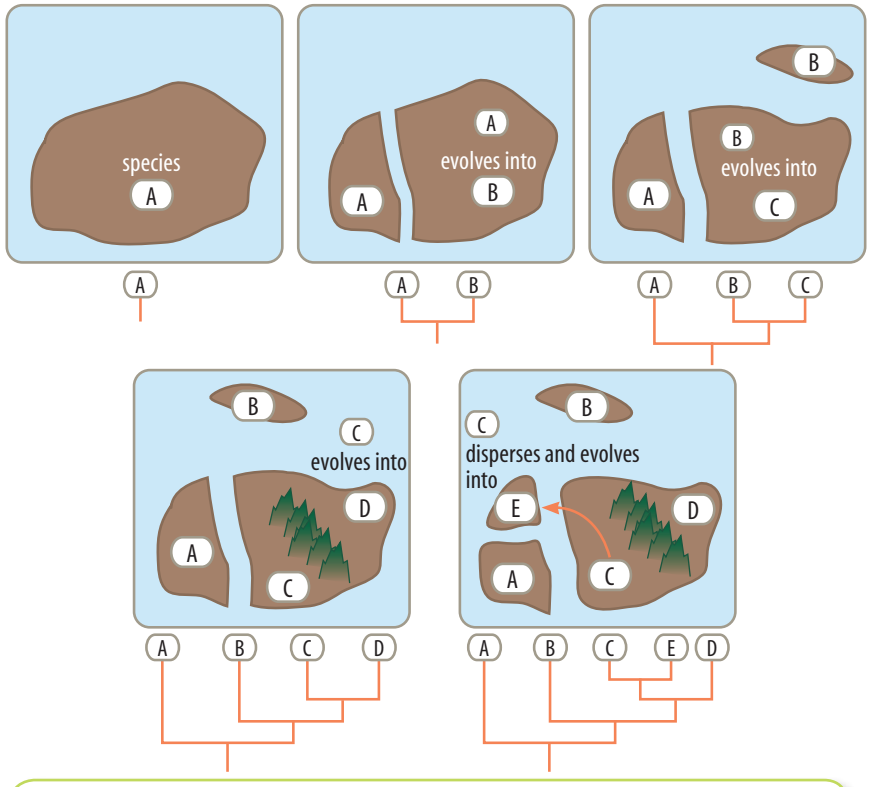
Analogous structures

Unrelated species living in very similar environments (with similar selection pressures) in different parts of the world have evolved similar structures. For example, the fins of a dolphin and a shark, or the wings of a bat and a butterfly, are the result of convergent evolution. Structures

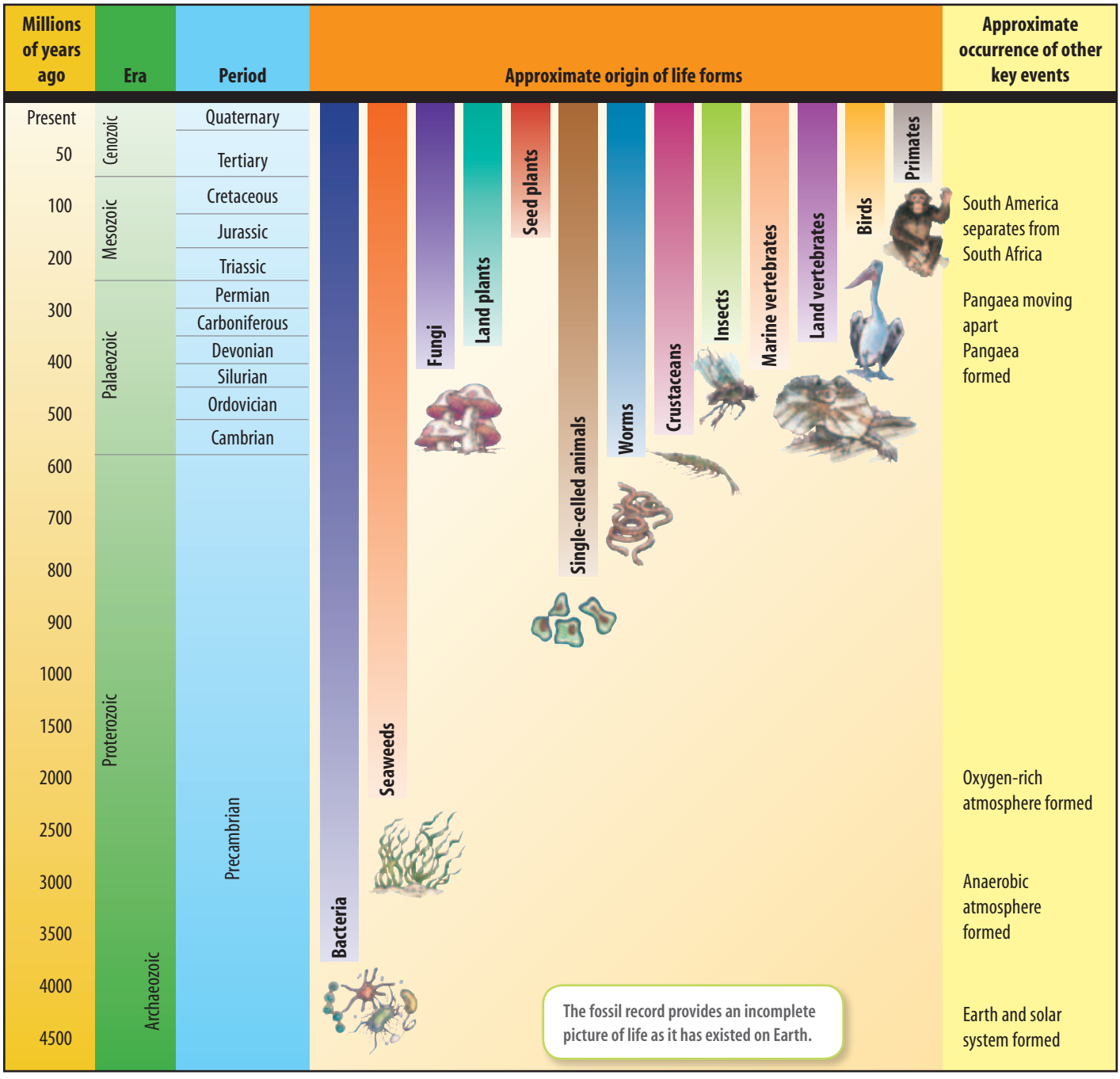
that perform the same role but have different evolutionary origins are called **analogous structures**.

Geological time

Our Earth is old. Its current age is estimated to be around 4.6 billion years. Geologists have constructed a geological timeline that divides this time into five **eras**, some of which are further divided into **periods**. This timeline with its divisions and information from fossil records are shown in the figure on the next page.



Divergent evolution can describe how isolated populations of a species can evolve into new species due to different selection pressures (see section 3.4). Species A, initially living on a supercontinent, evolves into different species B–E as tectonic plates move apart. *Source:* Modified with permission from *Understanding Evolution* (www.evolution.berkeley.edu), University of California Museum of Paleontology.



INQUIRY: INVESTIGATION 3.3

4.6 billion years of history

KEY INQUIRY SKILL:

- communicating

Equipment:

roll of toilet paper, cash register tape or similar

- Use the roll of paper to create a timeline of the history of the Earth. Begin by choosing an appropriate scale to represent the 4.6 billion years of history.
- Indicate the events shown in the figure above on your timeline.

DISCUSS AND EXPLAIN

1 A student was describing the evolution of life on Earth and wrote 'for much of Earth's history not much happened'. Is this statement justified?

2 Explain why a long roll of paper is necessary to construct this timeline.

UNDERSTANDING AND INQUIRING

REMEMBER

1 About how many plates is the Earth's crust thought to be divided up into?

2 Provide an example of evidence that the Earth's crust is still moving.

3 State the name of:
- (a) the giant landmass that once made up all of Earth's land surface
- (b) the two supercontinents
- (c) the supercontinent in which Australia was located
- (d) the other continents in the same supercontinent as Australia.

4 Outline five pieces of evidence that support the theory of plate tectonics.

5 What does biogeography refer to?

6 Suggest the relationship between biogeography and evolution.

7 What is meant by the term *analogous structures*?

8 Provide examples of analogous structures.

9 Approximately how old is Earth estimated to be?

ANALYSE, THINK AND DISCUSS

10 Read the article below and then answer the questions that follow.
- (a) Using an atlas and the diagrams in this section, locate Chile, Tasmania and Antarctica. Does their position on the supercontinent support the claims made by the researchers in the article? Explain.
- (b) Why aren't Fitzroya trees found on the Antarctic continent today?

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.

11 Refer to the fossil record and geological timeline in this section to answer the following questions.
- (a) List the eras from most recent to least recent.
- (b) List the periods in the Mesozoic era.
- (c) Which period came first, the Cambrian or the Permian?
- (d) In which period are we currently living?
- (e) Humans are primates. In which era did primates appear?
- (f) Dinosaurs became extinct about 65 million years ago. Identify the period and era of this time.
- (g) Humans have been blamed for causing the extinction of many other organisms. On the basis of data in the timeline, did they cause the extinction of the dinosaurs? Explain.
- (h) Suggest why humans could not have survived 4 billion (4000 million) years ago.
- (i) Identify the first life forms to appear.
- (j) Identify the most recent life forms to appear.
- (k) List the following life forms in order of their appearance: fungi, birds, worms, insects, primates, crustaceans.
- (l) Suggest the difference between land plants and seed plants.
- (m) Suggest a reason for the appearance of seed plants and birds around the same time.
- (n) Suggest why the term *Cambrian explosion* is often associated with the Cambrian period.

INVESTIGATE AND CREATE

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12 Use the **Madagascar** weblink in your eBookPLUS to watch a video and read about the geological and evolutionary history of Madagascar.

HOW ABOUT THAT!

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.

work sheet 3.3 Geological time

Yesterday's plants

Imagine walking along the shores of the primeval oceans and observing the first traces of life on Earth. What would you see?

First findings

If you were to observe the first traces of life on Earth, you would see a rich, slimy soup in the primeval oceans. The earliest known traces of life were primitive bacteria, the ancestors of modern-day organisms. Their fossil remains are found from the rock structures (stromatolites) they produced 1000 million years ago. These ancient **stromatolites**, like upside-down ice-cream cones up to 18 metres high and about 10 metres across, loomed above the silent seabed in greenish-white forests that stretched for hundreds of kilometres.

The earliest forms of animal life did not appear until plants were well established. In Australia, this was in the early Cambrian period, which was about 570 million years ago.

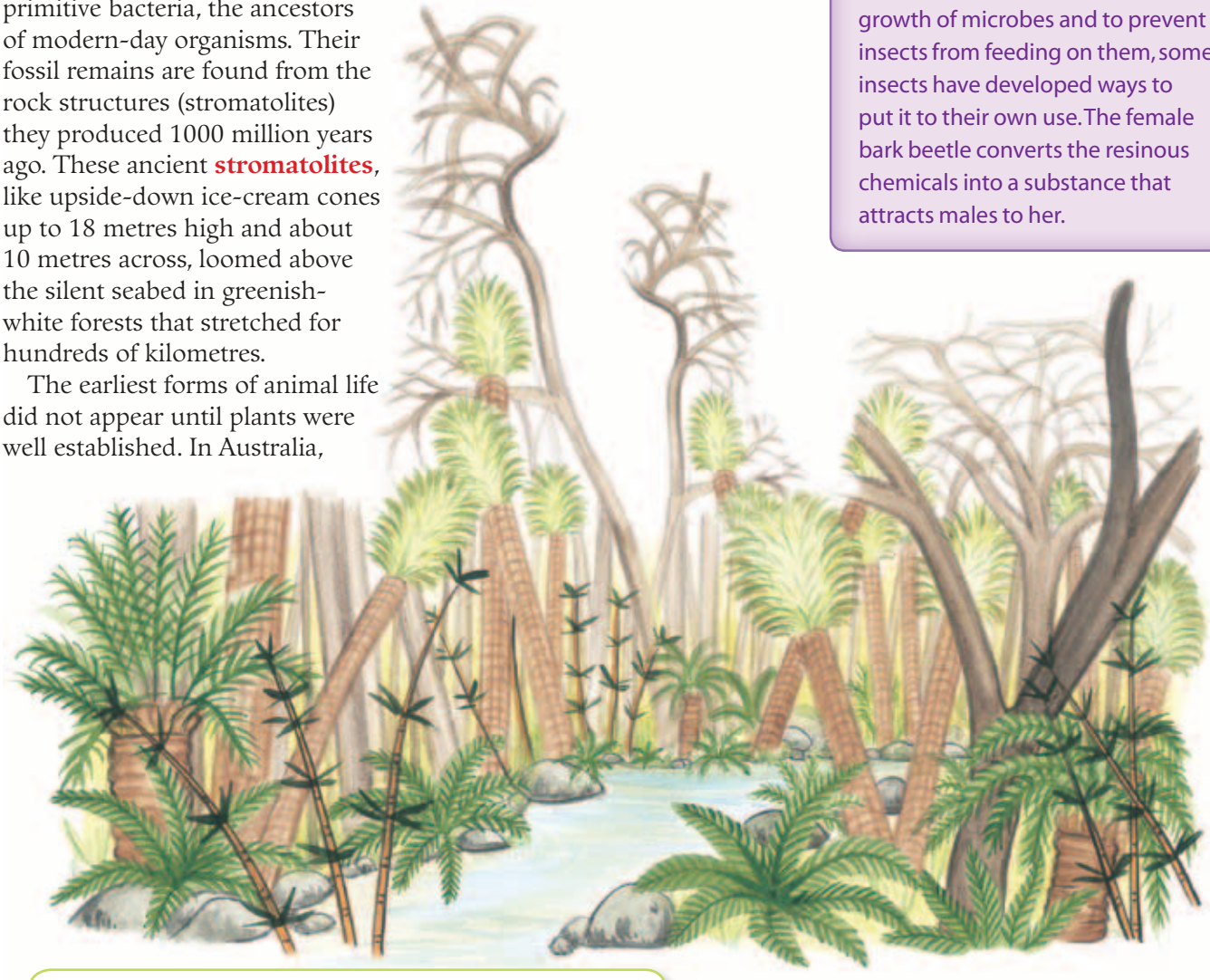
From forests to coal

Over 300 million years ago, during the Devonian and Carboniferous periods, plants had developed into a variety of complex forms. Close relatives of the horsetails, clubmosses and ferns formed vast ancient forests. Thick layers of their rotting remains became solidified over time, to form the coal beds found today.

About 350 million years ago, the first seed-producing plants appeared. **Gymnosperms** were the dominant plants in the Permian, Triassic and Jurassic periods. Gymnosperms such as conifers, cycads and maidenhair trees are living descendants of the first pollen-producing plants.

HOW ABOUT THAT!

Many conifers produce a sticky, aromatic, oily material called resin. This material gives them their characteristic smell. Although the resin is produced to stop the growth of microbes and to prevent insects from feeding on them, some insects have developed ways to put it to their own use. The female bark beetle converts the resinous chemicals into a substance that attracts males to her.



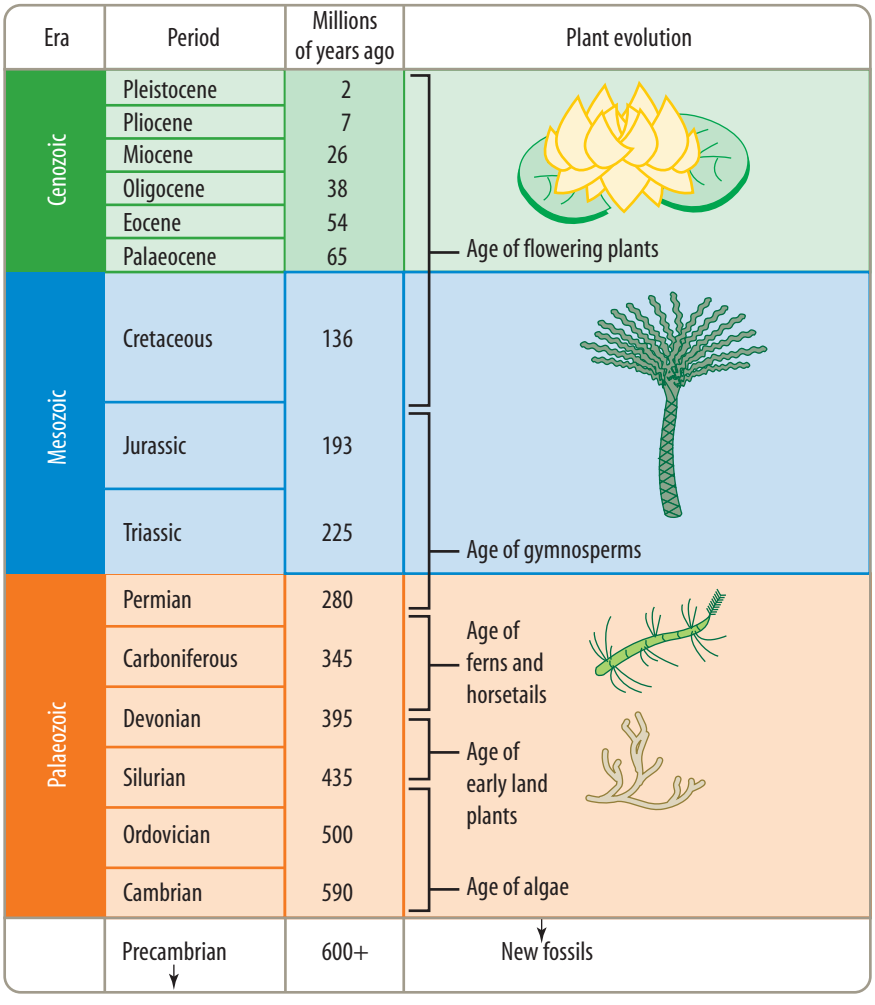
Some of these ancient forests contained horsetails and clubmosses 45 metres tall.

Blooming flowers

It was during the Cretaceous period, about 135 million years ago, when dinosaurs still flourished, that flowering plants appeared. During this period, **angiosperms** or flowering plants became the dominant plants. These plants were closely related to those found today.

Pollen power

Fossilised pollen grains survive for millions of years. By studying ancient pollen, scientists can investigate vegetation that existed in the past. In Australia the oldest fossil pollen from a flowering plant is from the native holly genus *Ilex*. Millions of years ago, most of the surface of Australia was covered by forests. Over time, Australia gradually became drier. The change in climate resulted in fewer rainforests. Eucalypts, acacias and proteas, with their tough, hard leaves and often woody fruits, were well suited to these dry conditions. Pollen fossil evidence suggests that eucalyptus plants appeared about 30 million years ago.



Geological table of plant evolution

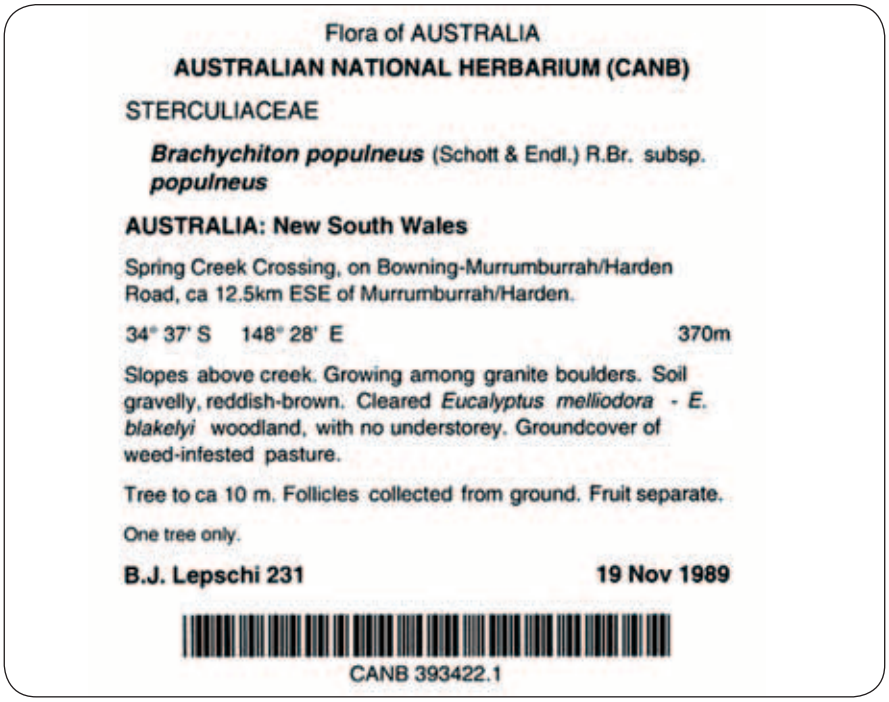
Plants tell tales of history

Judy West is a scientist involved in Australian native plant taxonomy and heads the Centre for Plant Biodiversity Research which houses the Australian National Herbarium.

Dr Judy West, Executive Director of the Australian National Botanic Gardens, is involved in botanical research.

The Australian National Herbarium contains over six million specimens of plants dating from the earliest days of European exploration. Each specimen has its own story and history documented. This has enabled the ANH to maintain a historical record of over two hundred years of changes to our vegetation.

The records that ANH have kept have also enabled monitoring of the changes in the names given to plants over the last 200 years in Australia. Their plant information system, which is based on 'scientifically verifiable voucher specimens', ensures the 'currency of names' as we continue to find out more about our Australian plants.



Flora of AUSTRALIA

AUSTRALIAN NATIONAL HERBARIUM (CANB)

STERCULIACEAE

Brachychiton populneus (Schott & Endl.) R.Br. subsp. ***populneus***

AUSTRALIA: New South Wales

Spring Creek Crossing, on Bowning-Murrumburrah/Harden Road, ca 12.5km ESE of Murrumburrah/Harden.

34° 37' S 148° 28' E 370m

Slopes above creek. Growing among granite boulders. Soil gravelly, reddish-brown. Cleared *Eucalyptus melliodora - E. blakelyi* woodland, with no understorey. Groundcover of weed-infested pasture.

Tree to ca 10 m. Follicles collected from ground. Fruit separate.

One tree only.

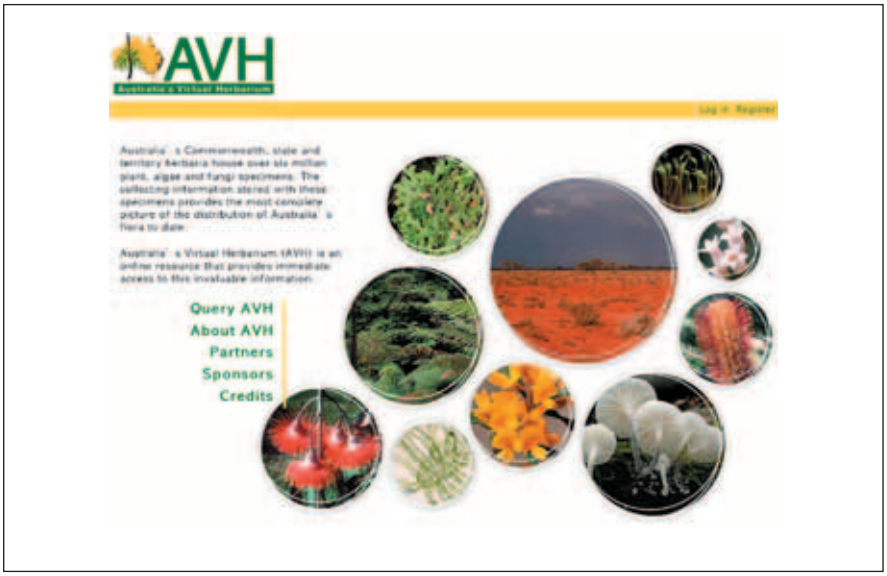
B.J. Lepschi 231 **19 Nov 1989**

CANB 393422.1

An example of a label from the Australian National Herbarium: each label includes the plant names, basic details about where, when and by whom it was collected, and information about the habitat and the appearance of the plant. All these details are stored in a database so that they can be managed and made available for research and analysis.

ePLANTS

The Australian National Herbarium maintains a database in which you are able to search for information about many different plants online. AVH is a dynamic project that includes many plans for future developments. Perhaps you will be a part of this project in the future, providing images and descriptions or creating identification tools for future generations?



Australia's Virtual Herbarium (AVH) is an online resource. It provides access to plant specimen data held by Australian herbaria.

UNDERSTANDING AND INQUIRING

REMEMBER

1 What is the relationship between stromatolites and modern-day plants?

2 When did the angiosperms become the dominant plants?

3 Which characteristics make eucalypts well suited to the dry Australian environment?

THINK AND REASON

4 Use the geological table in this section to complete the following.
   (a) List the plant groups in order of their appearance, from most primitive to most recent.
   (b) Draw a timeline showing the times when these plant groups dominated the Earth.

THINK

5 Suggest why no new major plant groups have arisen over the past 130 million years.

6 Suggest why flower fossils are very scarce.

7 If a botanist studies plants and a palaeontologist studies fossils, what do you think a palaeobotanist studies?

INVESTIGATE

8 The ginkgo or maidenhair tree is often described as a living fossil. It is descended from trees that date back to the Triassic period, about 200 million years ago. Find out how it differs from the other groups of living gymnosperms, such as conifers and cycads. Suggest reasons for the differences.

9 Find out more about the following ancient plants:
   (a) giant clubmoss, *Archaeosigillaria*
   (b) horsetails
   (c) *Lepidodendron*
   (d) *Cooksonia*
   (e) *Baragwanathia*.

10 Investigate research on the history of Australian plants. Report your findings in a storyboard or as a PowerPoint or PhotoStory presentation.

Fossils

To gain insight into what life was like in the past, you need look no further than rocks. Within rocks you may find fossils — evidence of past life. The study of organisms by their fossil remains is called **palaeontology**.

Fossils

Fossils can be parts of an organism, such as its bones, teeth, feathers, scales, branches or leaves. 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** can work out the size, weight and speed of the dinosaur that made them.

How are fossils formed?

Fossilisation is a rare event. Usually when an organism dies, micro-organisms are involved in its decomposition so 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 if it becomes trapped in a mudslide or in the silt at the bottom of the ocean), the micro-organisms responsible for decomposition cannot do their job because of the lack of oxygen. Over millions of years, the material covering the dead organism is compressed and turned into rock, preserving the fossil within it.

Dating fossils

There are two main ways in which the age of fossils is estimated. One is called **relative dating** and the other is called **absolute dating**. The key difference between these two types of dating can be outlined using the following analogy.

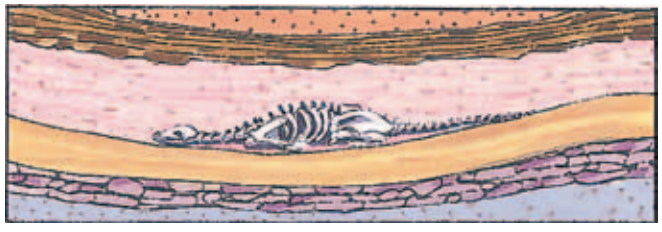
If you were to ask me 'What is your **relative age**?', I would reply, 'I am the eldest of three daughters'. If you were to ask me 'What is your **absolute age**?', my response would be to tell you how old I was in years.

RELATIVE DATING

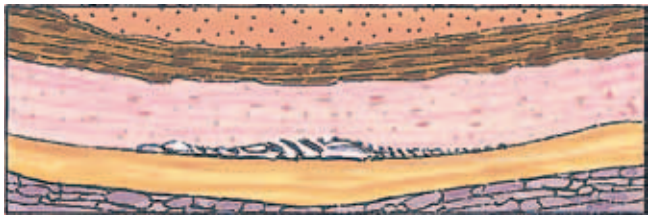
Relative dating is used to determine the relative age of a fossil. As the layers of sedimentary rock are usually arranged in the order they were deposited, the most recent layers are near the surface and the older layers are further down. The position or location of a fossil in the strata, or layers, of rock gives an indication of the time in which it lived.

Fossil formation

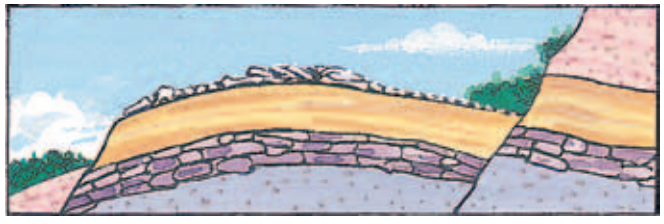
1. A dinosaur dies and is quickly covered by sediment.



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.

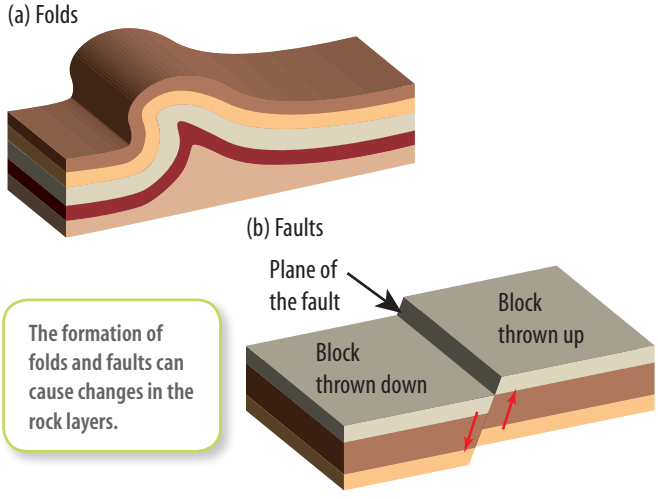


4. The rock is folded and eroded and the fossil can be seen on the surface.

Relative dating can also provide information about which other species were living at the same time in that area, and the order in which they appeared in the area.

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

Interpretation of the relative dating method requires taking into consideration the movement of tectonic plates in which the rocks lie. 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**.



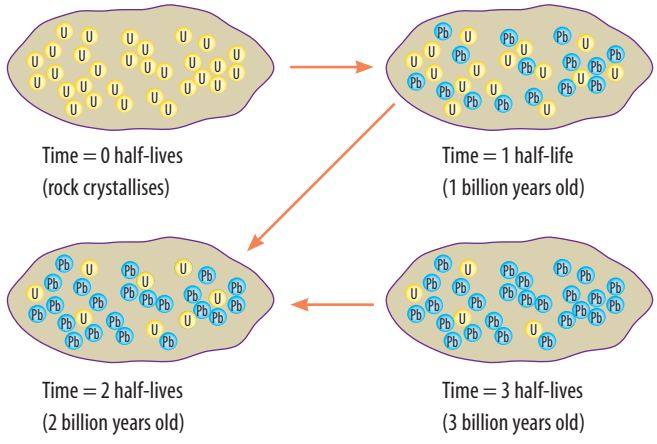
The formation of folds and faults can cause changes in the rock layers.

ABSOLUTE DATING

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**. The half-life of an isotope is the amount of time it takes for its radioactivity to halve. The use of these techniques to determine the absolute age of rocks and fossils is called **radiometric dating**.

Carbon dating is a specific type of radiometric dating and can be used to date fossils up to about 50 000 years old. Most of the carbon contained in living things is carbon-12, but there is also a small amount of the radioactive isotope carbon-14. Organisms have incorporated this into their bodies from the small amount of radioactive carbon dioxide that is naturally present in the air. When an organism dies, the unstable carbon-14 decays, but the carbon-12 does not. The ratio between carbon-12 and carbon-14 can be used to determine the absolute age of the fossil.

Radiometric dating can also be used to determine the age of inorganic materials (materials not containing carbon), such as the rocks surrounding fossils. **Potassium–argon dating** is commonly used to determine the absolute age of ancient rocks. Another example involves measurement of the ratios of decay of uranium-238 to lead-207 and uranium-235 to lead-206. The diagram below outlines how these ratios can change over time.



Over time the uranium present in the rocks decays into lead. The half-life of uranium is the amount of time it takes for half the uranium initially present in the rock to decay into lead.

Fossils telling tales

The fossil record gives us evidence that species have changed over time. For example, a fossilised skeleton of a bird (*Archaeopteryx*) found in Bavaria has been dated at 150 million years old. It clearly shows feathers, which are a feature of all modern birds; however, it also has dinosaur characteristics such as

Some radioactive isotopes and their daughter products of decay

Radioactive parent isotope	Daughter product	Half-life (years)	Uses
Carbon-14	Nitrogen-14	5730	Used for dating organic (carbon-based) remains up to about 60 000 years old
Uranium-235	Lead-207	710 000 000	Used for dating igneous rocks containing uranium-based minerals in the range from about 1000 to 1 000 000 years
Potassium-40	Argon-40	1 300 000 000	Used for dating igneous rocks containing potassium-bearing minerals in the range from 500 000 years and older
Rubidium-87	Strontium-87	47 000 000 000	Used to date the most ancient igneous rocks

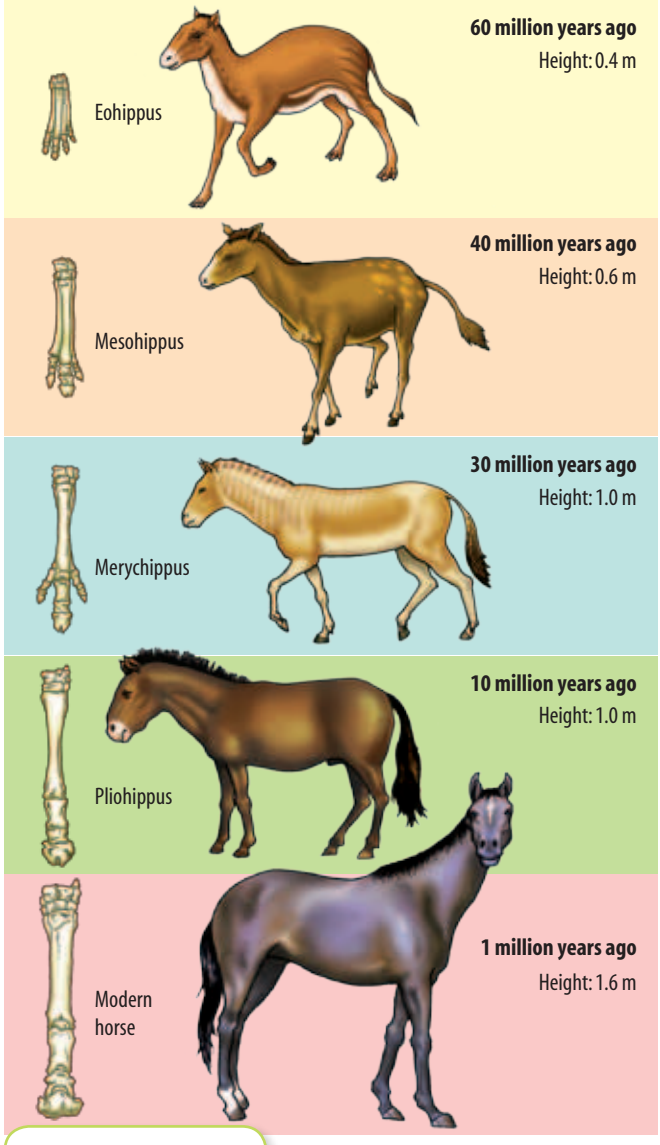
The longer the half-life of a radioactive isotope, the older the material that can be dated using a particular radiometric method.

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.

The fossilised skeleton of *Archaeopteryx*

Horsing around in time

The fossil record gives us evidence of gradual change occurring over time. An example can be seen in observations of fossils of horse species from different times. Fossils indicate that horses have become taller, their teeth are now better suited to grazing than eating leaves and fruit, and their feet have a single hoof rather than spread-out toes. Over time, environmental changes have led to different variations having a selective advantage over others. Reduced availability of fruit and leaves but increased availability of tough grasses resulted in selection for teeth better suited to grazing. As forests were replaced by open plains, longer legs and hoofs may have been selected for to provide a better chance of escaping predators.



The evolution of the horse

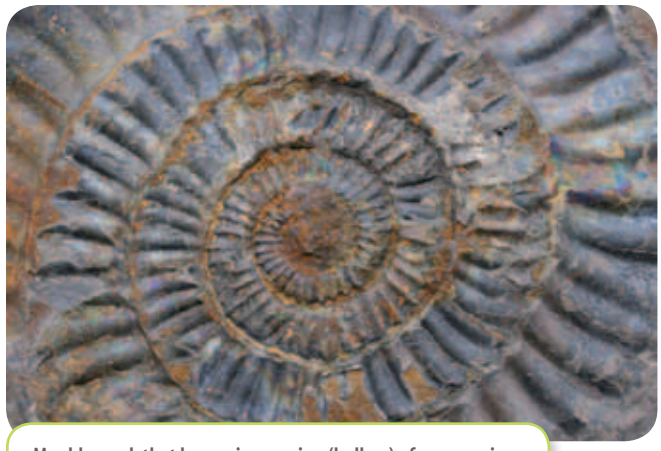
Types of fossils

There are many different types of fossils. These types include moulds, casts, imprints, petrified organisms, and whole organisms that have been frozen or trapped in sap or amber.

Cast: a rock with the shape of an organism protruding (sticking out) from it

Carbon imprint: the dark print of an organism that can be seen on a rock

Whole organism: larger organisms that have been preserved whole by being mummified or frozen, such as the baby mammoth found in 2007 in Siberia



Mould: a rock that has an impression (hollow) of an organism

Amber fossils: parts of plants, insects or other small animals that have been trapped in a clear substance called amber

Petrified fossil: organic material of living things that has been replaced by minerals, such as petrified wood

INQUIRY: INVESTIGATION 3.4

Studying fossils

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

fossils, fossil casts or pictures of fossils

- Copy and complete the table for each type of fossil.

Name	Description	Type of fossil (cast, mould, imprint or other)

UNDERSTANDING AND INQUIRING

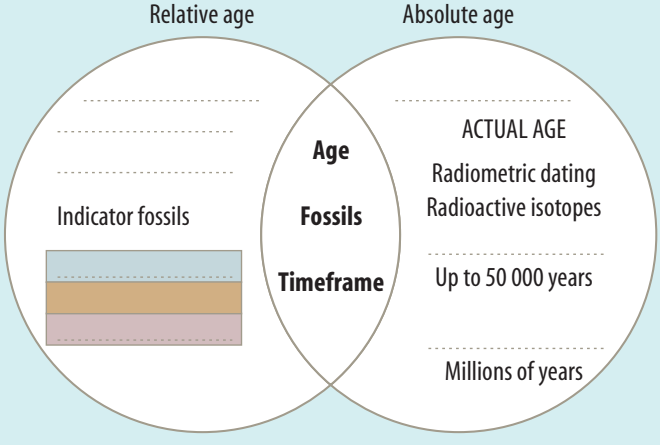
REMEMBER

1 Define the following terms.
   (a) Fossil
   (b) Palaeontology
   (c) Half-life of an isotope
2 Provide examples of different types of fossils.
3 Explain why fossilisation is a rare event.
4 Describe how fossilisation can occur.
5 Name the two main ways of dating fossils.
6 Outline the difference between the two main ways of dating fossils.
7 Suggest the connection between tectonic plates and dating fossils.
8 State the relationship between carbon dating and radiometric dating.
9 Describe how carbon dating is used to estimate the age of fossils.
10 Suggest why you might use potassium–argon dating rather than carbon dating.
11 Outline what the fossil record tells us about the evolution of horses.

THINK AND DISCUSS

12 The Venn diagram below uses some analogies as well as key differences to distinguish the relative age versus the absolute age of fossils. Copy and complete the Venn diagram below using the following terms.

Order Potassium–argon dating
16 years old Most recent Strata
Eldest of three daughters Carbon dating Oldest



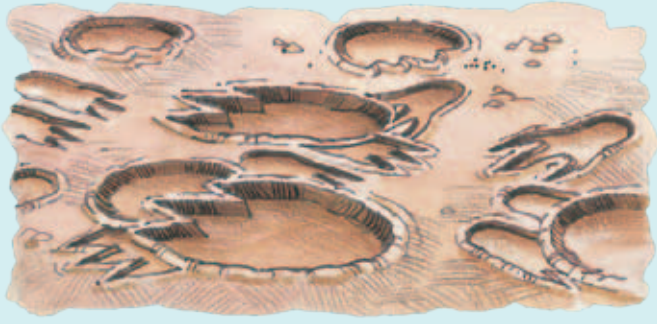
13 Examine the diagram in this section showing the evolution of the horse.
   (a) Describe how horses have evolved over the last 60 million years.
   (b) What type of horse would have been fittest (in terms of biological fitness) 60 million years ago? Explain your answer.
   (c) What type of horse would have been fittest one million years ago? Explain your answer.
   (d) Horse breeders pay large sums of money to have prize-winning racehorses breed with the mares in their stables. The fastest horses are flown around the world for breeding purposes. It is also possible to collect and freeze sperm from successful competition horses. This sperm can be used to impregnate many mares. Explain how this might affect the evolution of the horse. How might horses look in another million years?

ANALYSE AND EVALUATE

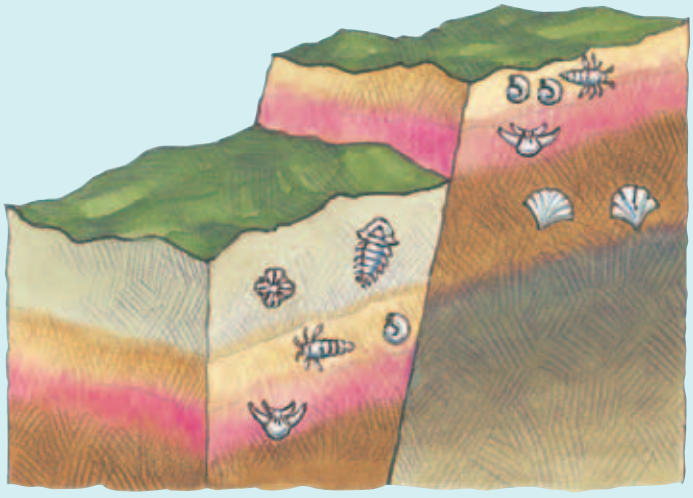
14 Examine the picture of the fossilised dinosaur below. Write a brief description of the animal, including what it may have eaten and how it may have moved. Why do you think it had so many large openings in its skull?

Fossilised skeleton of the Saurischian dinosaur

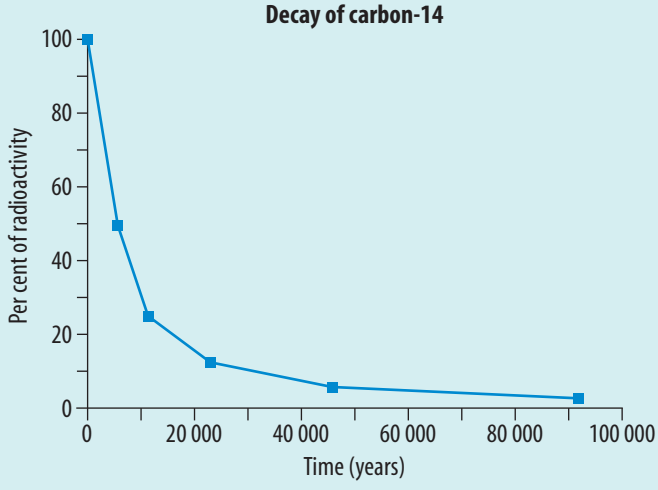
15 Examine the dinosaur track below to decide:
   (a) which dinosaur walked along this track first, and which walked here last
   (b) which dinosaurs probably walked on two legs, and which probably walked on four
   (c) which dinosaur hopped
   (d) which dinosaur was the heaviest.
   (Identify the dinosaur(s)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



16 The layers of rock shown in the illustration below have been disturbed by plate movements.
(a) Was the plate movement caused by folding or faulting?
(b) Which layer of rock is the youngest? Justify your answer.
(c) Which layer of rock is the oldest? Justify your answer.



17 Carefully observe the graph below showing the decay of carbon-14 and answer the following questions.



(a) Estimate the time taken for the radioactivity of carbon-14 to reduce by 50 per cent.
(b) On the basis of this graph, what is the half-life of carbon-14?
(c) Approximately how much radioactivity will be present at:
(i) 10 000 years
(ii) 30 000 years
(iii) 80 000 years?

INVESTIGATE

18 What do geologists and palaeontologists do?

19 Investigate the claims of life on Mars (for example, information on the rock sample labelled ALH84001) through newspaper reports and websites. Use the **Center for Mars Exploration** weblink in your eBookPLUS. Are you convinced that life once existed on Mars?

20 Research and prepare a report on carbon dating.

CREATE

21 Create a dinosaur track using modelling clay.

22 Make a cast of a leaf fossil using modelling clay or plasticine. To do this, first 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.

23 Make a model or draw a picture to show what a common ancestor of both mammals and birds may have looked like.

24 Use an image search engine such as Google, Bing or Picsearch to locate images of each of the types of fossils described under the heading *Types of fossils* in this section. Cut and paste the pictures into a Word document. Write a caption for each image. The caption should include the name of the fossilised organism shown in the picture, the location where the fossil was found and the type of fossil (e.g. cast).

25 There are a number of great fossil sites in Australia. Use the **Fossils** weblinks in your eBookPLUS and other sources to investigate one of the following fossil sites: Naracoote, Riversleigh, Bluff Downs, Murgon, Lightning Ridge.
Summarise information about the fossil site you have chosen under the following headings:
(a) Why the area is rich in fossils
(b) Examples of fossils that have been found here
(c) Age of the fossils found in this area
(d) Important information revealed by the fossils found in this area

26 Test your knowledge of all things old by completing the **Revelation: 'Fossils'** interactivity. Success rewards you with a video interview with a paleontologist where you can see some real fossils. **int-1018**

work sheets
3.4 Fossils
3.5 Ages of fossils

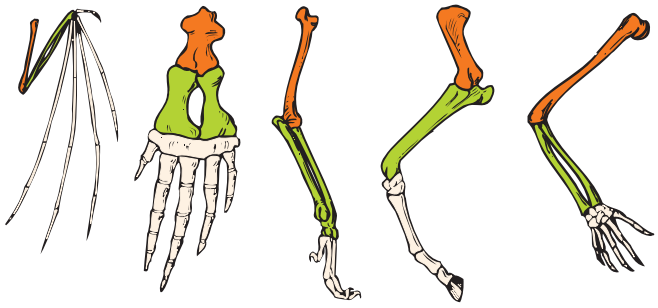
More evidence for evolution

The theory of evolution by natural selection was developed from the many observations that Darwin and Wallace made on their journeys. Since then, more evidence has been collected to further support their theory. Some of these have involved the use of new technologies.

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. The structure of the forearm can be traced back to the fin of a fossilised fish from which amphibians are thought to have evolved.

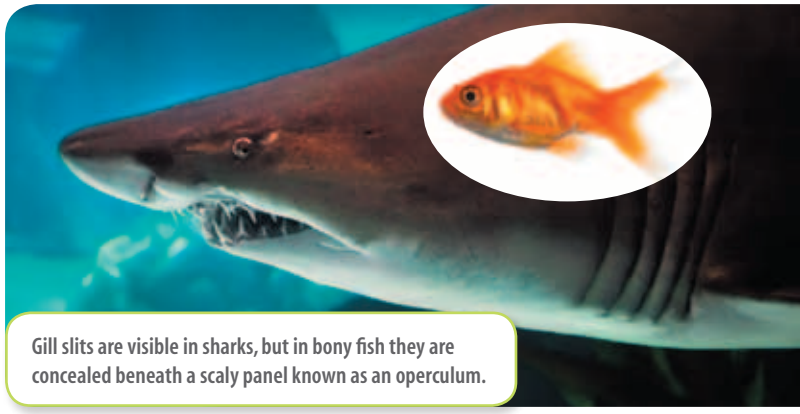
Similarity in characteristics that result from common ancestry is known as **homology**. Anatomical signs of evolution such as the similar forearms of mammals are called **homologous structures**. For example, in the diagram below, you can see that each limb has a similar number of bones that are arranged in the same basic pattern. Even though their functions may be different, the similarity of basic structure still exists.



The structures shown have the same basic structure since they are all derived from a vertebrate forelimb. Do they have identical functions?

COMPARATIVE EMBRYOLOGY

Organisms that go through similar stages in their embryonic development are believed to be closely related. During the early stages of development, the 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 fish. It is thought that gill slits were a characteristic that all these animals once shared with a common ancestor.

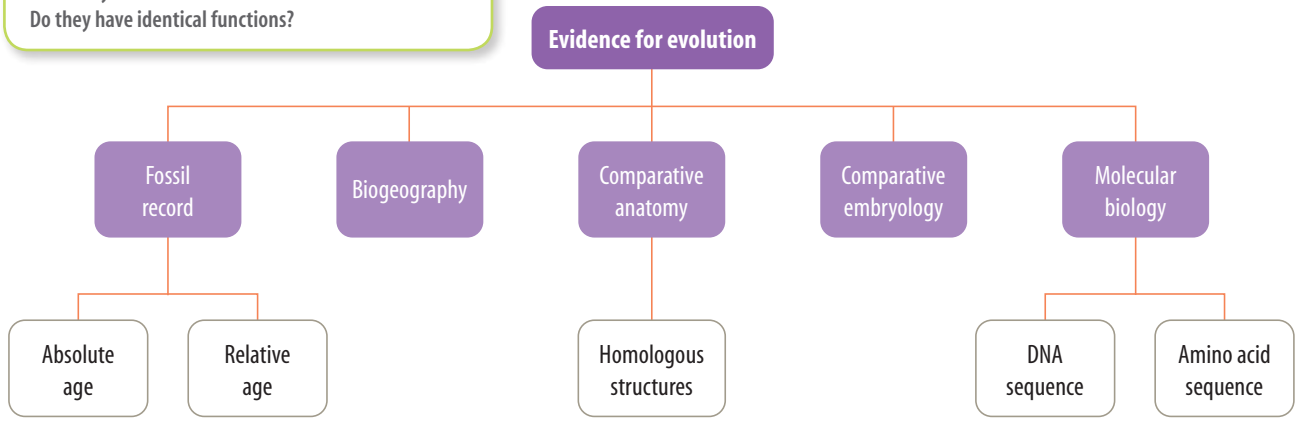


Gill slits are visible in sharks, but in bony fish they are concealed beneath a scaly panel known as an operculum.

eBookplus eLesson

Ancient DNA
Watch a video from the ABC's *Catalyst* program about the DNA of ancient and not so ancient humans.

eles-1069



Molecular biology

How amazing is it that all living things share the same overall genetic coding system or language? Although the sequences may vary, the possible letters or nucleotides and the rules of reading them are basically the same. This is one of the reasons that we can cut DNA out of one organism and paste it into another so that it will make a protein that it did not previously have the genetic instructions for.

We can use this concept of a universal genetic code to determine the evolutionary relationships between species. The similarities and differences between their DNA sequences, amino acid sequences and proteins can be used to determine how closely they are related to each other and to estimate the period since they shared a common ancestor.

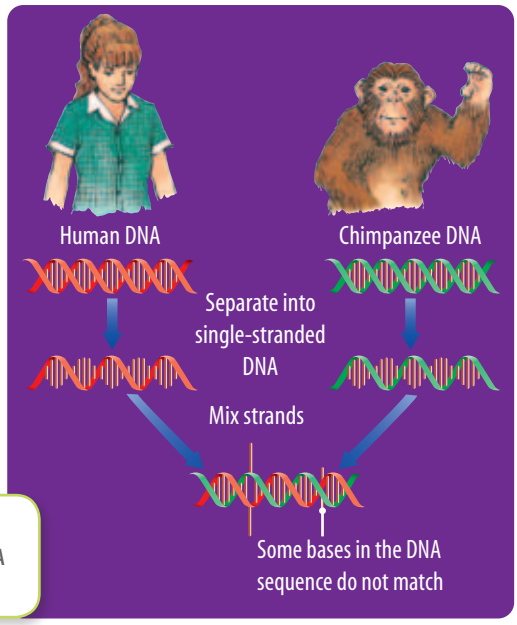
LINKING PROTEINS, AMINO ACIDS, DNA AND EVOLUTION

Proteins are universally important chemicals that are essential to the survival of organisms. In chapter 2 of this book we looked at the coding and synthesis of proteins (see section 2.2).

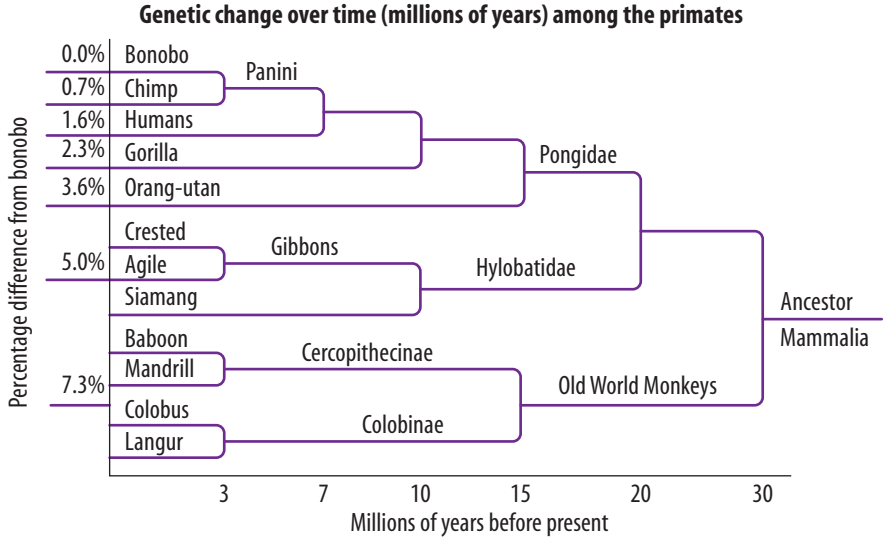
The genetic message to make proteins is stored in DNA. A section of the DNA (gene) is transcribed into messenger RNA (mRNA), which is then translated into proteins. Each of the DNA triplets and mRNA codons code for a specific amino acid, and the sequence of the nucleic acids determines the sequence of the amino acids that will make up a specific protein.

DNA SEQUENCES

DNA hybridisation is a technique that can be used to compare DNA sequences in different species to determine how closely related they are. The tree diagram below shows the evolutionary relationships within a group of primates. Which primate is most closely related to humans and which is least closely related?



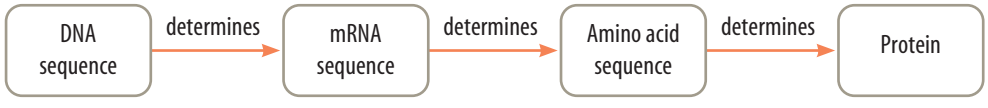
DNA hybridisation. The more closely related organisms are, the more similar are their DNA sequences.

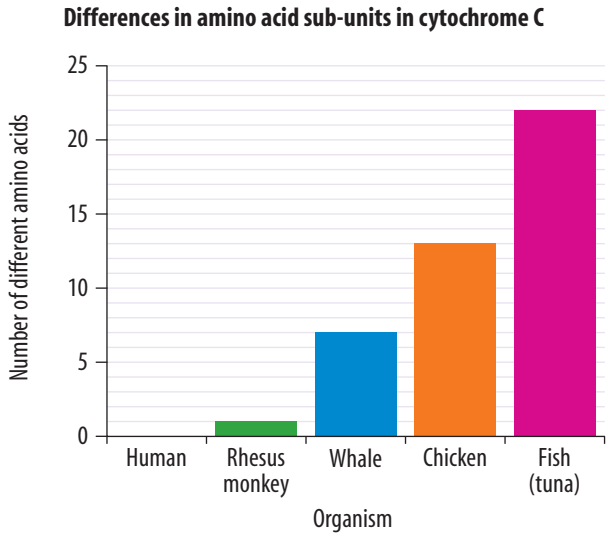


Tree showing inferred evolutionary relationships between primates based on DNA hybridisation evidence

AMINO ACID SEQUENCES

A change in the DNA sequence may lead to a change in the type and sequence of amino acids present, which may result in a change in the protein produced. This idea is used in comparing the amino acid sequences of specific proteins in organisms. The graph on the next page provides an example of the number of differences in the amino acid sequence of a protein called cytochrome C. This protein is found in many species, but different species have slightly or significantly different versions of the protein.



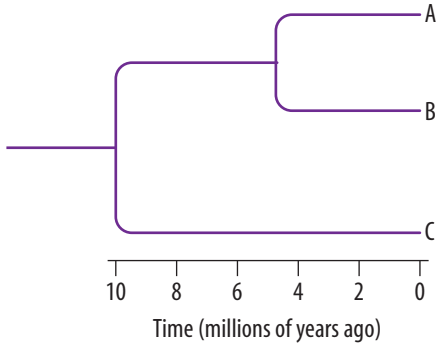


Cytochrome C is an important protein involved in the conversion of energy into a form that the cell can use. Although a part of the cytochrome molecule maintains a specific shape, over time other parts of the molecule have mutated.

THE MOLECULAR CLOCK

In 1966, biochemists Vincent M. Sarich and Allan Wilson noticed that changes in the amino acid sequences of particular proteins in related species appeared to occur at a steady rate. They found more amino acid sequence differences the longer that the two species had existed separately. From these observations the concept of the molecular clock arose. This concept used differences in two species' amino acid sequences to estimate the time since the species had diverged. Based on the analysis of immunological evidence, Sarich and Wilson concluded that humans and African apes shared a common ancestor a lot later (no more than five million years ago) than was suggested by palaeontologists (15–25 million years ago).

Vincent M. Sarich, a professor of anthropology, contributed to the development of the molecular clock. He was awarded the Kistler Prize in 2004 for his research on human evolution.



This figure illustrates the molecular clock concept. It suggests that, on the basis of amino acid sequence differences, species A and B are more closely related than A and C or B and C. It also suggests that species A and B diverged from a common ancestor just over 4 million years ago and that species A, B and C shared a common ancestor about 10 million years ago.

UNDERSTANDING AND INQUIRING

REMEMBER

1 List five types of evidence that support Darwin's theory of evolution.

2 Define the following terms.
(a) Homology
(b) Homologous structures

3 Provide examples of homologous structures.

4 Describe how the following can be used as a source of evidence for evolution.
(a) Homologous structures
(b) Comparative embryology
(c) DNA sequences
(d) Amino acid sequences

5 What is DNA hybridisation and why is it useful?

6 Suggest a link between proteins, amino acids, DNA and evolution.

7 Suggest the purpose of the molecular clock.

INVESTIGATE AND CREATE

8 Find out the names of several species of Australia's indigenous flora and fauna and the reasons they are unique.

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 have given 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.

14 Cytochrome C is known primarily for its function in mitochondria and its involvement in ATP synthesis. Scientists are also researching its involvement in the process of programmed cell death (apoptosis) and to determine evolutionary relationships.
   (a) Find out more about the structure and functions of cytochrome C.
   (b) Construct a model of a cytochrome C protein.
   (c) Report your findings in a creative multimedia format.

15 Use the **Whale kiosk** weblink in your eBookPLUS to work through an interactivity on whale evolution. After completing the interactivity, write a brief report that outlines how DNA evidence can be used to work out evolutionary relationships between organisms.

THINK AND DISCUSS

16 Examine the table below showing the DNA sequence from part of a haemoglobin gene from four different mammalian species.
   (a) T, G, C and A represent nitrogenous bases. Suggest what they are abbreviations for.
   (b) (i) In terms of the first 11 nitrogenous bases, which mammalian species is most similar to humans?
   (ii) How is this species different from humans?
   (c) (i) In terms of the first 11 nitrogenous bases, which mammalian species is least similar to humans?
   (ii) How is this species different from humans?
   (d) On the basis of the data in the table, rank these species in terms of how long they may have shared a common ancestor with humans.
   (e) Suggest how these differences in the sequence of nitrogenous bases in DNA may have arisen.

17 Examine the data in the table below and then answer the questions that follow.
   (a) Reorder the information so that the species are arranged from the most to the least related to humans.
   (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.

DNA differences among closely related species

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

DNA sequence from part of a haemoglobin gene from four mammalian species.

Species	DNA sequence
Human	TGACAAGAACA - GTTAGAG - TGTCCGAGGACCAACAGATGGGTACCTGGGTCCCAAGAAACTG
Orang-utan	TCACGAGAACA - GTTAGAG - TGTCCGAGGACCAACAGATGGGTACCTGGGTCTCCAAGAAACTG
Rhesus monkey	TGACGAGAACA A GTTAGAG - TGTCCGAGGACCAACAGATGGGTACCTGGGTCTCCAAGAAACTG
Rabbit	TGGTGATAACA A GACAGAG A TATCCGAGGACCAGCAGATAGGAACCTGGGTCTCTAAGAAGCTA

Differences between the human DNA sequence and those of other species are shown by coloured letters. The dash (-) is used to keep the sequences aligned. Note that there are two differences between the human and the sequences of some other primates (orang-utan and monkey), but there are more between the human and the rabbit DNA sequences. Why?

3.9 SCIENCE UNDERSTANDING

Origin of whose species?

A modern reconstruction of a Neanderthal. The excerpt below from the famous book *Clan of the Cave Bear* refers to the Clan, who are Neanderthals, and Ayla, a Cro-Magnon or early modern human.

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.

Source: The Clan of the Cave Bear by Jean M. Auel

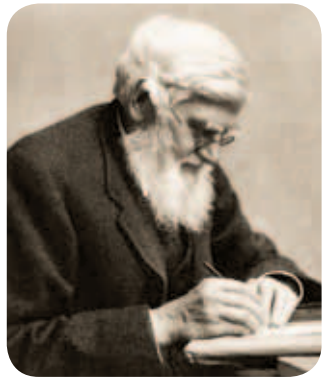
There are many alternative cultural and religious views as to the origin of life and where humans fit into it. The current scientific view is based on Darwin's and Wallace's theory of evolution of species by natural selection. This theory changed the way many viewed the origin of life and its diversity on our planet.

Where do humans fit in?

Until recently, in western cultures, life on Earth was considered as unchanging and due to the unrelated products of special creation. It is no surprise that the theory of evolution caused such outrage.

In 1858, Alfred Wallace sent a letter to Charles Darwin that summarised his own independently constructed theory of evolution. This finally prompted Darwin to publish his own controversial theory of evolution in *The Origin of the Species* later that year. This publication was to result in the beginning of many heated debates about where humans fit into the pattern of life on Earth. The development of this theory and its impact is further explored in section 1.5 of this book.

Charles Darwin (1809–1882) aged 40 in 1849

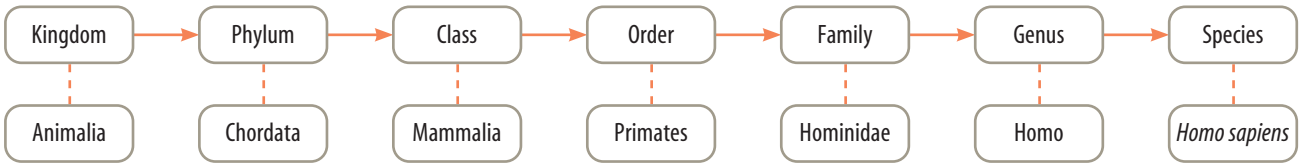


Alfred Russel Wallace (1823–1913)

Darwin published *The Descent of Man* in 1871. In this book, he suggested that humans and other species on Earth were related. At the time, this idea was met with outrage and disbelief. Just over a hundred years later, we have biochemical evidence to support Darwin. DNA sequencing has shown that the DNA between humans and chimpanzees differs by only about 1 per cent! There are also shared patterns of relatedness with other primates and organisms from other levels of classification.

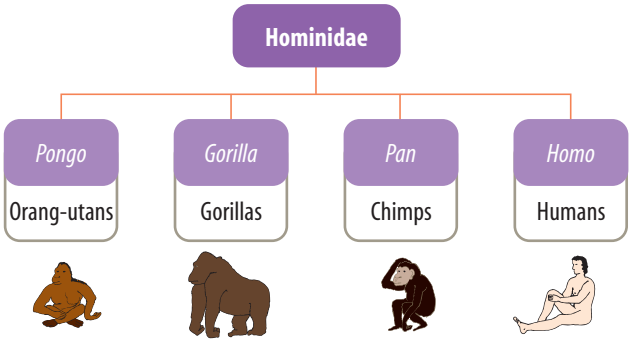
Humans are primates

Humans, orang-utans, gorillas and chimpanzees all belong to the primate order of classification. Primates are placental mammals, and many of their features relate to their ancestors having an arboreal (tree-dwelling) lifestyle. Primate hands (and sometimes feet) are able to grasp and manipulate objects using their five digits; they have a prehensile thumb or toe, and nails instead of claws. Most primates also rely more on sight than smell. This is why their faces are flatter than many other types of mammals; their forward-facing eyes enable stereoscopic vision. Unlike many other groups of mammals, they have colour vision so they are able to detect when particular foods may be ready to eat, and their teeth allow for a varied diet.

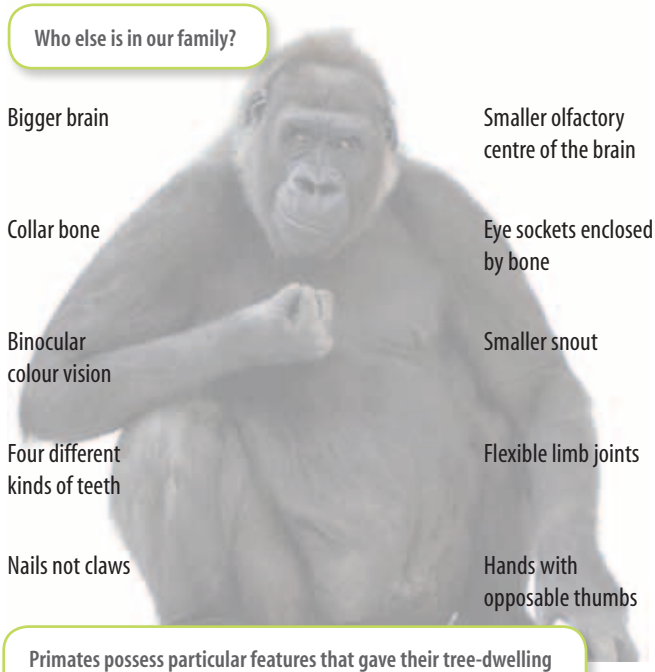


Where humans fit into the classification system

Humans did not evolve from apes or monkeys. Evidence suggests, however, that we do share a common ancestor.



Who else is in our family?



Primates possess particular features that gave their tree-dwelling ancestors a selective advantage.

THE MISSING LINK?

Once Darwin's theory of evolution became more widely accepted, one of the next questions was where the missing link is between humans and apes. Research and discoveries suggest that, rather than one missing link, there are many different ancestral species in our history. The diagrams at right provide examples of some important fossil finds. While these have assisted in helping us to discover parts of the jigsaw that make up our evolutionary history, there is considerable debate about how these pieces fit together.

Australopithecus afarensis
Dated: 7–3 mya
Located: Africa
Known for being: First group classified as hominid and believed to be a common ancestor of both humans and living apes.
Alias: 'Lucy'

Homo habilis
Dated: 2.2–1.6 mya
Located: South and East Africa
Known for being: First member of genus *Homo*

Homo ergaster
Dated: 1.8–1.2 mya
Located: Africa
Known for: Migrating out of Africa to Asia at least 1.8 mya. Could be a different population of *Homo erectus*?

Homo erectus
Dated: 1 800 000–20 000 years ago
Located: Africa, Asia (& Europe?)
Known for: Walking upright
Alias: 'Upright man', Java Man (Indonesia), Peking Man (China)

Homo neanderthalensis
Dated: 230 000–29 000 years ago
Located: Europe and western Asia
Known for: Being well adapted to very cold climates and used spears and sharp tools — and possibly basic words.
Alias: Neanderthal man

Early *Homo sapiens*
Dated: 100 000 years ago
Located: ?
Known for: Possibly being our direct descendant and producing complex tools, jewellery and paintings on cave walls.
Alias: Cro-Magnon man

The variety of interpretations of fossilised skulls and other fossilised parts has led to the development of different theories and timelines to describe the evolutionary relationships between humans and our erect walking ancestors.

A Scottish doctor, Robert Broom (1866–1951), made important fossil discoveries. One of these was of a famous *Australopithecus africanus* fossil known as Mrs Ples.

HOW ABOUT THAT!

Scientists are investigating genetic patterns in mitochondrial DNA (mtDNA) in various populations. There is a controversial theory that suggests that Earth's current human population evolved from one female (Mitochondrial or African Eve) who lived in Africa 200 000 years ago.

Ancient DNA is telling us new stories about Neanderthals and also about how closely we may be related to them. In 2007, DNA studies suggested that some Neanderthals had red hair and pale skin with similar pigmentation to some modern-day humans. In 2010, another DNA study suggested that most humans have at least 1–4 per cent Neanderthal DNA within their genome. This suggests that *Homo sapiens* interbred with Neanderthals. Some studies estimate that Neanderthal DNA is 99.7 per cent identical to modern human DNA, compared to 98.8 per cent similarity between humans and chimpanzees. What will the next fossils discovered and new technologies dig up?

Use the **Human evolution** weblink in your eBookPLUS to watch videos, try interactivities and use a timeline to learn more about human evolution.

eBook*plus*

UNDERSTANDING AND INQUIRING

REMEMBER

1 Suggest why the theory of evolution caused such outrage.

2 Suggest what prompted Charles Darwin to finally publish his theory of evolution.

3 State the following classifications for humans.
(a) Class
(b) Order
(c) Family
(d) Genus
(e) Species

4 (a) Describe features that are common to all primates.
(b) Suggest why primates share these features.

5 List three other members of the Hominidae family.

6 Did humans evolve from apes? Justify your response.

INVESTIGATE, THINK AND CREATE

7 (a) Select one of the skulls described in this section and research its owner.
(b) Construct a skull model out of plasticine, dough, clay or another suitable material.
(c) Create a story about a week in the owner's life.

INVESTIGATE AND DISCUSS

8 Find out more about Neanderthals and the research that is linking them even closer to our species. Compare these findings with previous theories about where they fitted into our family tree.

9 Find out more about the debates regarding interpretation of fossils to develop an evolutionary tree for *Homo sapiens*. What's the problem?

10 A very important characteristic that palaeontologists look for in fossils is whether the individual was bipedal (capable of walking on two legs). Find out more about features that they look for in a fossil to determine whether this is the case.

ANALYSE, THINK AND DISCUSS

11 Examine the skulls illustrated below of a chimpanzee, *Australopithecus africanus* and *Homo sapiens*.
(a) Describe how they are similar.
(b) Describe how they are different.
(c) Suggest reasons for the differences.

(a) Chimp (b) *Australopithecus africanus* (c) Human

See you later, alligator

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)

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?

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 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.

HOW ABOUT THAT!

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, Leadbeater's possum, helmeted honeyeater and orange-bellied parrot have all been saved from extinction in this manner, and large breeding populations are now established in the wild.

Why are species disappearing?

Over the last 100 years, the number of extinctions has dramatically increased. Some of the reasons for this 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 and 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.

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 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.

The Leadbeater's possum is an endangered animal.

Deforestation destroys the habitat of many species.

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, the number of Chinese giant pandas is 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.
- 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 was a bird with a large, hooked beak and a plume of white feathers on its rear. It was first sighted on Mauritius, an island in the Indian Ocean, in 1598. In 1681, only 83 years later, all dodos were extinct!

Although the dodo could not fly, it was 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's loss of the ability to fly? How could this be advantageous to its survival? Scientists believe that, with no natural predators, the dodo did not need to fly and so evolved into a flightless bird.

The dodo's nests were on the ground since it was flightless. This and a lack of natural predators made the dodo easy prey for the Dutch sailors who discovered them, and subsequent Portuguese invaders would club the birds to death for sport or food. However, one of the main causes of 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.

Dodos 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 the head, neck and front portion of their body. The unusual stripes, like those on zebras, may have rendered the animal less visible and given some protection against predators. Can you suggest a reason for the variation of stripes in the quagga compared to other types of zebra?

Will quaggas make a reappearance?

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 a quagga mare at 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 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.

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 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?

UNDERSTANDING AND INQUIRING

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 and how is it thought to have become extinct?
7 Why did the dodo build its nests on the ground and lose its ability to fly?
8 Draw a timeline to show the history of 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, 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 (the approximate year of extinction is given in brackets) and describe the animal, its lifestyle and the theory of the cause of its extinction: flightless ibis (1000), giant lemur (500), giant moa (1500), aurochs (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.

3.11 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.

how to ...?

Helps you to use both your imagination and organisational skills to capture and share thoughts and ideas

why use?

What are the main scenes in a story or event?

question

Storyboard

A Outline of scene 1	B Outline of scene 2	C Outline of scene 3
D Outline of scene 4	E Outline of scene 5	F Outline of scene 6

also called

Comic strip

comparison

Similarity

Both show the sequence of events.

Difference

Storyboards use sketches or diagrams while Gantt charts use tables.

Gantt chart

example

Action	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1							
2							
3							
4							
5							
6							
7							
8							

UNDERSTANDING AND INQUIRING

THINK AND DISCUSS

1 Read through the boxed text *A tangled family tree* and 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 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 its lineage.
   (b) Use a Gantt chart to summarise your findings.
   (c) Create a storyboard for a possible day in the life of *Homo floresiensis*.

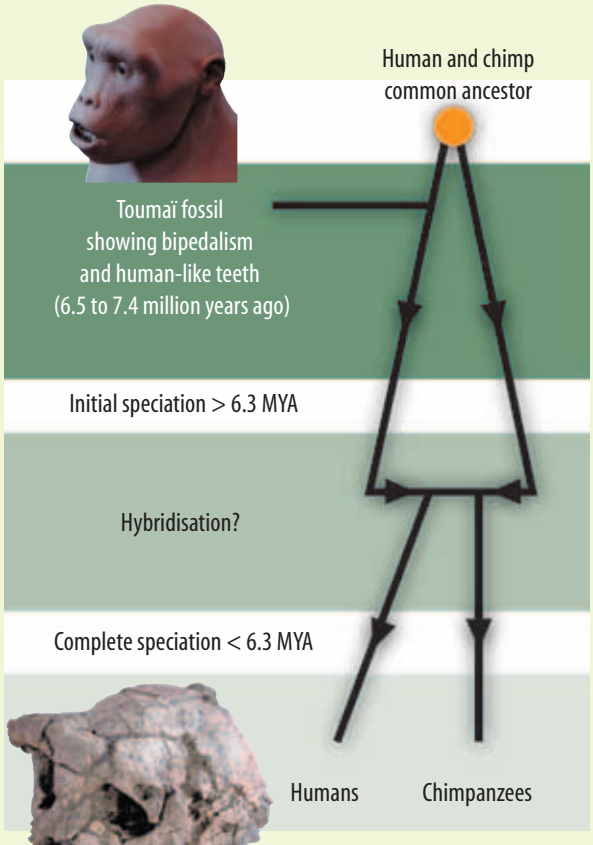
6 Find out more about one of the following topics and report your findings using a thinking tool of your choice.

- 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

A TANGLED FAMILY TREE

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 effect may these findings have on our current interpretations of fossils and theories of human evolution?



The Toumaï fossil (*Sahelanthropus tchadensis*) is thought by some to be the earliest fossil from the human family tree.

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

STUDY CHECKLIST

BIODIVERSITY

- outline some sources or causes of genetic diversity
- suggest the relationship of biodiversity to evolution
- describe the potential impact of reproductive technologies and genetic engineering on genetic diversity
- describe a possible consequence of artificial selection to biodiversity

THE HISTORY OF LIFE ON EARTH

- extract information from diagrams and tables relating to the history of life on Earth
- construct a timeline for the history of life on Earth
- sequence the major events in the evolution of life on Earth

FOSSILS

- define the term 'fossil'
- outline conditions necessary for fossilisation
- distinguish between the following types of fossils: moulds, casts, imprints and petrified fossils
- distinguish between relative and absolute dating of fossils

THE THEORY OF EVOLUTION BY NATURAL SELECTION

- define the following terms: evolution, selection pressure, natural selection
- suggest how genetic characteristics may have an impact on survival and reproduction
- describe the process of natural selection using examples
- explain the important of variations in the process of evolution

EVIDENCE SUPPORTING THE THEORY OF EVOLUTION

- describe how the fossil record provides evidence for evolution
- outline how comparative anatomy has been used to support the theory of evolution and to determine evolutionary relationships between species
- describe examples of molecular biology techniques and how they are used to work out evolutionary relationships
- outline conditions necessary for fossilisation
- distinguish between the following types of fossils: moulds, casts, imprints and petrified fossils
- distinguish between relative and absolute dating of fossils
- evaluate and interpret a variety of different types of evidence used to support the theory of evolution

ICT

eBookplus Summary

eLESSONS

How a new species evolves

Learn how a combination of environmental and genetic factors allows new species to form over time through the process of evolution.

Searchlight ID: eles-0162

Ancient DNA

Watch a video from the ABC's *Catalyst* program about the DNA of ancient and not so ancient humans.

Searchlight ID: eles-1069

INTERACTIVITY

Revelation: 'Fossils'

Test your knowledge of all things old by playing this Revelation game. Success rewards you with a video interview with a palaeontologist where you can see some real fossils.

Searchlight ID: int-1018

INDIVIDUAL PATHWAYS

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Activity 3.1	Activity 3.2	Activity 3.3
Evolution	Investigating evolution	Investigating evolution further

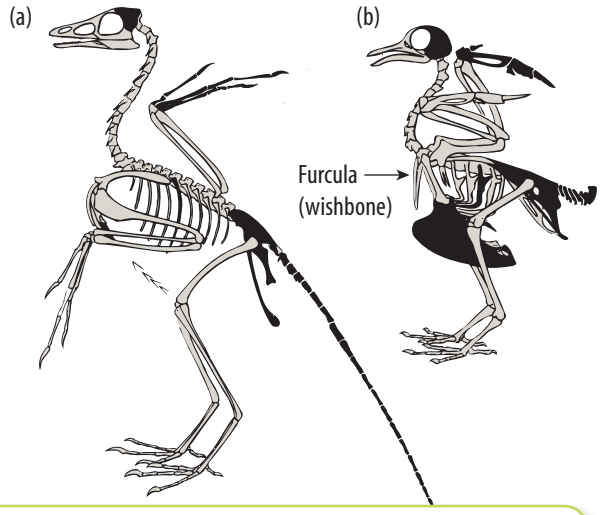
LOOKING BACK

1 Identify the term from the following list that matches the meaning below.

Variation Competition Adaptation
Biodiversity Biogeography
DNA hybridisation Radiometric dating Fossil
Analogous structures Comparative anatomy
Natural selection Artificial selection
Convergent evolution Clone Protein

(a) The process by which the individuals with the most advantageous variation survive and reproduce more successfully than others
(b) A special characteristic that improves an organism's chance of surviving in an environment
(c) The range of different structural and behavioural differences in a species
(d) Evidence of past life
(e) Structures that may look similar due to similar selection pressures rather than shared ancestry
(f) A technique used to compare the similarity of DNA
(g) The struggle for resources between members of the same species
(h) The geographical distribution of species
(i) Comparing the structure of organisms
(j) A process by which unrelated organisms living in similar environments develop similar features
(k) A technique that uses measurements of isotopes to determine the age of rocks and fossils
(l) Variation among organisms at the ecosystem, species and gene level
(m) The process in which organisms with particular features are selected and bred together
(n) A genetically identical organism
(o) Made up of amino acids

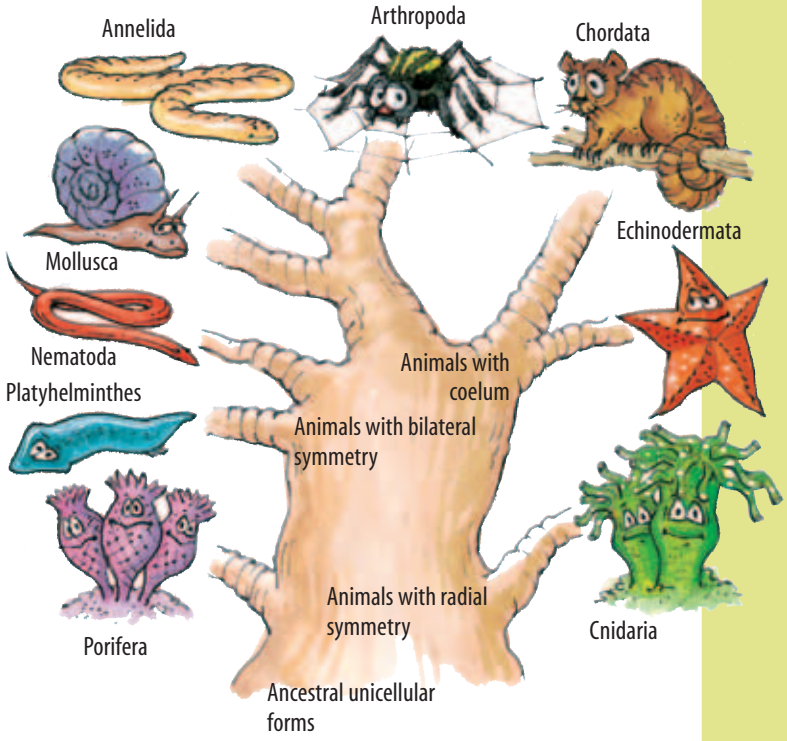
2 Examine the figures of the Archaeopteryx and a modern flying bird.



Skeleton of (a) *Archaeopteryx* and (b) a modern flying bird. The black regions on the skeletons show distinctive reptilian features (at left) and bird features (at right).

(a) How are they similar?
(b) How are they different?
(c) Suggest reasons for the similarities and differences.

3 Refer to the animal kingdom evolutionary tree below to answer the following questions.
(a) Which animal group (or phylum) is most closely related to the Chordata?
(b) Which is more closely related to the Mollusca phylum, the Arthropoda or Nematoda?
(c) Which animals have radial symmetry?
(d) Do you think that Platyhelminthes would have more or less in common with Annelida than with Cnidaria? Explain.
(e) Suggest the significance of adaptations of organisms in relation to their survival.



The animal kingdom evolutionary tree based on genetic and structural information

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

5 Identify the following.
(a) The scientific name for humans
(b) The abbreviation for deoxyribonucleic acid
(c) The southern supercontinent
(d) My name is included in a system of nomenclature.
(e) Around 30 of these make up the surface of the Earth.
(f) A permanent change in DNA
(g) The type of dating that assumes that lower layers of rock are older than the ones above
(h) The rank between phylum and order
(i) Members of the same species living together in the same place at the same time

6 Examine the figure below and identify the epoch in which:
(a) Aborigines arrived in Australia
(b) the first marsupials appeared in Australia
(c) swimming and flying mammals appeared
(d) the dinosaurs became extinct.

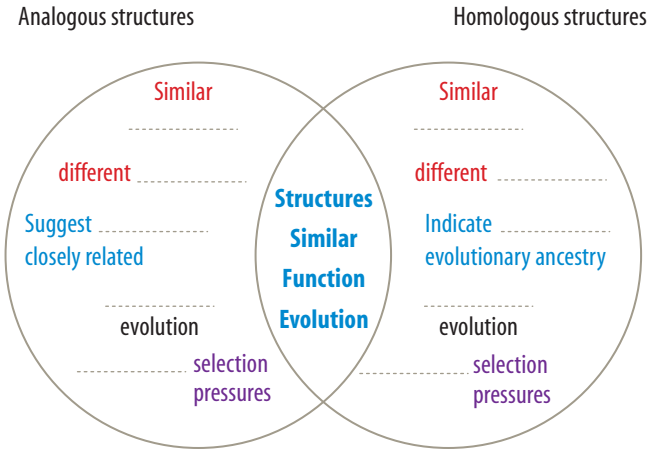
Some marsupial fossil finds and events	Epoch (millions of years ago)		Major mammal events
Present	HOLOCENE 0.01–present	Quaternary period	Humans investigate Earth's history.
Most of the large Pleistocene marsupials became extinct about 15 000–30 000 years ago.	PLEISTOCENE 1.64–0.01 mya		Aborigines arrived in Australia about 55 000 years ago.
Many giant browsing marsupials became extinct; there were grazing kangaroos and lots of diprotodons.	PLIOCENE 5.2–1.64 mya	Tertiary period	*Homo habilis*, the earliest known human, appeared in East Africa.
Primitive marsupial 'mice' and 'tapirs' were found at Lake Eyre, South Australia, and diprotodons at Bullock Creek, Northern Territory.	MIOCENE 23.5–5.2 mya		Lots of marsupial mammals were living in Australia and South America.
First Australian marsupials occurred about 23 million years ago. Diprotodons and a relative of pygmy possum fossils were found in Tasmania.	OLIGOCENE 35.5–23.5 mya		First marsupials appeared in Australia. First primates appeared.
Lots of marsupial fossils of this age were found in South and North America.	EOCENE 56.5–35.5 mya		Swimming and flying mammals appeared.
Dinosaurs became extinct about 65 million years ago.	PALAEOCENE 65–56.5 mya		More mammals appeared after dinosaurs became extinct.

Cenozoic era

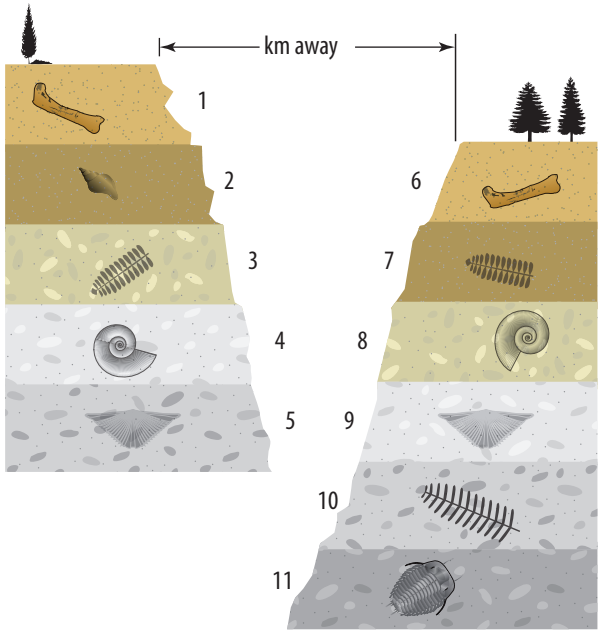
A timeline of some marsupial fossil finds and major mammal events

7 Copy and complete the Venn diagram at right using the terms below.

function Similar structure NOT common Different Divergent Convergent structure function



8 Examine the diagram below and deduce the answers to the following questions.
(a) Write down the names of the fossils in order from youngest to oldest.
(b) Which layer is the same age as layer 3, layer 4 and layer 5 respectively? How can you tell?
(c) Out of all the fossil layers numbered 1–11, which layer is oldest?



9 A 2006 study showed that, because Australia had banned the use in livestock of one particular group of new antibiotics (the fluoroquinolones), the level of resistance to the human antibiotic cyprofloxacin was only 2 per cent. In countries where these antibiotics are used, the resistance level is around 15 per cent. Explain these findings.

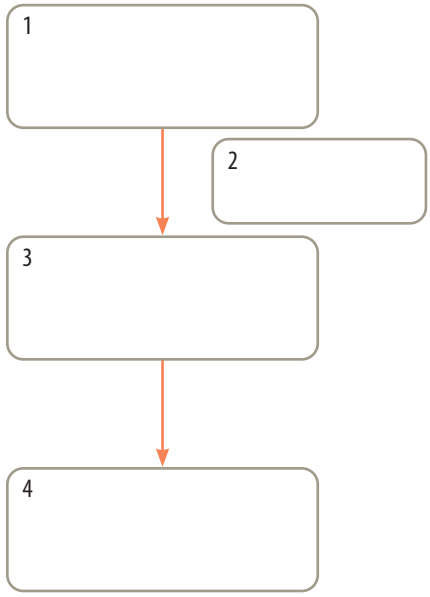
10 It is 100 000 years ago, and you are a Cro-Magnon individual whose tribe has captured some wild dogs and are interested in breeding them. Write a story describing which dogs you choose to breed from and why. How do the pups turn out — is there much variation? How do you decide which dogs to keep? Does everyone agree?

11 Biologists make inferences about evolutionary relationships based on comparative anatomy. Molecular biology techniques such as DNA hybridisation and protein sequences may support or contradict these inferences. Explain how molecular biology techniques can be used to work out evolutionary relationships.

12 When Darwin visited the Galapagos Islands he found that longer-beaked species of finches were found in areas were insects were plentiful and shorter-beaked species were found where seeds were the main food source. Account for this observation using the theory of evolution by natural selection.

13 Sequence the following into the correct evolutionary order.
- Flowering plants evolve
- Early dinosaurs evolve
- Mammals, flowering plants, insects, fish and birds dominate
- Bacteria evolve
- All living things are in the ocean; massive increase in multicellular organisms
- Most dinosaurs become extinct
- Greatest mass extinction of all time
- Dinosaurs dominate the planet

14 Insert the following labels in the diagram below to produce a model of how natural selection brings about genetic change in a population.
- Selective agent acts
- Next generation contains more of the favourable characteristic
- Individuals best suited to the environment (fittest) survive and reproduce more successfully
- Population contains genetically different individuals



15 Find out about difficulties that one of the following scientists had in being able to express their scientific opinions because of society during their lifetime.
(a) Gregor Mendel
(b) Jean Baptiste de Lamarck
(c) Charles Darwin

16 Are humans still evolving? Organise a class debate to discuss this issue.

work sheets
3.6 Evolution: Puzzles
3.7 Evolution: Summary

projectsplus

Natural Selection — the board game!

SEARCHLIGHT ID: PRO-0112

Scenario

There are few people in Australia today who haven't played a board game such as *Monopoly*, *Scrabble* or *Civilisation* sometime in their life. Even today, when computer games such as *Halo* or online games such as *World of Warcraft* are regularly played by tens of thousands of Australians, sales of old-school board games such as *Snakes and Ladders*, *Kingmaker* and, yes, *Monopoly* are still a healthy component of the income for a toy and game store. Apart from the fact that they are a great choice when there's no electricity and they can be played and enjoyed by people from completely different generations, psychologists suggest that their continued popularity can also be attributed to the fact that there is just as much luck as skill that determines the winner. In this way, board games are much like real life!

The effectiveness of using game play as a way of teaching concepts is the stock in trade of the educational game company BrainGames, who produce computer games that teach science, maths, history and geography concepts. Games such as *The Revenge of Pavlov's Dogs* and *Where in the World is Amerigo Vespucci?* have made them the leader in the educational games market. However, keen to exploit the non-computer-equipped market sector, BrainGames now want to branch out into board games and the first board game they want to produce will be based on one of the key ideas of biology.

Your task

As part of the Games Development Division at BrainGames, you and your team are to develop a prototype board game based on the idea of natural selection and evolution. In this game, players will be able to select a variety of characteristics to give an organism and then, over the course of the game, see whether these organisms survive intact as their environment is changed. Your prototype must include:

- a game board
- game pieces
- a rule book.

You may also choose to include game mechanics such as cards, spinners or dice.

Process

- Open the ProjectsPLUS application for this chapter located in your eBookPLUS. Watch the introductory video lesson and then click the 'Start Project' button to set up your project group. You can complete this project individually or invite other members of your class to form a group. Save your settings and the project will be launched.
- Navigate to your Research Forum. Here you will find headings for suggested research topics that may help you with your design. If you wish, you may add other topics to research.
- Go to your Media Centre; here you will find links to websites about aspects of game design and what characteristics make a good board game.
- Start your research. Make notes of information you discover that will assist you in your design. Enter your findings as articles under your topic headings in the Research Forum. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about how natural selection works to influence the survival and adaptation of organisms in a particular environment over time. You may also include notes and ideas for

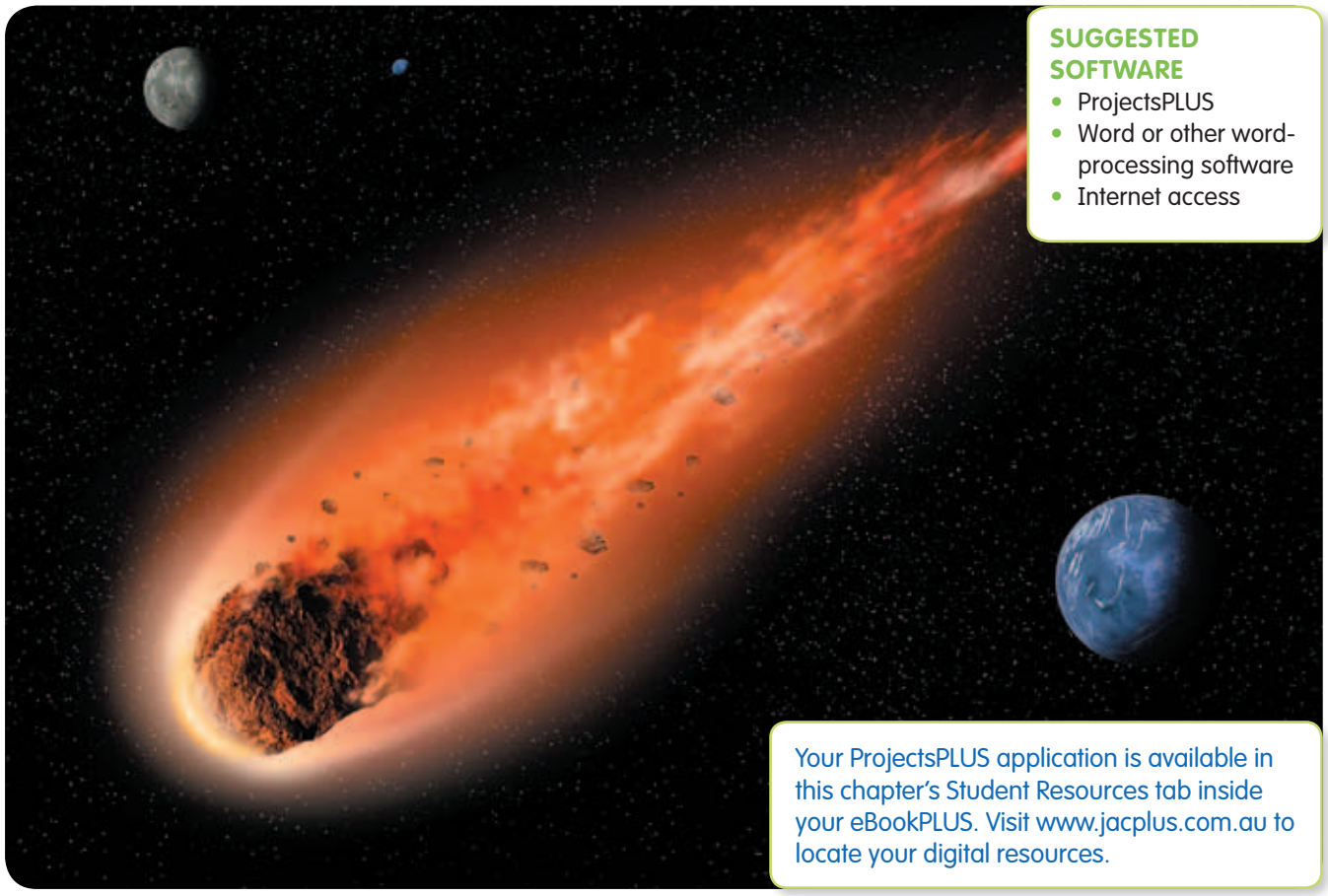
different aspects of your game. You can view and comment on other group members' articles and rate the information that they have entered. When your research is complete, print out your Research Report to hand in to your teacher.

- Use your research to come up with a board game design.
- Visit your Media Centre and download the sample rule book. Using this as a model, create the rule book for your board game. It should cover the contents of the game box, how to set the game up to start, how each player's turn is completed, what players have to do to win and so on. Keep in mind that the rules should be clearly written and easily understood by the players.
- Build a simplified version of your game and test its playability. Add or remove aspects of the game until you are happy with the way it works. Only then should you work on your final prototype. In your Media Centre, you will find a collection of images that you may find useful when assembling and making your final game components.

MEDIA CENTRE

Your Media Centre contains:

- a sample rule book
- a selection of useful weblinks
- a selection of images
- an assessment rubric.



SUGGESTED SOFTWARE

- ProjectsPLUS
- Word or other word-processing software
- Internet access

Your ProjectsPLUS application is available in this chapter's Student Resources tab inside your eBookPLUS. Visit www.jacplus.com.au to locate your digital resources.