TOPIC 3
Evolution

3.1 Overview

3.1.1 Why learn this?
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?

3.1.2 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?

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3.1.3 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 LUCA** 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) As 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.

3.1.4 Five minutes to midnight

If we compressed 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.
3.2. Classification

3.2.1 Classification can change
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.

3.2.2 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 for categorising organisms into groups. Classification systems help us to see patterns and order, so we can make sense and meaning of the natural world in which we live.

3.2.3 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

INVESTIGATION 3.1
The common ancestor
• Carefully observe the features of the possums in the figure.
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.

- Multicellular organism
- Systems
- Organs
- Tissues
- DNA
- Nucleus
- Cells
- Kingdom
- Phylum
- Class
- Order
- Species
- Genus
- Family
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*.

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 a genus name as the first word and a 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*.

### WHAT DOES IT MEAN?
The word *binomial* comes from the Latin terms *bi-*, meaning ‘two’, and *nomen*, meaning ‘name’.

3.2.4 **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.

### 3.2 Exercises: Understanding and inquiring

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

**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.
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.
3.3. Biodiversity

3.3.1 I am a dog!
Look at the dogs in the photograph at right. What differences can you see? How did this variation come about when all the individuals belong to the same species?

3.3.2 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.

3.3.3 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 a change in the protein that is coded for and produced by that segment of DNA. This can change the organism’s characteristics. In the diagram at the right, for example, a change in DNA has led to the production of a protein that changes 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.

3.3.4 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. The combination of gametes that fuse together during fertilisation provides another source of variation, as does the selection of a particular mate.

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?
3.3.5 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 var-
iation 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 — 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 off-
spring 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 envi-
ronment. Some individuals may have genes (or
alleles) that assist in their survival. They may
then pass these favourable genes on to their off-
spring. On the other hand, if a large number of
frogs emigrated or were removed from a par-
ticular 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) may result in the addi-
tion 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.

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 migrated to Australia, they 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.

3.3.6 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 that species may become extinct. Over the last
100 years, the natural habitats of many species have been changed so significantly that they have not pos-
sessed the genetic variation to be able to adapt to the new conditions. Many species have therefore died out.
3.3.7 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 animals will mate together based on their possession of particular features, to increase the chances that their offspring will have features that suit our needs. This type of selective breeding is called artificial selection.

Because fewer individuals are selected for breeding, 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 also possess the race-winning features of its father. This leads 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.

3.3 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

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.
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.
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 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. Unscramble the following terms.
    (a) vteydioirsib
    (b) gmtimiranio
    (c) egsatem
    (d) seosimi
15. Suggest what will happen if a species does not possess the genes that allow it to adapt to new environmental conditions.
16. *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 on next page.
    (b) Suggest how these differences came about.
Investigate and create
17. 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.
18. Investigate meiosis and its involvement in generating genetic variation. Construct a model that shows independent assortment and crossing over.
19. Construct a model that shows possible variations of outcome from the fertilisation of gametes.
20. 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
21. Read the article below and answer the questions that follow.
   (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.

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BACTERIA DON’T SUNBAKE!

The ozone layer helps to filter out many harmful UV rays. In Precambrian times, over 540 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.
3.4 The evolution revolution

3.4.1 The theory of evolution — bigger than one man

Do you and the apes that you see at the zoo share a common ancestor? This concept caused much controversy between religion and science.

The concept of organisms sharing common ancestors contributed to the development of the theory of evolution. Although this theory is usually credited to one man — Charles Darwin (1809–1882) — it is really a culmination of the ideas of many individuals both in Darwin’s time and before it. With technological advances and new knowledge, refinements have been made to Darwin’s theory and continue to be made. The theory of evolution itself is evolving.

3.4.2 Evolution ownership

Like many other scientific theories, although one person may be credited as its sole creator, it is really a story of awareness, relationships, passion and wonder. The development of a theory usually requires an appreciation of and connection to what has been before and the transfer of this knowledge to new discoveries. It often involves seeing links, patterns or connections that can tie all of the knowledge together into a new framework of understanding.

3.4.3 Grandpa sows his own seeds

Erasmus Darwin (1731–1802) was not only a British physician and leading intellectual of his time, but also Charles Darwin’s grandfather. He believed that all living organisms originated from a single common ancestor and in 1794 published Zoonomia — a book that sowed the seeds for later ideas regarding the theory of evolution.

3.4.4 Classifying life

Carolus Linnaeus (1708–1778) is considered the founder of taxonomy — the branch of biology concerned with naming and classifying the diverse forms of life. He developed his classification system ‘for the greater glory of God’, rather than in the interest of scientific understanding. His ideas, however, were used as a basis for the development of the theory of evolution.
3.4.5 Hints in the ground

Without the contribution of geologists, the theory of evolution may still not have been developed. Geology bestowed a great gift upon Darwin’s generation of scientific thinkers — the gift of time.

In the eighteenth century, many believed that the Earth was only around 6000 years old and that — other than changes brought about by sudden, dramatic catastrophes (like Noah’s biblical flood) — it was unchanging. This was the theory of catastrophism.

3.4.6 An underground time machine

James Hutton (1726–1797) proposed the theory of gradualism, which suggested that Earth’s geological features were due to the cumulative product of slow but continuous processes. He used money from farming and his invention of a process for manufacturing the chemical sal ammoniac to devote his life to his scientific quests. It was not until almost ten years after he presented his theories to the Royal Society of Edinburgh in 1785 that they were taken seriously enough to be vigorously attacked. Hutton’s response was to publish Theory of the Earth in 1795. Hutton’s geological theories were built upon by others who also observed evidence that contradicted the theological teachings of the time.

English surveyor William Smith (1769–1839) made great contributions to the development of geology and could be considered the ‘father of English geology’. He is credited with creating the first nationwide geological map (more information can be found in his biography, The Map That Changed the World (2002)) and was the first person to make a systematic study of fossils.

Smith was the son of a blacksmith and his life was not an easy one. He published his first geological map of Britain in 1815. Unfortunately, the map was plagiarised and he became bankrupt and then served time in debtor’s prison. He did not receive recognition for his contributions until many years later in 1831.

Smith’s work as a surveyor took him down into mines where he observed different layers of rocks (strata) and the fossils that they contained. Smith noticed a regular pattern to the distribution of types of fossils in the particular rock layers in the different locations where he worked. This pattern suggested that the Earth must be very old and that successive strata had been laid down one on top of the other. His observations also suggested that different types of organisms had appeared, lived for a while, and then been replaced by others.

Born in the same year as William Smith, Baron Georges Cuvier (1769–1832) played a key role in the development of palaeontology (the study of fossils). He is credited with recognising that fossils in deeper strata were older than those in strata closer to the surface.
Sir Charles Lyell (1797–1875) was born the year that James Hutton died. He incorporated Hutton’s gradualism into uniformitarianism theory — the antithesis of catastrophism. Lyell also played a key role in Darwin’s decision to finally publish, and formally presented Darwin’s (and Wallace’s) theory of evolution to the scientific community in 1858.

### 3.4.7 Use it or lose it!

Jean-Baptiste de Lamarck (1744–1829) was one of the first scientists to suggest that populations of organisms changed over time and that old species died out and new species arose. He believed that if a particular feature was not used then it would eventually be lost over succeeding generations. He also suggested that changes acquired within the lifetime of an individual could be passed on to its offspring. The example often given to describe this theory relates to the long necks of giraffes. Lamarck’s explanation would be that the giraffes had to reach the leaves high up in the trees, stretching their necks. He would then suggest that the lengthened necks that resulted from this stretching were passed on to their offspring.

### 3.4.8 Seeds of inheritance

Gregor Mendel (1822–1884), an Austrian monk, used peas of different colours and shapes in his experiments and is responsible for the development of the fundamentals of the genetic basis of inheritance. Although most of his work was destroyed, his gene idea was recognised 34 years after his death and provided a mechanism for natural selection.

Living around the same time as Mendel, Herbert Spencer (1820–1903) suggested the concept of survival of the fittest. Born twelve years after Mendel, August Weismann (1834–1914) demolished Lamarck’s theory of the inheritance of acquired traits, and is well known for his experiment that cut the tails off mice to collect evidence that tail loss during the parent’s lifetime was not inherited by their offspring. He later also suggested that chromosomes were the basis of heredity.

### 3.4.9 Darwin’s journey of selection

In 1831, a 22-year-old Charles Darwin set sail on a five-year voyage on the HMS Beagle. It was a journey that would greatly change his views on life. He noted the similarities and differences in the flora and fauna...
inhabiting the different regions that he visited. His observations made him question the belief at the time that the Earth was only a few thousand years old and that its organisms were the unchanging work of a creator.

Darwin was particularly puzzled by the features of animals on the Galapagos Islands near South America. On these islands, he noticed a number of different species of finches that were similar in size and colour, but varied in the size and shapes of their beaks. He recorded that these variations suited them to particular types of foods.

**Darwin's doubts doubled**

By the time Darwin had sailed from Galapagos, his observations and awareness of the ideas of the geologist Sir Charles Lyell (who had been influenced by James Hutton) led him to doubt the church’s position that the Earth was static and only a few thousand years old. He was particularly influenced by Lyell and Hutton’s views that geological change resulted from slow, continuous actions rather than sudden events.

After returning home in 1837, Darwin began his notebooks on the origin of different species and in 1844 (at 35 years of age), wrote his essay *On the Origin of Species*. Aware of the controversy that such ideas may fuel, he left this essay unpublished for over ten years.

### 3.4.10 Why do some die and some live?

While Darwin continued to develop his theory, an English naturalist reached the same conclusion. His name was Alfred Wallace (1823–1913). Wallace was a school teacher with a passion for botany and collecting plants and insects. Like Darwin, Wallace had travelled extensively and made many detailed observations of variations in the species that he came across. In 1848, he began a series of expeditions, first to the Amazon and later to the Malay Archipelago where he stayed for eight years.

In February 1858, while he was recovering from a bout of malaria, Wallace remembered reading a book titled *Essay on the Principle of Population* (1798). This book was written by the mathematician, economist and founder of demography Thomas Malthus (1766–1834), and had also influenced Darwin’s thinking. Wallace connected what he had remembered from this book to his observations. It is documented that the idea of survival of the fittest then came to him in a flash. In his autobiography, *My Life: A Record of Events and Opinions* (1905), Wallace wrote:

> If occurred to me to ask the question, why do some die and some live? And the answer was clearly that, on the whole, the best fitted lived.

Within two evenings, Wallace had written an essay on his theory of evolution and sent it to Darwin in the next mail.

### 3.4.11 Publish or perish

Imagine the shock of seeing your life’s work summarised in a letter, sent to you for comment on its possible publication. This is what must have happened when Darwin opened Wallace’s letter describing his theory of evolution. This forced Darwin to reconsider publishing his previously unpublished work on his theory. Given his wife and family’s religious connections, this must have been a difficult personal time for him and later for his family.
On the advice of Sir Charles Lyell and the eminent botanist Sir Joseph Hooker, Darwin decided to publish his work along with Wallace’s essay in a joint paper. In July of 1858, Sir Charles Lyell presented Darwin’s previously unpublished 1844 essay along with Wallace’s work to the Linnean Society of London. Later, in 1859, Darwin finally published his book *On the Origin of Species by Means of Natural Selection*. Many people were outraged by the suggestion that humans could be related to apes. There were many debates and arguments about the theory of evolution. A young anatomist, Thomas Henry Huxley (1825–1895), fought the case for evolution in many public debates. He did this so fiercely that he became known as ‘Darwin’s bulldog’. Eventually, the scientific community came to accept Darwin’s theory, some even expressing embarrassment at not having thought of such a simple explanation before.

### 3.4.12 Natural selection

Darwin’s theory was different from others in that it included a process by which evolution could occur. Although this process is often referred to as ‘survival of the fittest’, he called it **natural selection**. He believed that by this process a single species could have given rise to many new species, and that these new species were much better suited to the environment in which they lived.

Natural selection proposes the following:

1. There is variation of inherited characteristics in a species and some of these variations will increase the chances of surviving in a particular environment.
2. In the struggle to survive, those members with favourable traits will have an increased chance of survival over others.
3. Surviving members have an increased chance of reproducing and passing on their inherited traits to their offspring.
4. Over time and many generations, organisms will possess traits that are better suited to their environment and increase their chances of survival.

Some view this as the time when science broke away from religion. Would it still have occurred if Wallace had not sent his theory to Darwin? Would the theory of the less well-known Wallace have been taken seriously? Given the changing ideas and new knowledge being discovered at that time, would someone else have come up with the same idea?

### 3.4.13 Brave new world

There are two other Huxleys who have had an impact on how we see the world. Both of these are the grandsons of Thomas Henry Huxley. Sir Julian Huxley (1887–1975) was involved in the formulation of Darwinian evolution that incorporated developments in genetics and palaeontology. Aldous Huxley (1894–1963) was the author of novels that both inspired and caused fear, as well as increasing public awareness of the possible implications of science for our future humanity. The novels *Brave New World* (1932) and *Island* (1962) (and their subsequent movies) have caused many to pause, reflect and consider the potential ethical issues that new scientific discoveries and their applications may hold for our species.
The theory of evolution is a culmination of ideas from many different individuals.

![Huxley family tree](image)

3.4 Exercises: Understanding and inquiring
To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

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

3.5.1 Best suited

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.

3.5.2 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.

3.5.3 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 3.4.) According to this theory, some of these variations will provide an increased chance of survival over 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 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.

3.5.4 Selection

Organisms live within ecosystems, which are made up of various living (biotic) and non-living (abiotic) factors. These factors contribute to selecting which variations provide the individual with an increased chance of surviving. 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.

3.5.5 Competition

Individuals within a population compete with each other for resources such as food, shelter or mates. Those with a selective advantage over other individuals are better able to compete for the resource.

There may be situations in which competing is not 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 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?

3.5.6 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 with resistance against the control method, making it no longer effective.

3.5.7 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.

3.5.8 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 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 reduces the effectiveness of the control method.

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

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

INVESTIGATION 3.2
Modelling natural selection

AIM: To use a model to simulate natural selection

Materials:
100 green toothpicks (or rubber bands)
100 red toothpicks (or rubber bands)

Method and results
1. Copy and complete the table at right.
   - 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.
2. 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.
3. 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
3.5.9 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 the 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 thought that chloroplasts, like those in plant cells, evolved in a similar way.

3.5 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au.

Note: Question numbers may vary slightly.

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.

<table>
<thead>
<tr>
<th>Predation</th>
<th>Competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation in phenotypes</td>
<td>Selection pressures</td>
</tr>
<tr>
<td>Climatic factors</td>
<td>Population</td>
</tr>
<tr>
<td>Less favourable</td>
<td>Most favourable</td>
</tr>
<tr>
<td>Disease</td>
<td>Lower chance</td>
</tr>
<tr>
<td>Over many generations</td>
<td>Higher chance</td>
</tr>
<tr>
<td>Survival</td>
<td>Phenotype</td>
</tr>
<tr>
<td>Genetic contribution to next generation</td>
<td>Decreased numbers</td>
</tr>
<tr>
<td>Individuals</td>
<td>Increased numbers</td>
</tr>
</tbody>
</table>
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 penicillin and its history and use.
   (b) Suggest reasons why some bacteria are now resistant to 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 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 it 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.
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 Resources section to see a cartoon about how a cricket manages to mate.

Which moth is more easily seen?

learnON RESOURCES — ONLINE ONLY
- Explore more with this weblink: Sneakermales
- Complete this digital doc: Worksheet 3.1: Struggling to survive
  Searchlight ID: doc-19421
- Complete this digital doc: Worksheet 3.2: Isolation and new species
  Searchlight ID: doc-19422
3.6 Evolution

3.6.1 The formation of new species

Variation, struggle for survival, selective advantage and inheritance of advantageous variations formed the basis for Charles Darwin’s theory of evolution by natural selection. They 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.

3.6.2 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 a barrier (such as a geographical barrier, for example a mountain or...
ocean) 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 results 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 offspring. It is at this point that they are referred to as different species. Speciation has occurred.

3.6.3 Adaptive radiation

Adaptive radiation is said to have occurred when divergent evolution of one species results 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 show examples of species that have arisen from a common ancestor.

3.6.4 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.
3.6.5 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 from a flower with a particular shape. The plants have evolved flowers of a particular colour that may be attractive to its pollinator, and nectar that not only attracts but rewards the bird for its task of being involved in pollination.

3.6.6 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 3.12.

3.6 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

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 divergent evolution and 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 on next page show two species of North American hares that are closely related and share a common ancestor. The snowshoe hare, Lepus americanus (left), lives in northern parts of North America where it snows in winter. The black-tailed jack rabbit, Lepus californicus (right), lives in 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.

<table>
<thead>
<tr>
<th>Niche</th>
<th>Placental mammal</th>
<th>Australian marsupial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glider</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. (a) Carefully examine each of the pairs of organisms shown at right. 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.

Investigate, think and create

14. The figure below 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 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.
3.7 Long, long ago

3.7.1 Geographical jigsaw

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 it is today.

3.7.2 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.
3.7.3 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.

3.7.4 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.
3.7.5 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.

3.7.6 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.

3.7.7 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.
The fossil record provides an incomplete picture of life as it has existed on Earth.

### INVESTIGATION 3.3

**4.6 billion years of history**

**AIM:** To construct a timeline of the history of the Earth

**Materials:**
roll of toilet paper, cash register tape or similar

**Method, results and discussion**

- 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.

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.
3.7 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

Remember

1. About how many plates is the Earth’s crust thought to be divided 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?

Analyze, think and discuss

10. Read the article below and then answer the questions.
   (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 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.
### 3.8 Yesterday’s plants

#### 3.8.1 First findings

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

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 in 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.

#### 3.8.2 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, club mosses and ferns formed vast ancient forests. Thick layers of their rotting remains became solidified over time, forming 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.

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**Investigate and create**

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

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**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.

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**learnon**

**RESOURCES — ONLINE ONLY**

- Watch this eLesson: How did we get here?
  Watch a video from The story of science about evolution
  Searchlight ID: eles-1776
- Explore more with this weblink: Madagascar
- Complete this digital doc: Worksheet 3.3: Geological time
  Searchlight ID: doc-19424

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**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.

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**3.8.2 From forests to coal**

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

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.

3.8.3 Plants tell tales of history
Judy West is a scientist involved in Australian native plant taxonomy and heads the Centre for Plant Biodiversity Research that houses the Australian National Herbarium.

The Australian National Herbarium (ANH) 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.

An example of a label from a plant specimen held at 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 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**

Data from Australian herbaria are maintained in a database called Australia’s Virtual Herbarium (AVH) which you can search for information about many different plants online. Australia’s Virtual Herbarium 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.

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

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

**3.8 Exercises: Understanding and inquiring**

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. **Note:** Question numbers may vary slightly.

**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 to complete the following.
   (a) List the plant groups in order of their appearance, from oldest 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 club moss, *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 Photo Story presentation.

3.9 Fossils
3.9.1 Evidence of past life
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*.

3.9.2 Fossils
Fossils can be parts of an organism, such as its bones, teeth, feathers, scales, branches or leaves. They can also be footprints, burrows and other evidence that an organism existed in an 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.

3.9.3 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.
3.9.4 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?’, I would tell you how old I am 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 the animal lived. Relative dating can also provide information about which other species were living at the same time and the order in which they appeared in the area.

Interpretation of the relative dating method requires considering 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**.

**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 60,000 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 incorporate 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 on the right outlines how these ratios can change over time.

### 3.9.5 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 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.

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

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

The fossil record gives us evidence of gradual change occurring over time. An example can be seen in 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.

3.9.6 Types of fossils

There are many different types of fossils, including 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 this 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

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

INVESTIGATION 3.4
Studying fossils
AIM: To describe and classify different types of fossil

Materials:
fossils, fossil casts or pictures of fossils
- Copy and complete the table for each type of fossil.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Type of fossil (cast, mould, imprint or other)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.9 Exercises: Understanding and inquiring
To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

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.
11. Outline what the fossil record tells us about the evolution of horses.
Think and discuss

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

13. Examine the diagram 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 on the right. 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?

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 dinosaurs in your answers to the above questions as A, B, C or D.)

16. The layers of rock shown in the illustration on the right 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 on the next page 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 Resources section. 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 to locate images of each of the types of fossils described under the heading Types of fossils. 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 Resources section 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.
3.10 More evidence for evolution

3.10.1 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 this evidence involved the use of new technologies.

3.10.2 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 are different, the similarity of basic structure still exists.

3.10.3 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.
3.10.4 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 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 and amino acid sequences in proteins can be used to determine how closely they are related and to estimate the period since they shared a common ancestor.

3.10.5 Linking proteins, amino acids, DNA and evolution

Proteins are universally important chemicals that are essential to the survival of organisms. In chapter 2 we looked at the coding and synthesis of proteins (see section 2.4).

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.

3.10.6 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?

3.10.7 Amino acid sequences

A change in the DNA sequence may lead to a change in the type and sequence of amino acids in the protein produced. This idea is used in comparing the amino acid sequences of specific proteins in organisms. The graph above 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.

3.10.8 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 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).

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.

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.

3.10 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

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 a 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 Resources section 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 ago 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.

<table>
<thead>
<tr>
<th>Species</th>
<th>DNA sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>TGACAAGAACA - GTTAGAG - TGTCGGAGGACCAACAGATGGTACCTGGGTCCCAAGAAAATCG</td>
</tr>
<tr>
<td>Orang-utan</td>
<td>TCAGAAGAACA - GTTAGAG - TGTCGGAGGACCAACAGATGGTACCTGGGTCCCAAGAAAATCG</td>
</tr>
<tr>
<td>Rhesus monkey</td>
<td>TGACGAGAACA A GTTAGAG - TGTCGGAGGACCAACAGATGGTACCTGGGTCCCAAGAAAATCG</td>
</tr>
<tr>
<td>Rabbit</td>
<td>TGATGATAAGA A GACAGAG A TAATCCGGAGACCGAGACATAGGACTCTGCTGCTGCTAAGAGCTA</td>
</tr>
</tbody>
</table>

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 sequence differences between the human and some other primates (orang-utan and monkey), but there are more between the human and the rabbit DNA. Why?

17. Examine the data in the table at right 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 is most closely related to humans?
   (c) Which species is less likely to be closely related to humans?
   (d) Use the information in the table to construct a flowchart, graph or diagram to show the likely relationship between the seven listed species.

<table>
<thead>
<tr>
<th>Species tested against human DNA</th>
<th>Percentage differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>–</td>
</tr>
<tr>
<td>Gorilla</td>
<td>1.8</td>
</tr>
<tr>
<td>Green monkey</td>
<td>9.5</td>
</tr>
<tr>
<td>Orang-utan</td>
<td>3.6</td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>1.4</td>
</tr>
<tr>
<td>Capuchin monkey</td>
<td>15.8</td>
</tr>
<tr>
<td>Gibbon</td>
<td>5.3</td>
</tr>
</tbody>
</table>
3.11 Origin of whose species?

3.11.1 Changing views

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.

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*

3.11.2 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 resulted 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 3.4.
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 in 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.

### 3.11.3 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.

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

### 3.11.4 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 below provide examples of some important fossil finds. While these have helped us to discover parts of the jigsaw that make up our evolutionary history, there is considerable debate about how these pieces fit together.
The variety of interpretations of fossilised skulls and other parts has led to the development of different theories and timelines to describe the evolutionary relationships between humans and our erect walking ancestors. (mya = million years ago)

<table>
<thead>
<tr>
<th>Species</th>
<th>Dated</th>
<th>Located</th>
<th>Known for being</th>
<th>Alias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australopithecus afarensis</td>
<td>7–3 mya</td>
<td>Africa</td>
<td>First group classified as hominid and believed to be a common ancestor of both humans and living apes.</td>
<td>'Lucy'</td>
</tr>
<tr>
<td>Homo habilis</td>
<td>2.2–1.6 mya</td>
<td>South and East Africa</td>
<td>First member of genus Homo</td>
<td></td>
</tr>
<tr>
<td>Homo ergaster</td>
<td>1.8–1.2 mya</td>
<td>Africa</td>
<td>Migrating out of Africa to Asia at least 1.8 mya.</td>
<td>'Upright man', Java Man (Indonesia), Peking Man (China)</td>
</tr>
<tr>
<td>Homo erectus</td>
<td>1.800,000–20,000 years ago</td>
<td>Africa, Asia (and Europe?)</td>
<td>Walking upright</td>
<td></td>
</tr>
<tr>
<td>Homo neanderthalensis</td>
<td>230,000–290,000 years ago</td>
<td>Europe and western Asia</td>
<td>Being well adapted to very cold climates and used spears and sharp tools — and possibly basic words.</td>
<td>Neanderthal man</td>
</tr>
<tr>
<td>Early Homo sapiens</td>
<td>100,000 years ago</td>
<td>?</td>
<td>Possibly being our direct ancestor and producing complex tools, jewellery and paintings on cave walls.</td>
<td>Cro-Magnon man</td>
</tr>
</tbody>
</table>

**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 Resources section to watch videos, try interactives and use a timeline to learn more about human evolution.

A Scottish doctor, Robert Broom (1866–1951), made important fossil discoveries. One of these was of this famous Australopithecus africanus fossil known as Mrs Ples.
3.11 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

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.

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 on the right 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.

3.12 See you later, alligator

3.12.1 Extinction
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 strikes. 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 dinosaurs. About 10 000 years ago 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.

3.12.2 Why are species disappearing?

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

- 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 50 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 mines and dams. 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 population 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.

### 3.12.3 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 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 be important 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, water 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 their survival being threatened by human interference.

### 3.12.4 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 are attempting 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 they 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 them off. For example, sand dunes at beaches are sometimes closed off to allow the growth of plants and the reintroduction of animal species.

### 3.12.5 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 dodos lived. This led to a reduced food supply. The other major cause was the introduction by humans of new species, such as cats, rats and pigs, which destroyed their nests.

3.12.6 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?

Like other grazing mammals, quaggas were 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.

3.12.7 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 fetus 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.

Australian Museum scientists tried to determine the entire thylacine genome and clone the animal, but the DNA was highly degraded and the project was abandoned. Some scientists still hope that one day we will bring the thylacine back to life.

### 3.12 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

**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 large 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 do you prefer? 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.

### 3.13 Tapestries within our biosphere

#### 3.13.1 Interwoven threads

Throughout history, life on Earth has been connected to global climate change. The evolution of species has been linked not only to their environments but also to each other. Like threads in a three-dimensional tapestry, the components that make up our Earth’s biosphere are interwoven on many different levels.

#### 3.13.2 Prokaryotic cells change our planet

When the first signs of life appeared on Earth, its atmosphere was not as it is today. There was no oxygen for cellular respiration and no ozone layer to protect organisms from the sun’s harmful ultraviolet radiation.
The first cellular organisms to appear were prokaryotes, such as bacteria. Fossils of prokaryotes have been found in 3.5-billion-year-old rocks, and fossil records suggest that mounds of these bacteria once covered the Earth.

**Mutations, biodiversity and oxygen**

Various types of mutations occurred in these prokaryotes. This resulted in an increasingly diverse range of new life forms. The selection of a sequence of these mutations enabled some bacteria to harvest energy from the sun and use carbon dioxide in the atmosphere to make their own food. Using this process of photosynthesis, they released oxygen back into the atmosphere. Over time, this changed the composition of Earth’s atmosphere, with some of the oxygen also being converted into ozone, which later formed the ozone layer.

**3.13.3 Eukaryotic cells finally appear**

Eukaryotic cells finally made their entrance on Earth around 1.8 billion years ago. These cells differed from prokaryotic cells in that they contained a variety of membrane-bound organelles. These included a nucleus, endoplasmic reticulum and Golgi bodies. Some scientists have suggested that these may have originated from deep folding of the plasma membrane.

The fossil record suggests that organisms made up of many eukaryotic cells appeared about one billion years ago. Cells within these multicellular organisms became specialised for particular functions.

**3.13.4 Endosymbiotic theory of evolution**

Symbiosis describes a relationship between two different species in which they both benefit from living and working together. When one of these organisms lives within the other it is called endosymbiosis. The endosymbiotic theory describes how an ingested bacteria and its larger host cell could become so dependent on each other that after many years of evolution they could not live without each other.

**3.13.5 Chloroplasts and mitochondria contain their own DNA**

Chloroplasts and mitochondria are membrane-bound organelles that are found in eukaryotic cells. They possess striking similarities to prokaryotic cells. They are surrounded by a double membrane and contain their own DNA, which is different and separate from the
DNA located within the nucleus. Their DNA is used to produce many of the proteins (such as enzymes) that are essential for their function. These organelles also reproduce like bacteria and coordinate their own DNA replication and division.

It is thought that animals and plants shared a common ancestor that had acquired mitochondria by the process of endosymbiosis. Later, plants also acquired chloroplasts, and their evolutionary path diverged from that of animals.

With increased numbers of photosynthetic organisms, there was an increase in the amount of oxygen in the atmosphere. This provided an environment with conditions suitable for the evolution of a variety of organisms that could use this oxygen in the process of cellular respiration. This process removed oxygen from the atmosphere and released carbon dioxide back into it.

3.13.6 Parasitic superpowers
In various science fiction and superhero stories there are numerous characters (usually the nemesis or enemy of a superhero) that can steal superpowers from others. Did you know that there are organisms that can actually do this?

Amid the diversity of life currently on our planet, some animals have evolved mechanisms to be able to incorporate organelles (such as chloroplasts) or specialised cells from other species into their own bodies and then use the functions of what they have stolen.

One recent discovery is a type of sea slug, *Elysia chlorotica*. These sea slugs steal chloroplasts from algae and then start photosynthesising themselves. Some scientists view this as a type of symbiosis at a genetic level, with partners sharing genes.

Stealing stinging powers
A type of nudibranch, *Phidiana crassicornis*, can extract the stinging organelles (cnidocytes) from jellyfish and coral and insert them into their own tissue, giving them a weapon that they didn’t have before! Once they use these cells, however, they need to find a fresh supply. This is not the case with *Elysia chlorotica*.

Solar-powered animals
After just one single meal of algae (*Vaucheria litorea*), *Elysia chlorotica* possesses the ability to photosynthesise for life. Scientists have found that the slug actually cuts open the algal filaments and sucks out the contents. It then transfers the living chloroplasts into cells lining its gut. This phenomenon is sometimes referred to as *kleptoplasty* and the captured plastids as *kleptoplasts*.

As these chloroplasts are in the somatic cells and not the gametes of the sea slugs, they are not inherited when the slugs reproduce. Their offspring need to have their own meal of algae to gain the ability to photosynthesise.

We can’t survive without you!
Scientists have also discovered that not only is the association between *Elysia chlorotica* and *Vaucheria litorea* specific, it is
also obligate. This means that the algae are essential to the life cycle of the sea slug. *Elysia chlorotica* will not complete metamorphosis and develop into an adult in the absence of its algal prey.

### 3.13.7 A mystery yet to solve

Scientists are currently exploring questions about how these chloroplasts can continue to function without the algal nucleus on which they were previously dependent. Some scientists suggest that the slug’s genome may contain genes transferred from the alga without which the chloroplasts could not function, making it a **holobiont** (combined genome) of slug genes and algal genes.

Other scientists consider that the survival of the chloroplasts is a result of multiple endosymbiotic events, gene transfer and the evolution of modern-day chloroplasts and mitochondria. Scientists are still asking questions and will hopefully be able to use genomic, biochemical, molecular and cellular approaches to unravel the mystery. Will you be the one to solve it?

### 3.13.8 Looking at the past

There are many scientific careers involved in exploring Earth’s history, unlocking mysteries of life from the past and relating it to the present and future. These include palaeogeology, palaeobiology, geology and archaeology.

#### 3.13 Exercises: Understanding and inquiring

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

**Remember**

1. Identify the first type of cellular organisms to appear on Earth.
2. How long ago does the fossil record suggest that cellular organisms on Earth appeared?
3. Suggest an environmental effect caused by photosynthesis.
4. Approximately how long ago did eukaryotic cells first appear on Earth?
5. Identify a way in which prokaryotic and eukaryotic cells differ from each other.
6. Outline the difference between symbiosis and endosymbiosis.
7. Describe features that mitochondria and chloroplasts have in common.
8. Explain how *Elysia chlorotica* adults can contain chloroplasts when their sex cells (eggs) do not.
9. The relationship between *Elysia chlorotica* and *Vaucheria litorea* is specific and obligate. What does this mean?
10. State the types of scientific approaches that scientists may need to use to solve the mysteries of the evolutionary relationship between *Elysia chlorotica* and *Vaucheria litorea*.

**Investigate, think and discuss**

11. Find out more about the evolution of:
   - (a) chloroplasts and mitochondria
   - (b) *Elysia chlorotica* and *Vaucheria litorea*
   - (c) prokaryotic cells and eukaryotic cells.
12. A 268-million-year-old fossil found on the southern coast of NSW by Professor Guang Shi of Deakin University is considered to contain two species of fossilised bacteria that lived in symbiosis with a burrowing animal. Shi suspects that the animal acted like a gardener, cultivating the bacterial species best suited to changing climatic conditions. Find out more about this research and other research related to palaeobiology, palaeogeology and global change.
13. Examine the figure on the next page and read the relevant information in this section.
   - (a) At what age do these sea slugs reproduce?
   - (b) Do the eggs of *Elysia chlorotica* contain chloroplasts?
(c) Describe what happens five days after the larva feed on algae.
(d) Suggest an evolutionary advantage of the relationship being selected for.
(e) Suggest a future application of this knowledge.
(f) Suggest a hypothesis about this process that could be investigated.

14. Research and report on scientific contributions or research from one of the following eminent Australian palaeontologists: Geoffrey Archer, Malcolm Walter, Neil Archbold, Neil Marshall, Alan Partridge, David Haig, John Laurie, Dana Milder, John Mortimer.

15. In 2008, palaeontologist Kate Trinajstic from Curtin University in Perth made one of Australia’s most significant fossil discoveries. The famous ‘mother fish’ fossil, Materpiscis attenboroughi (named after the well-known science presenter David Attenborough) pushed back the earliest known live birth an astonishing 200 million years. The analysis of her discovery brought together scientists from different science disciplines and showed the need to develop new techniques for further investigations.
   (a) Find out more about Dr Trinajstic’s ‘mother fish’ fossil and how it changed our evolutionary theories.
   (b) Find out examples of science disciplines that are involved in analysing fossils.
   (c) Dr Trinajstic is now working with Kilti Grice, professor of chemistry at Curtin University and Director of the Western Australia Organic and Isotope Geochemistry Centre, to identify biomarkers in fossils that will reveal what the fish were made of and what they ate. Research and report on:
      (i) the use of biomarkers to find out more about fossils
      (ii) organic and isotope geochemistry.
   (d) In 2010, Dr Trinajstic won the Malcolm McIntosh Prize for Physical Scientist of the Year. To listen to her speak about her work, click on the Prime Minister’s Prize for Science weblink in your Resources section.

Investigate, imagine and create

16. Construct models to link the endosymbiotic evolution theory to either mitochondria or chloroplasts.
17. Find out more about organisms that steal functions from other species. Create a science fiction story that links what you have found to your imagination.
18. Imagine that you are a palaeobiologist or palaeogeologist. Click on the Australian Museum Palaeontology Collection weblink in your Resources section to do some research.
   (a) Write a story describing an exciting week in your life.
   (b) Suggest three research questions that you may be involved in investigating.
3.14 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.
4. Mentally stand back and examine your story outline; make any desired changes to enhance its dramatic impact.

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

- Comic strip
  - also called
  - why use?

- Storyboard
  - Outline of scene 1
  - Outline of scene 2
  - Outline of scene 3
  - Outline of scene 4
  - Outline of scene 5
  - Outline of scene 6

- Gantt chart
  - Action
  - Sunday
  - Monday
  - Tuesday
  - Wednesday
  - Thursday
  - Friday
  - Saturday

- how to ...?
- question
- comparison
- Similarity
  - Both show the sequence of events.
- Difference
  - Storyboards use sketches or diagrams while Gantt charts use tables.

Explore more with this weblink: Prime Minister’s Prize for Science
Explore more with this weblink: Australian Museum Palaeontology Collection

Watch this eLesson: Ancient DNA
Searchlight ID: eles-1069
3.15 Project: Natural selection — the board game!

3.15.1 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 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 in determining 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.

3.15.2 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 Resources section. Watch the introductory video lesson and then click the ‘Start Project’ button to set up your project group.

Individual pathways

<table>
<thead>
<tr>
<th>ACTIVITY 3.1</th>
<th>ACTIVITY 3.2</th>
<th>ACTIVITY 3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revising science</td>
<td>Investigating evolution</td>
<td>Investigating evolution further</td>
</tr>
<tr>
<td>doc-8467</td>
<td>doc-8468</td>
<td>doc-8469</td>
</tr>
</tbody>
</table>

ONLINE ONLY

Will the organism you create be more successful than the dodo?
3.16 Review

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 on 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 importance 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
- evaluate and interpret a variety of different types of evidence used to support the theory of evolution

3.16 Review 1: Looking back

To answer questions online and to receive immediate feedback and sample responses for every question, go to your learnON title at www.jacplus.com.au. Note: Question numbers may vary slightly.

1. Identify the term from the following list that matches the meaning on the right.
   (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 structural and behavioural differences in a species
   (d) Evidence of past life
   (e) Structures that may look similar due to comparable 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

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

   Variation | Competition | Adaptation
   DNA hybridisation | Biogeography | Radiometric dating
   Fossil | Comparative anatomy
   Analogous structures | Artificial selection
   Natural selection | Clone
   Convergent evolution | Protein
Comparing the structure of organisms
A process by which unrelated organisms living in similar environments develop similar features
A technique that uses measurements of isotopes to determine the age of rocks and fossils
Variation among organisms at the ecosystem, species and gene level
The process in which organisms with particular features are selected and bred together
A genetically identical organism
Made up of amino acids

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

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

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).
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.

A timeline of some marsupial fossil finds and major mammal events

<table>
<thead>
<tr>
<th>Some marsupial fossil finds and events</th>
<th>Epoch (millions of years ago)</th>
<th>Major mammal events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>HOLOCENE 0.01–present</td>
<td>Humans investigate Earth’s history</td>
</tr>
<tr>
<td>Most of the large Pleistocene marsupials became extinct about 15 000–30 000 years ago.</td>
<td>PLEISTOCENE 1.64–0.01 mya</td>
<td>Aborigines arrived in Australia about 55 000 years ago</td>
</tr>
<tr>
<td>Many giant browsing marsupials became extinct; there were grazing kangaroos and lots of diprotodonts.</td>
<td>PLOICE 5.2–1.64 mya</td>
<td>Homo habilis, the earliest known human, appeared in East Africa</td>
</tr>
<tr>
<td>Primitive marsupial ‘mice’ and ‘tapirs’ were found at Lake Eyre, South Australia, and diprotodonts at Bullock Creek, Northern Territory.</td>
<td>MIocene 23.5–5.2 mya</td>
<td>Lots of marsupial mammals were living in Australia and South America</td>
</tr>
<tr>
<td>First Australian marsupials occurred about 23 million years ago. Fossils of diprotodonts and a relative of the pygmy possum were found in Tasmania.</td>
<td>Oligocene 35.5–23.5 mya</td>
<td>First marsupials appeared in Australia. First primates appeared</td>
</tr>
<tr>
<td>Lots of marsupial fossils of this age were found in South and North America.</td>
<td>Eocene 56.5–35.5 mya</td>
<td>Swimming and flying mammals appeared</td>
</tr>
<tr>
<td>Dinosaurs became extinct about 65 million years ago.</td>
<td>Palaeocene 65–56.5 mya</td>
<td>More mammals appeared after dinosaurs became extinct</td>
</tr>
</tbody>
</table>

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

| Function similar structure not common different divergent convergent structure function |
|-----------------------------------------|---------------------------------------------|
| Analogous structures | Homologous structures |

8. Examine the diagram on the next page 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 of one particular group of new antibiotics (the fluoroquinolones) in livestock, the level of resistance to the human antibiotic ciprofloxacin was only 2 per cent. In countries where these antibiotics are used in livestock, the human 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 sequencing 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 where insects were plentiful and shorter-beaked finches 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 on the right 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.
17. 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 skull. 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.
18. 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.
19. Research current theories on human evolution. Use a Gantt chart to summarise some of your findings.
20. Find out more about an aspect of human evolution that interests you and construct a storyboard to share what you have found out.
21. (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*.
22. 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

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**A Tangled Family Tree**

A recent genetic study has suggested that human and chimp ancestors may have continued to interbreed after evolution had split them apart.

The genomes of humans, chimps and gorillas were compared using a molecular clock to estimate how long ago the three groups diverged.

It had been thought that the last common ancestor of chimps and humans lived over 7 million years ago. However, patterns in genes on the X chromosome suggest that the two lineages may have split between 5.4 and 6.3 million years ago.

The research suggested that after humans and chimps initially split into separate species, they continued to interbreed and in fact rehybridised into a single species in a reverse speciation event.

Other research has contested these results, suggesting that the genetic changes can be explained by differences in mutation rates between species and that the reverse speciation did not occur.

The Toumaï fossil shown here is thought to be the earliest fossil from the human family tree, but may also be a common ancestor to chimps and humans, or even fit elsewhere on the evolutionary tree.

What effect may this research have on our current interpretations of fossils and theories of human evolution? What will future research tell us about our family tree?