Chapter 2: Evolution

Pages 39–64

Teacher notes

Introducing the chapter:

This chapter outlines the processes and mechanisms of evolutionary change. Natural selection as the mechanism of evolution is discussed, as well as the effect natural selection has on the allele frequency of different populations. Artificial selection is also discussed. An overview of the contributions of different scientists – including Darwin and Wallace – to the theory of natural selection is covered. This chapter evaluates the different selection pressures that cause divergence and convergence, as well as different forms of evidence for evolution, including fossil and chemical (DNA and protein) evidence.

Teacher notes

2.1 Darwin and Wallace were co-conspirators

Pages 40–43

Introducing the topic:

This topic covers evolutionary theories and the reproducible scientific evidence on which these theories are based. Theories are contested and refined over time by other scientists. The process of natural selection proposed by Charles Darwin and Alfred Wallace is covered, as well as other theories that have been disputed with scientific evidence.

Teaching tip:

Build on student prior knowledge. In Year 7 students learnt about the diversity of species, and in Year 9 the biotic and abiotic selection pressures that exist in ecosystems was covered.

Teaching tip:

Point out to students that searching for information on evolution on the internet can be difficult, with many pseudoscience websites set up to promote a particular point of view. Students should ensure they use credible sites, such as those set up by universities or government facilities.

Teaching tip:

Scientific theories are explanations of the natural world that are based on well-substantiated evidence. Although many scientists still debate *how* evolution occurred, they do not question that it has happened. Students should understand that evolution is a slow process of change that takes thousands and sometimes millions of years to occur. For this reason it is important to choose words carefully when teaching evolution.

Evidence or proof:

The term ‘proof’ is often used in mathematics or a court of law and implies absolute certainty. Because science involves the gathering of evidence to support or refute hypotheses or theories, it is not appropriate to use the term ‘proof’.

Additional activity: species diversity and selection pressures

Pretesting of prior evolutionary knowledge to review species diversity and selection pressures may be useful at this stage.

Additional activity: timeline

Create a timeline of both Darwin and Wallace’s work and compare their ideas and how each formed the same theory using different examples.

Going further:

Students could compare and contrast the process of natural selection and artificial selection using a Venn diagram, or concept maps.

Have a discussion on why evolution will only ever be a theory, rather than fact.

Teacher notes

2.2 Natural selection is the mechanism of evolution

Pages 44–45

Introducing the topic:

Natural selection is the mechanism of evolutionary change. Selection pressures within the environment act on the variation within a population, and gradually change the frequency of alleles in the gene pool over time.

Teaching tip: clarify misconceptions

Evolution is not a struggle to achieve perfection. Each organism that survives is better than its fellow organisms that have not survived in the same environment. This does not mean that the surviving organism is perfect for that environment.

Although random mutation is the ultimate source of genetic variation, evolution is not random. Evolution is a process by which organisms best suited for a particular environment survive.

Organisms do not try to change or adapt. They either have the genes best suited for survival and producing offspring, or they do not.

Teaching tip: explain fitness

The ‘fittest’ suggests the organism that is both most suited to its environment, and is able to produce and support offspring until they are able to reproduce. In biological terms, a grandparent is the fittest individual.

Additional activity: fitness and fertility

Compare the fitness of: a body builder who is infertile, with a thin, weak individual who is fertile. The students can be asked ‘who is the fittest individual?’.

There are many examples of animals using a variety of techniques (and they don’t have to be the biggest or strongest) to ensure they produce offspring.

• Sly male crickets do not chirp themselves. Instead, they spy a female moving to another cricket’s call and intervene, pretending the call came from them.

• Some sneaker squid move up to a couple that has recently mated, rapidly deposit sperm in the female (in six seconds) and then run away.

• Small dung beetles excavate a side entrance into a tunnel system usually guarded by the larger dominant beetle, mate with the female chambered there and then slip away undetected.

• Male cuttlefish take on female colouration, hide their masculine fourth arm and hold their arms in the posture of an egg-laying female in order to sneak up to a guarded female.

Additional activity: the Linnaean classification system

This is an ideal opportunity to revise the Linnaean classification system that was learnt in Year 7. It is useful to cut and paste a series of pictures of many different types of animals.

• Draw a large circle on an A3 sheet of paper. This is for all animals in the kingdom Animalia. Paste or draw some plants outside the circle.

• Draw a smaller circle inside the large circle. This is for all animals in the phylum Chordata. Draw or paste an insect and jellyfish inside the Animalia circle but outside the Chordata circle.

• Draw a third circle inside the previous two circles. This is for the class Mammalia. Draw or paste a frog and a snake outside this circle but inside the Chordata circle.

• Draw a fourth circle inside the previous three circles. This is for the order Primates. Draw or paste a cow and sheep outside this fourth circle but inside the mammalian circle.

• Draw or paste a human and a chimpanzee inside the fourth circle.

Additional activity: colourations and genotypes card activity

Have students create sets of cards for beetles/moths with different colourations and genotypes written on them – for example, some AA, some Aa, some aa. Have different selection pressures affect their gene pools (a mutation introduces a new colour and allele, the trees all get a disease and the leaves turn brown…etc). Select the beetles most likely to survive and demonstrate how allele frequencies change over time.

Keep the cards and use for different lessons later on – for example, allopatric speciation unit, or divergent evolution.

Going further:

Look at how silent mutations can be maintained within populations and how they may be beneficial to the evolution of a species in the future.

Going further:

Look at the effects of a gene pool size.

An example of this is the devil facial tumour disease (DFTD). Although the number of Tasmanian devils was large, the gene pool of the population was very limited. DFTD is a cancerous tumour that resulted from a mutation in one cell in one animal. Tasmanian devils bite each other and so when the original devil bit another devil, a small part of the tumour was broken off and passed on to the bitten devil. Because there was little difference in the alleles of the two devils, the tumour was able to grow in the second devil. This passing on of the tumour occurred over and over again because the gene pool of Tasmanian devils is so small. Because the tumours ultimately cause the devils to die of starvation, over 80% of the devil population died in the past 10 years. Thus, the entire population of Tasmanian devils may become extinct because of a small gene pool.

Teacher notes

2.3 Different selection pressures cause divergence. Similar selection pressures cause convergence

Pages 46–47

Introducing the topic:

When two populations become separated, the gene flow between the species is stopped. If the two species experience different selection pressures, then they gradually become more different from each other. Eventually they may become reproductively isolated and are said to have diverged. The two new species may retain homologous structures in common. If two very different species are exposed to the same selection pressures, they may develop analogous structures. Their structures will appear to converge.

Teaching tip: clarifying the ‘gene pool’

It is important for students realise that ‘gene pool’ refers all the **alleles** in a population and not just the genes in that population. The size of the gene pool is important. If the gene pool is small, then the variation in individuals within the population will be limited. This can have large consequences if a disease moves through the population and there are no allelic variations that are resistant to the disease. (It is for this reason that breeding programs in zoos are vitally important.)

Teaching tip: homologous vs analogous

It is often difficult to explain the difference between homologous structures and analogous structures. The key is to emphasise the ancestry and selection pressures.

Homologous structures have recent common ancestors, but different selection pressures mean the structure is used for different purposes.

Organisms with analogous structures have very distant common ancestors but live in similar environments and, as a result, have similar selection pressures resulting in similar (analogous) structures. A good example of organisms with analogous structures are the shark and dolphin. One is a fish and the other is a mammal (different ancestors), but both have the same shape body, tail and fins.

Teaching tip: common ancestor

You may notice that the definition of analogous structures does not say ‘no common ancestor’. This is because all organisms do have a common ancestor; however, the terms ‘recent common ancestor’ or ‘distant common ancestor’ are easier distinctions to make.

Additional activity: concept mapping

Students could find images of analogous and homologous structures in both plants and animals and create a visual concept map comparing them.

Additional activity: modelling speciation

A way of modelling allopatric speciation can be completed using smarties and a sheet of A4 paper.

**•** Place a small handful of smarties on a piece of paper in front of two students.

• Tear the paper in two, with half the smarties on each half. There is now a physical barrier between the two populations.

• Each student should eat their favourite colour of smarties. This is the selection pressure on the populations.

• The students should then eat their second favourite colour of smarties.

• This should be repeated until only one colour of smarties is left.

• Most groups will be left with different colours of smarties in each population. The smarties have become different species.

Going further:

Create a chart to compare types of speciation and types of isolation:

Allopatric speciation: This occurs when there is a permanent physical separation of the two groups following events such as earthquakes, volcanic eruptions, changing sea levels and the formation of deserts.

Sympatric speciation: A new species forms as a result of a chromosomal mutation or a hybrid formation from two different plant species. As a result, the new organism is unable to mate with its parent species.

Parapatric speciation: The two groups of organisms have some gene flow until there is a mutation that causes them to become reproductively isolated. This may be behavioural, temporal or mechanical.

Teacher notes

2.4 Fossils provide evidence of evolution

Pages 48–51

Introducing the topic:

Fossils are remains or traces of an organism that once existed. Transitional fossils are intermediary fossils that have traits of both the ancestral organism and the more recent organism. Relative dating and absolute dating are used to determine the age of a fossil. Living fossils are existing species that have not changed in form for a very long time as the selection pressures within the environment have not changed.

Teaching tip:

Brainstorm prior knowledge: fossils, types of rocks, requirements for fossilisation, sedimentation, erosion, eras etc.

Teaching tip:

When examining bones, laboratories generally have a good supply of bones and fossils. However, bones and fossils can be purchased from science suppliers and specialist shops.

Additional activity: dating fossils

Create an image of a rock layer containing different fossils found at different depths and get students to date the fossils using relative dating techniques.

Additional activity: dating fossils – Venn diagram

Students could make a Venn diagram comparing the two methods of dating fossils.

Going further:

Research, in greater detail, how scientists use absolute dating to determine the age of the fossil.

Students could look at fossil evidence for human evolution: For example:

A 3.2 million-year-old fossil of a foot bone found in Africa appears to be built to give the human ancestor a spring in their step, the ability to absorb shocks and a stiff platform that allowed them to walk upright. This bone is thought to be the fourth metatarsal of a foot and indicates that the ancestor that it belonged to had an arched foot. This indicates that the ancestor was able to walk upright. The discovery of this single bone was the first time scientists have been able to determine how soon our human ancestors were able to walk on two legs.

Teacher notes

2.5 Multiple forms of evidence support evolution

Pages 52–55

Introducing the topic:

Biogeography provides evidence for divergent evolution. Similarities in fossils and modern day species are found in locations once joined. Vestigial structures are now interpreted as evidence of an ancestral heritage in which these structures once performed other tasks. The sharing of common genes that control how an embryo develops is further evidence of evolution.

Teaching tip:

Some students may question early work in comparative embryology:

Many Creationists point out there are errors in the embryo diagrams that Haeckel produced and, to some extent, they are right. Haeckel did deceptively omit limb buds during the early stages of embryo development in echidnas and other organisms, despite the fact that they do exist at this stage. Despite this, genetic studies have shown that Haeckel was correct and that embryo development does reflect the course of evolution. However, the individual genes that control the way embryonic development occurs can mutate and cause changes that modify the linear progression that Haeckel originally suggested.

Teaching tip: ‘Evolved from’ or ‘share a common ancestor’

We cannot say we ‘evolved from chimpanzees’ because this implies that the chimpanzees have not changed since humans separated from their species. Instead, it is more appropriate to say ‘we shared a common ancestor’. This then allows for both humans and chimpanzees to continue to evolve.

Additional activity: comparing embryos

Collect images of early and late embryos of different species and get students to compare them.

Additional activity: kinaesthetic activity

You will need: A4 paper, stickers or diagrams of animals and plants, scissors, blue poster paper.

1 Students should stick or draw groups of similar animals on various parts of the page. The organisms should be loosely grouped together, but not touching.

2 Students should then draw tectonic plate lines that run through the groups of animals that separate the A4 paper into five sections of different shapes and sizes.

3 Cut out these shapes.

4 Place the shapes together in the centre of the blue poster paper and allow them to drift apart at different rates.

5 Glue the new continents down to form your new Earth. Describe how the organisms are now distributed.

6 Draw a line through the centre of your poster. This indicates the path of the sun (the equator). Are any of your organisms not suited to living on the equator? Draw a cross through the organisms that may die as a result of their new environment.

7 Continental drift happens very slowly and many organisms have time to evolve. Chose one of your organisms and suggest how it may evolve to adapt to its new environment.

Going further:

Research gene regulation in greater depth to explain how gill or tail genes can be switched down or off during human embryo development.

Teacher notes

2.6 DNA and proteins provide chemical evidence for evolution

Pages 56–57

Introducing the topic:

Many proteins that are essential for keeping organisms alive are conserved between species. Small differences in the sequences of amino acids can be used to determine the evolutionary relationship between species. The sequences in nucleotides in DNA can also be compared between different species. Mutations cause small differences that can accumulate over time. The more differences in the nucleotide sequence between organisms, the more time has passed since they shared a common ancestor, and the greater the evolutionary distance between the species.

Teaching tip: review

Review nucleotides, DNA, RNA, base pairing, genes, amino acids, proteins, and protein synthesis from the previous chapter.

Teaching tip: other techniques are sometimes used to compare DNA

Sometimes whole chromosomes can be compared. Special stains or probes that only bind to specific genes can be used to compare the location of genes between different organisms. For example, a probe that usually binds to a gene in chromosome 2 of humans is mixed with chromosomes from an ape. The probe binds to the ape’s extra chromosome (humans have twenty-three pairs of chromosomes, whereas chimpanzees have twenty-four). This suggests that an early ancestor of humans may have combined two chromosomes to form a new larger chromosome.

DNA sequencing often takes a long time to complete. A faster and simpler method of determining the similarity between the DNA of different species is DNA hybridisation.

Additional activity: phylogenetic trees and nucleotide sequences

Practise interpreting phylogenetic trees and nucleotide sequences.

Additional activity: concept map

Create a concept map for all the different types of evidence for evolution including examples of each.

Going further:

Compare other proteins, such as haemoglobin, that are similar in different species.

Teacher notes

2.7 Humans artificially select traits

Pages 58–59

Introducing the topic:

Artificial selection occurs when humans breed organisms that have desirable traits, increasing the likelihood of that trait occurring in the next generation. Over time, these organisms become domesticated and dependent on humans for survival. The frequent and incorrect use of antibiotics selects for resistant bacteria and can lead to an increase in some bacteria such as methicillin-resistant Staphylococcus aureus (MRSA).

Teaching tip: using dogs as an example of selective breeding

The evolution of dogs is a good example to use for evolution. All dogs are most closely related to a wolf (Canis lupus). An example of how this evolution occurred comes from studies conducted in the 1950s. A scientist began selectively breeding foxes on a fur farm in Russia. He deliberately chose foxes that were more tolerant of humans that the rest. Over a few generations the foxes became tamer, but also developed unusual coat colours, floppy ears and curly tails. These new foxes barked more and came into heat earlier and more often than their ancestors. These are all qualities that are evident in domestic dogs today. What if our ancestors did the same thing to the ancestors of wolves?

Teaching tip: graphing skills

Practise graphing skills using binary fission data to show the exponential growth of bacteria.

Additional activity: selective breeding of harmful mutations

Use the mutation which causes double muscling in cows as an example of humans selecting a harmful mutation which would not naturally be maintained in a population. Compare the advantages and disadvantages of farmers breeding from these cows to increase meat production.

Additional activity: Venn diagram

Create a Venn diagram to compare natural selection and artificial selection.

Going further:

Look at other modern day examples of evolution – for example: rats able to consume five times as much rat poison as in the past; head lice that are resistant to common treatments; increasing malaria protozoa that is resistant to sulfadoxine-pyrimethamine treatments.

Teacher notes

2.8 Natural selection affects the frequency of alleles

Pages 60–61

Introducing the topic:

Selection pressures within an environment affect the allele frequencies of certain genes within a population. Advantageous alleles are maintained within a population and increase over time. Malaria is an example of a selection pressure for the sickle cell anaemia allele. The number of sickle cell anaemia carriers is much higher in countries with a higher incidence of malaria. Carriers of the sickle cell allele cannot contract malaria and do not have sickle cell anaemia.

Teaching tip: reviewing Mendelian genetics

Review terms from Mendelian genetics first – for example: carriers, homozygous, heterozygous.

Teaching tip: calculating allele frequencies

Practise calculating allele frequencies of gene pools. You could either draw a population on whiteboard or create one in a power-point. Students could calculate the number of dominant and recessive alleles for genes before and after a mutation or other selection pressure.

Additional activity: sickle cell anaemia short film

Watch the short film which covers sickle cell anaemia and changes in allele frequencies on the HHMI site:

<http://www.hhmi.org/biointeractive/making-fittest-natural-selection-humans>

Additional activity: crossword

Students could create crosswords to review all the terms and definitions associated with natural selection. Students can then swap and complete each other’s crosswords.

Going further:

Debate or research other diseases that may have once had a selective advantage:

Some scientists suggest that cystic fibrosis may have once been similar to sickle cell, in that carriers had a survival advantage over homozygous dominant and recessive individuals in European regions where cholera was prevalent.