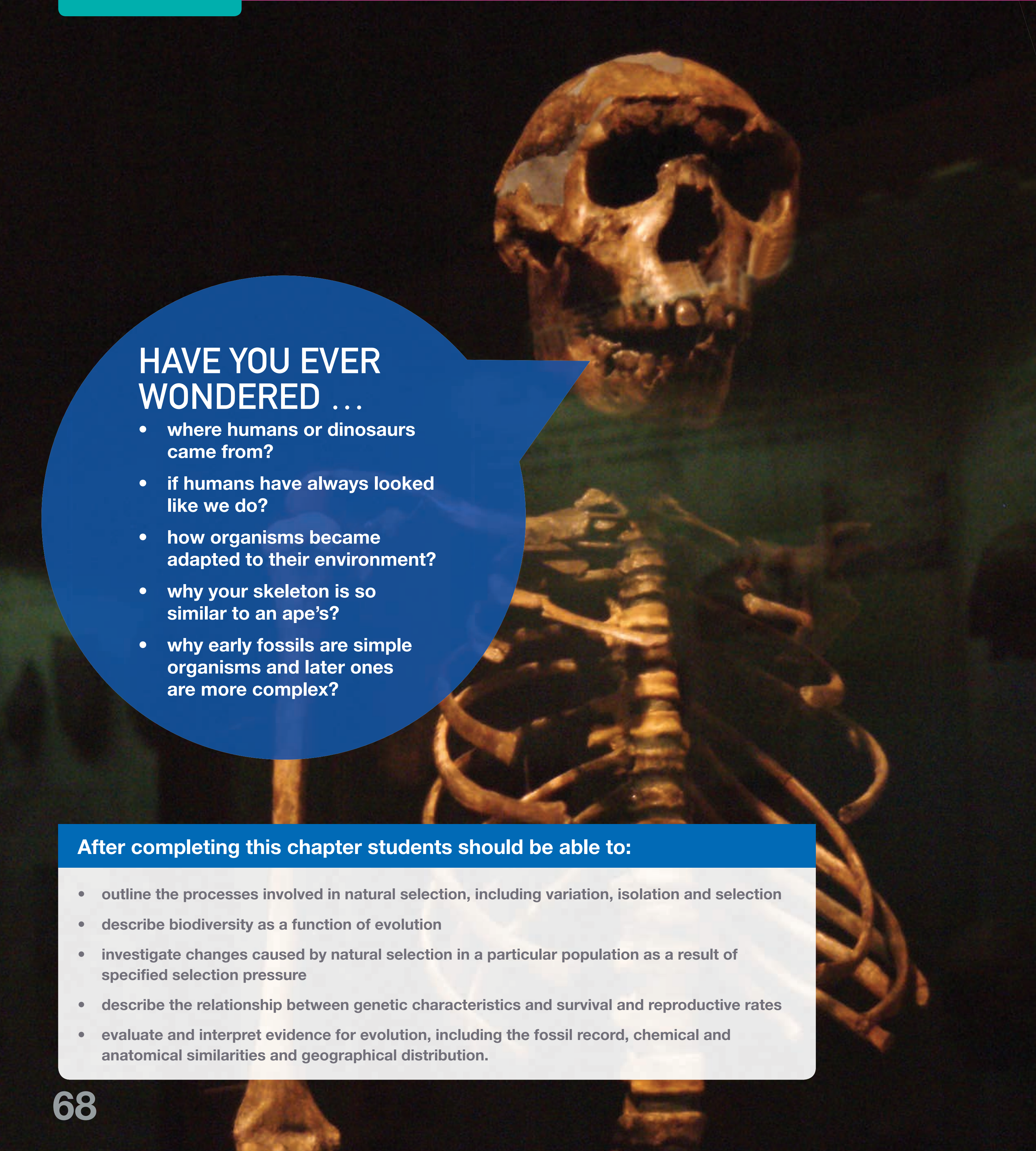
3 Natural selection and evolution



HAVE YOU EVER WONDERED ...

- where humans or dinosaurs came from?
- if humans have always looked like we do?
- how organisms became adapted to their environment?
- why your skeleton is so similar to an ape's?
- why early fossils are simple organisms and later ones are more complex?

After completing this chapter students should be able to:

- outline the processes involved in natural selection, including variation, isolation and selection
- describe biodiversity as a function of evolution
- investigate changes caused by natural selection in a particular population as a result of specified selection pressure
- describe the relationship between genetic characteristics and survival and reproductive rates
- evaluate and interpret evidence for evolution, including the fossil record, chemical and anatomical similarities and geographical distribution.

3.1 Changes over generations

The discovery of dinosaur fossils thrilled the public of the 1800s and museums would display the latest wonders for people to view. Scientists tried to explain where such organisms had come from. Their early studies of fossils, the anatomy of living organisms and the breeding of plants and animals led to the revolutionary view that a species can change over many generations.

Fossils and evolution

Fossils have shown that birds and one branch of the dinosaurs (the theropods) have many similarities in their structure (Figure 3.1.1). They are so similar that biologists are now convinced that theropod dinosaurs were the ancestors of birds.

Figure 3.1.1

Fossilised feathers on a dinosaur called *Anchiornis* discovered in China in 2009. These fossil feathers were so well preserved that scientists could determine what colour the feathers were.

Fossils of the lobe-finned fish and amphibians of the Devonian period (see page 57) show many similar bones in the limbs. However, these limbs also have more than just bones in common. They also show a gradual change in the structure of the whole limb over geological time. Each different species seemed to have small changes in its general structure, such as bone shapes and the number and position of toes.

This apparent change in species over time is called evolution. **Evolution** is defined as a genetic change in the characteristics of a species over many generations, resulting in the formation of new species. A **generation** is the time between the birth of an individual and when that individual produces their own offspring.

The fossil history of the horse is a good example of changes occurring over many generations. Fossil skeletons have been found of a horse-like animal that was about the size of a small dog. The scientific name of the genus of this animal is *Hyracotherium* (Figure 3.1.2 on page 70). It is not classified as a horse, but is similar enough that biologists consider it to be a likely ancestor of horses. Radioactive dating methods show that *Hyracotherium* lived about 52 million years ago.

Figure 3.1.2 *Hyracotherium* is a likely ancestor of creatures that became horses, but is different enough not to be classified as a horse.

The fossil skeletons of at least 17 different genera and many more species of horse have been found and dated. All these different types of horse form a complex family tree with many side branches. Some of these branches lead nowhere. These represent the development of new types of horses that then died out, becoming extinct. Other branches evolved with species steadily changing into another. Despite the complexity of the horse family tree, palaeontologists have been able to trace a path through it that leads to the modern horse. In this way, they have established its family line and the genus and species of its ancestors. One of those ancestors is *Mesohippus*, a genus of horse that lived around 40 million years ago. *Mesohippus* is recognised as a direct ancestor of the modern horse. You can see its skeleton in Figure 3.1.3.

Figure 3.1.3 *Mesohippus* is an ancestor of the modern horse.

There seems to be a gradual change in many parts of the skeletons of all the different fossil horses. Some obvious changes are that the body increases in size, the legs become longer and the number of toes decreases. Figure 3.1.4 shows key features of some different types of horse.

The change in the number of toes is of particular interest to scientists. *Hyracotherium* had four toes on its front legs. *Mesohippus* appears fairly early in the horse family, at about 40 million years, and had three toes. Compared with those of earlier horse genera, the middle toe of *Mesohippus* clearly seems to be thicker while the side toes are smaller.

At about 20 million years ago, a genus called *Merychippus* appeared in the fossil record. *Merychippus* also had an enlarged middle toe. Many other genera and species appeared after this and eventually the genus *Equus*, which includes the modern horses, zebras and donkeys, appeared in the fossil record about 3.5 million years ago.

SciFile

On your toes

Modern horses run on one large 'toe' on each foot. This toe is comparable to your middle finger. Biologists think the loss of the other 'toes' is an adaptation that allows faster running while supporting a large body.

Structure and relationships

When organisms are classified on the basis of their structure, some groups seem very similar. An example is cats and lions. Others, such as cats and jellyfish, seem quite different. The first biologists who studied evolution over 150 years ago proposed that organisms that were very similar in structure must be related. This view was based on the knowledge that organisms seemed to inherit their characteristics from their parents. However, at that time nothing was known about genetics.

Genetics has since shown us that species with the same basic structure have many genes the same or genes that are similar in their effect. It is the genes that control structure and function in organisms. Organisms with some identical genes must be related. This is because particular genes are copied from previously existing genes during meiosis. The obvious inference is that two species that share genes must have had the same ancestor at some stage. Many of the same genes have then been passed down to both species.

SciFile

Hox genes

Most species contain Hox genes, a group of genes that control where body parts such as the head and legs occur. The amazing thing about these genes is that they can be taken out of one species, such as a chicken, and put into another, such as a fly, where they work in exactly the same way. Scientists see this as evidence that all life is related.

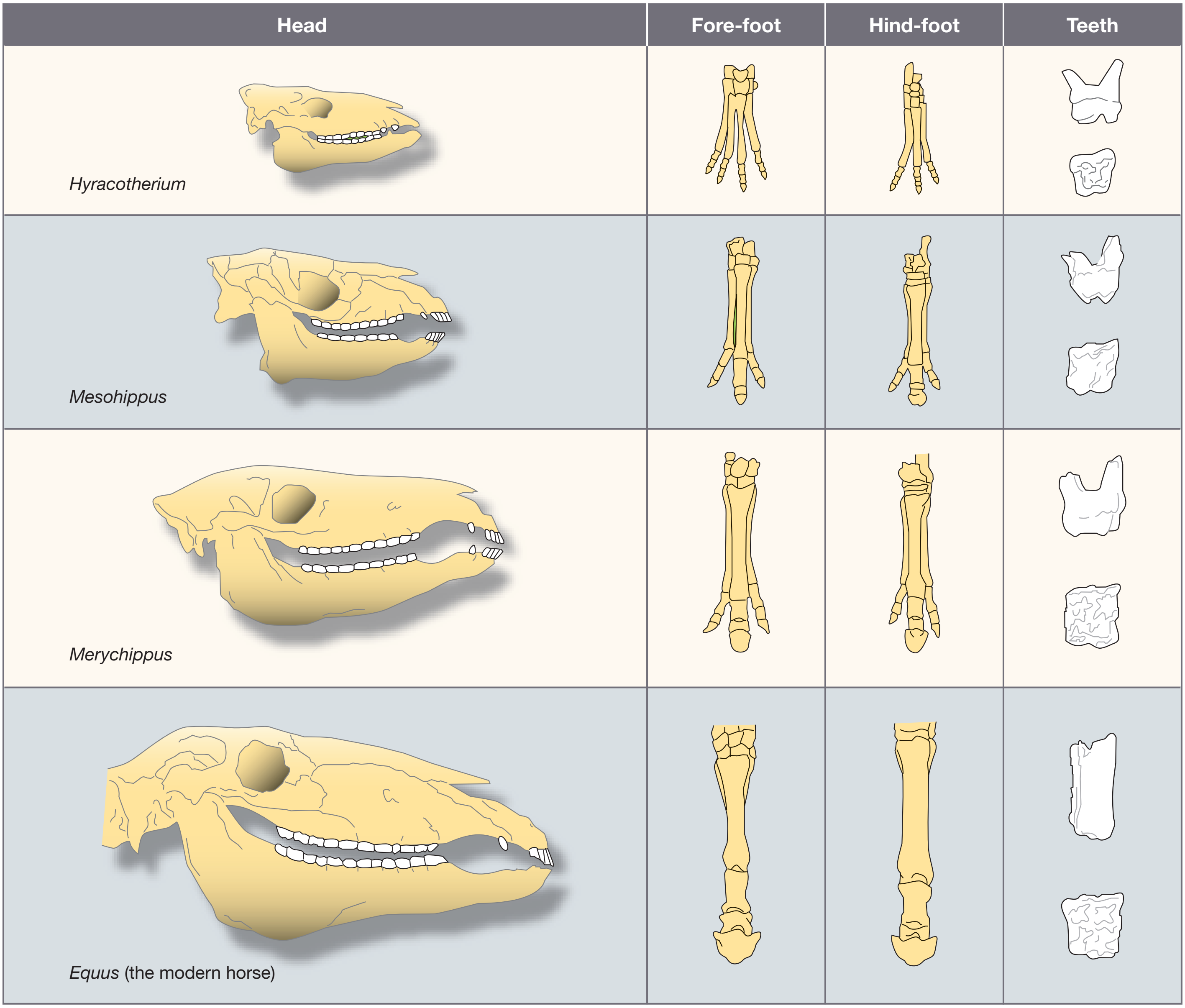


Figure 3.1.4 The fossil record of horses shows that the structure of the skull, jaw and feet changed over millions of years.

Homologous structures

In related species, characteristics that have the same basic structure are called **homologous** characteristics. Biologists have discovered that these are controlled by particular inherited genes. For example, the foot bones of the different fossil horses are homologous. A cat's paw and a lion's paw are considered homologous, but a cat's paw and an insect's foot are not homologous. A cat's paw and an insect's foot may have the same function, but their structure is very different.

In the last few decades, scientists have been able to isolate genes and study their chemical structures and how genes function. It has been discovered that the more alike two organisms are, the more genes they share. As you move from higher levels of classification to the lower levels, the more alike those genes become.

A homologous structure does not necessarily have the same function in all the groups that share it. For example, humans, whales and bats all have five digits at the end of their limbs. Humans have five digits (fingers and toes) on each of our hands and feet. Their function is to grip things and to get traction when walking. Five digits also form the bony structure of each of a whale's flippers, which are used to propel themselves through water. In contrast, the five digits that make up each of a bat's wings form the structure of their wings, allowing them to fly. A human hand, whale flipper and bat wing are homologous structures, despite having different functions.

1 p77
3.1

Analogous structures

Not all similar structures are homologous structures. For example, the dolphin and shark in Figure 3.1.5 have similar streamlined bodies and similar dorsal fins on their backs. However, these are not homologous structures because different genes are involved in their inheritance. Dolphins and sharks differ in most other structures. This shows that these animals are not very similar other than at the simplest (phylum) level—the fossil record shows that sharks evolved over 460 million years ago, while dolphins evolved about 10 million years ago.

Dolphins and sharks have similar body shapes and fins because they evolved in similar marine environments. Structures that look similar on genetically very different organisms are known as **analogous structures**.

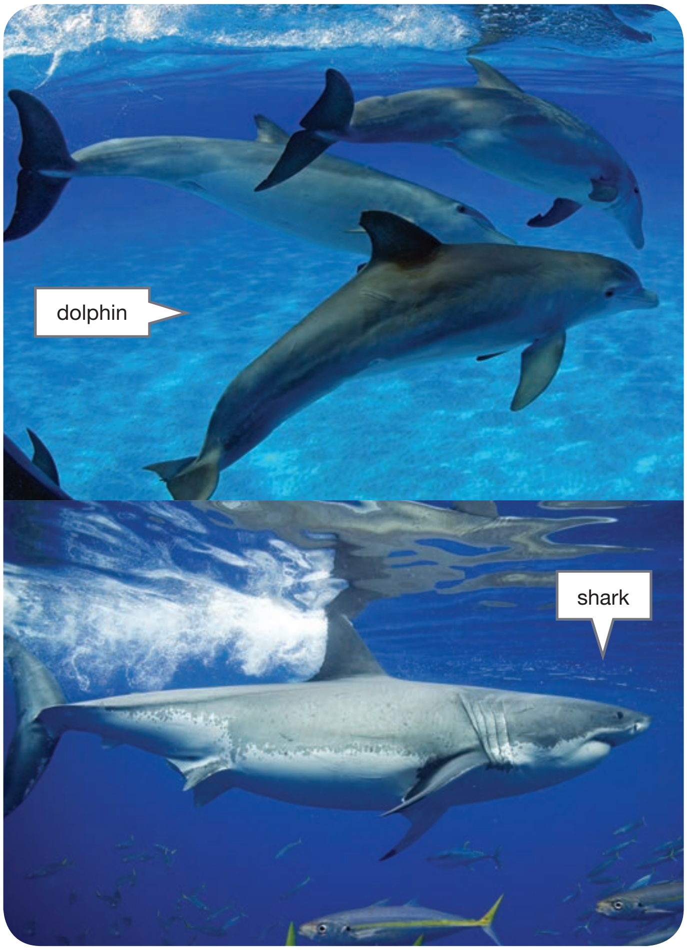


Figure 3.1.5 Sharks and dolphins are not closely related but look similar due to evolving in similar environments.

Dolphin ancestors

SciFile

Dolphins are air breathers, and scientists think their ancestors must have been land-living animals that went back into the water. That probably explains why they have lungs and breathe air.

Artificial selection

For many centuries, humans have selectively bred different animals and crossed different plants to gradually change the features of a species.

Artificial selection is the process by which we choose to breed particular organisms with desirable features. One example is breeding of budgerigars. Wild budgerigars are green and yellow. You can see one in Figure 3.1.6.

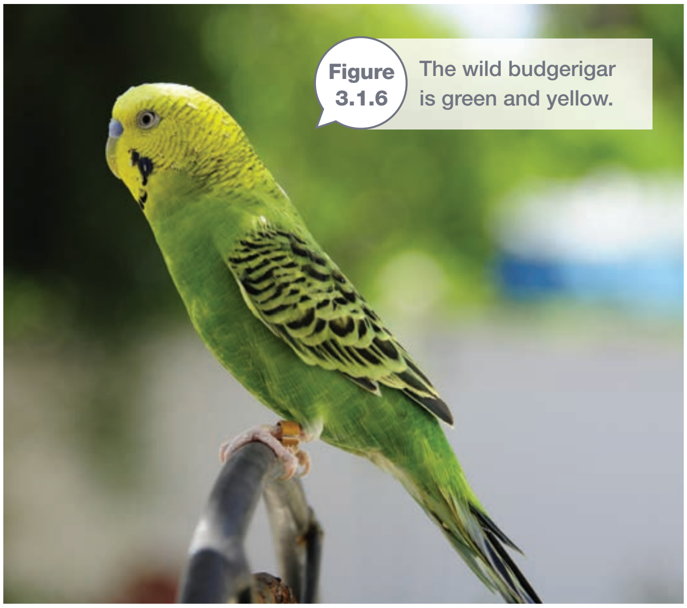


Figure 3.1.6 The wild budgerigar is green and yellow.

All the different pet budgerigars we have today have come from this wild type of budgerigar. Figure 3.1.7 shows some of the different colours. The different colours and patterns are the result of breeders choosing particular budgerigars as parents and breeding from them. They used wild budgerigars that showed small differences in colour, patterning and body size. These variations in the wild budgerigar population were all originally the result of mutations.

Figure 3.1.7 These budgerigars were all bred by artificial selection.

Figure 3.1.8 Different breeds of dog are all one species and were produced by artificial selection.

Occasionally new mutations occurred that the breeders had not seen in the wild birds. These were selected by the breeders and passed on to the offspring. For example, the blue colour in some budgerigars originated as a mutation of the gene controlling the green feather colour. All wild budgerigars are green, although occasionally blue ones are born, and sometimes all yellow ones are born. In this way, many new features were developed in pet budgerigars and they are markedly different from the original wild birds.

Artificial selection only happens over generations. The breeders cross (mate) the selected parents and then have to allow the offspring to reach maturity before selecting which will be bred.

The different colours in pet budgerigars have been produced in only about 100 years of artificial selection.

There are hundreds of other examples of species being changed by artificial selection. Domestic dogs are all one species (Figure 3.1.8), as are domestic cats. The different breeds in these two species have come from artificial selection.

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Big and small

The biggest dog breed is the Irish wolfhound, and the smallest is the chihuahua. Both are the same species and the differences in them have been developed by artificial selection.

Selective breeding methods

Selective breeding is used in two main ways. The first method is called **cross-breeding**. This is the process of combining in the offspring a desirable feature of one individual with a different desirable feature from another individual. An example is the creation of the dog breed called labradoodle. This is a cross between a labrador and a poodle, combining the features of both dogs. You can see a labradoodle in Figure 3.1.9.

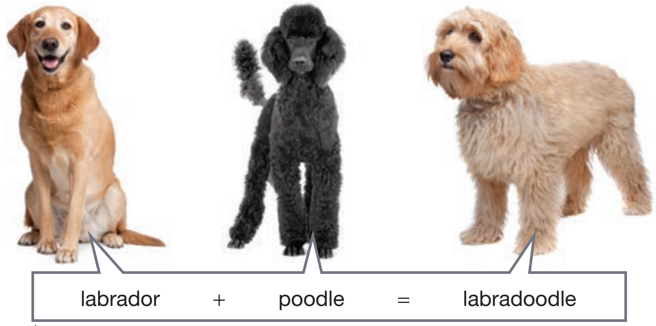


Figure 3.1.9 The labradoodle is the result of a cross between a labrador and a poodle.

Another method of selective breeding is **inbreeding**, or line-breeding. In this process, related individuals are allowed to mate. This method is not often used in animal breeding, as there can be health issues in the offspring. Deformities, sterility and genetic disease can be caused by inbreeding.

In plant breeding, there do not seem to be as many problems with breeding closely related plants, but this can depend on whether the species is self-pollinating or cross-pollinating.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Breeding a better lupin

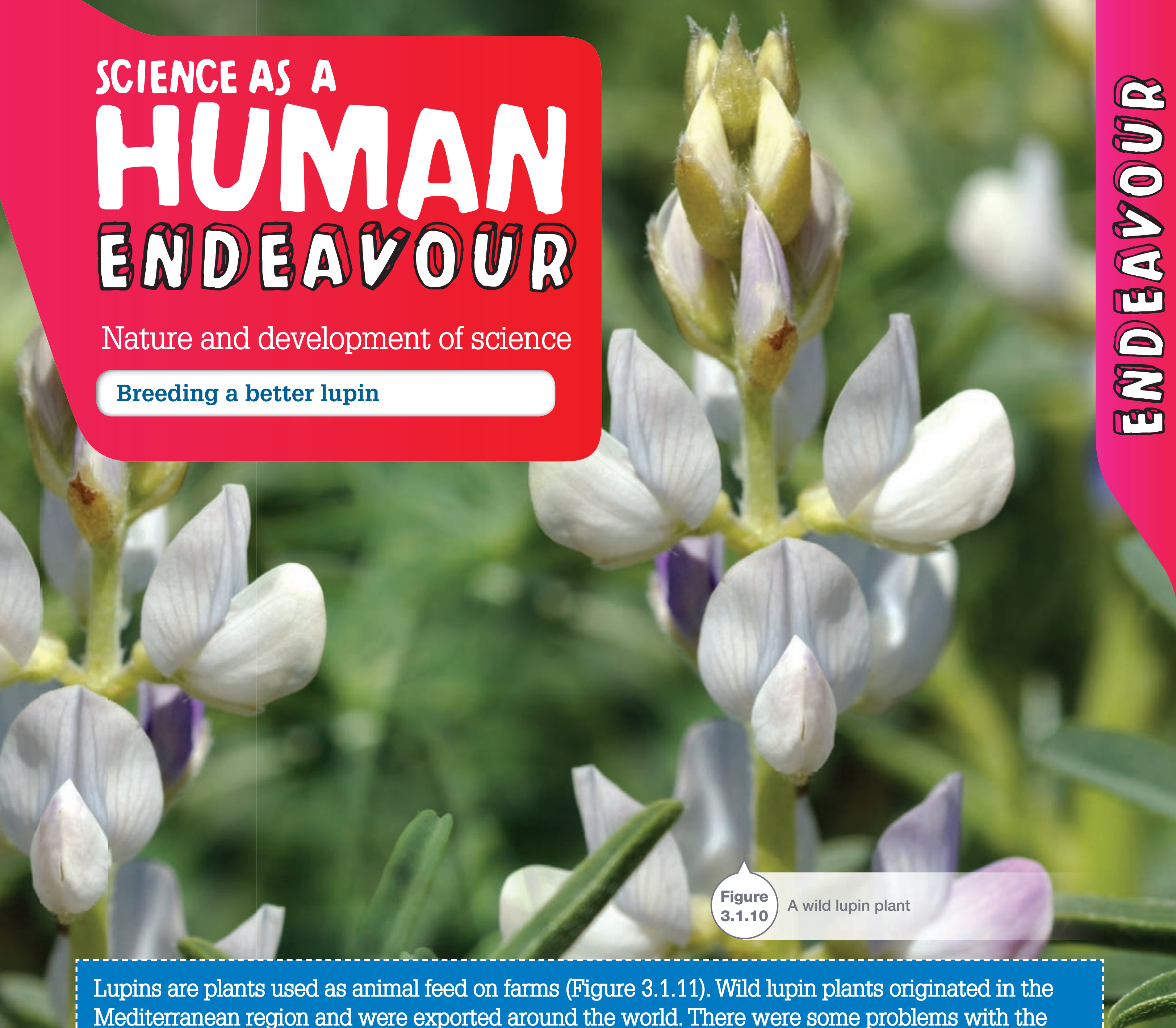


Figure 3.1.10 A wild lupin plant

Lupins are plants used as animal feed on farms (Figure 3.1.11). Wild lupin plants originated in the Mediterranean region and were exported around the world. There were some problems with the original plants, so selective breeding was used to improve them.

Figure 3.1.11 Lupins are used as animal feed on farms.

The original wild lupin seeds (Figure 3.1.10) had a rather bitter taste, so animals generally only ate the leaves. The seed pods also shattered and scattered their seeds, so farmers found it difficult to harvest the seeds for planting at a later time.

John Gladstones is a plant breeder from Western Australia. He thought he might be able to change lupins to make them into a better animal stock feed. He particularly wanted to produce seeds that animal stock would eat, and that would be easier to harvest. Gladstones began his research by searching through fields of lupins, looking for mutants that didn't have shattering pods. He eventually found two plants in which the seed pods had only partially shattered.

Figure 3.1.12 Wild lupin pods shatter but artificial selection produced non-shattering pods.

Studies of these two plants showed that pod shattering was controlled by two independently inherited recessive genes. These genes affected the seed pods in different ways to stop them shattering. Gladstones cross-bred these two plants and managed to produce a plant with completely non-shattering pods.

However, these lupins still had bitter seeds, which animals did not eat. So he crossed the bitter-seeded, non-shattering plants with lupins that had sweeter tasting seeds, but shattering pods. As Table 3.1.1 shows, some of the offspring were plants that had non-shattering pods and sweet seeds.

Gladstones then crossed these plants with lupins that had white flowers. He wanted to be able to easily spot the sweet-seeded non-shattering plants if they became mixed up with others. He finally succeeded in producing lupins that had non-shattering pods, sweet seeds and white flowers. This resulted in a stock feed that was worth many millions of dollars to farmers around Australia.

Table 3.1.1 Steps in selective breeding of lupins

Step	Plants crossed	Offspring included desired phenotype
1	Partially shattering pod × partially shattering pod	Non-shattering pod
2	Non-shattering pod with bitter seeds × shattering pod with sweet seeds	Non-shattering pod Sweet seeds
3	Non-shattering pod with sweet seeds and blue flowers × shattering pod with sweet seeds and white flowers	Non-shattering pod Sweet seeds White flowers

In terms of evolution, the story of lupins is important because it shows that the characteristics of a species can be changed by selecting which individuals breed. Selecting the phenotype (appearance) of the individuals means selecting their genotype (genetic make-up). In this way, the genetic make-up of a species can be altered by selection.

3.2

3.1 Unit review

Remembering

1 **List** some changes shown by fossil horses over geological time.

2 **List** some examples where artificial selection has changed a species.

3 **Recall** the fossil group that birds are most closely related to and the characteristic that these groups can share.

Understanding

4 **Define** the following terms.
  a evolution
  b generation
  c homologous

5 **Explain** how fossils can provide evidence for changes in the structure of a species over geological time.

6 Using an example, **explain** how artificial selection can alter a species.

7 **Explain** why scientists consider that species with the same basic structure are related.

8 a **Describe** what John Gladstones found when he searched through fields of wild lupins.
  b **Explain** where the genes for non-shattering pods would have come from originally.
  c **Explain** how this story of lupin breeding is similar to the one about breeding budgerigars.

Applying

9 **Demonstrate** that organisms whose appearances are very similar are not always closely related.

Analysing

10 For the different species of horse shown in Figure 3.1.4 on page 71, **compare**:
  a foot structure
  b head structure.

11 **Use** examples to **contrast** homologous and analogous structures.

12 'Homologous structures do not have to perform the same function in different species.'
Use a bat limb and a mouse limb to **justify** this statement.

Figure 3.1.13

13 **Compare** the processes of cross-breeding and inbreeding.

Evaluating

14 Breeders have bred blue budgerigars. **Propose** how they did this given that the wild population is commonly green and yellow.

15 **Justify** the view of palaeontologists that birds and dinosaurs are related.

Creating

16 a **Design** a series of steps for changing a rose with dark pink flowers and thorns into one with white flowers and no thorns.
  b **Explain** the processes used at each step.

Inquiring

1 Research the fossil history of vertebrates, discussing some evidence that fish evolved into amphibians and amphibians into reptiles.

2 Research the fossil history of mammals, discussing the evidence that mammals are related to reptiles.

3.1 Practical activities

1 Signs in the skeletons

Purpose

To compare vertebrate limbs and propose reasons for their similarities.

Materials

- skeletons of human, cat, bird, frog, fish and lizard

Procedure

1. Copy the table below into your workbook.
2. Use the labelled diagram in Figure 3.1.14 of the human arm to identify the same bones in the human skeleton.
3. Move around to the various specimens and carefully observe their front and rear limbs.
4. Identify any bones that are similar to the human forearm or leg. List similarities and differences between the different animals and the human.

Results

Complete your results table for each animal.

Discussion

1. Using your table, **identify**:
   - a. the two animal skeletons that are most alike in their limb structure.
   - b. two that are least alike.
2. a. **Identify** animals that you think may have homologous limb bones.
   - b. **Identify** the particular bones involved.
3. **Explain** how these animals could have skeletons that are so similar.
4. The bony fish is a vertebrate, but an extremely distant relative of these other vertebrates. **Discuss** evidence in the skeletons that fish are related to these other vertebrates, but very distantly. (Hint: Look for other homologous structures.)

Animal	Description of front limbs	Description of rear limbs
Human		
Cat		
Bird		
Frog		
Fish		
Lizard		

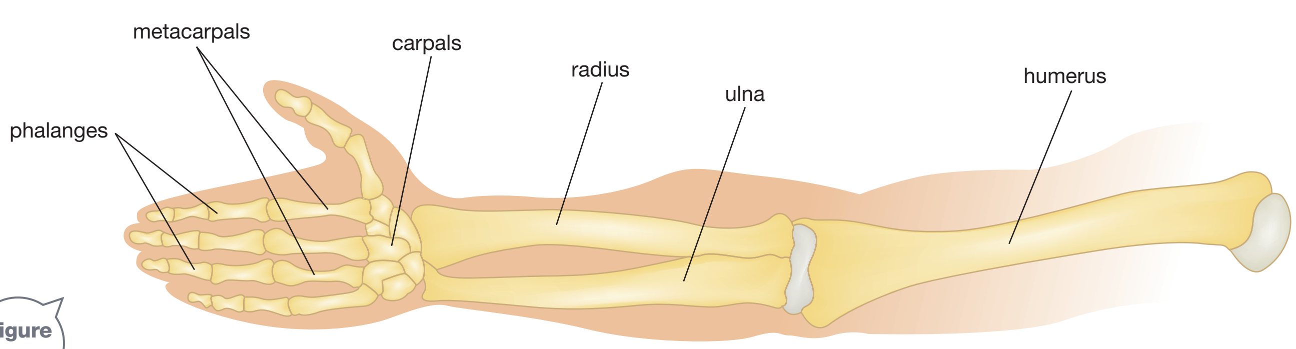
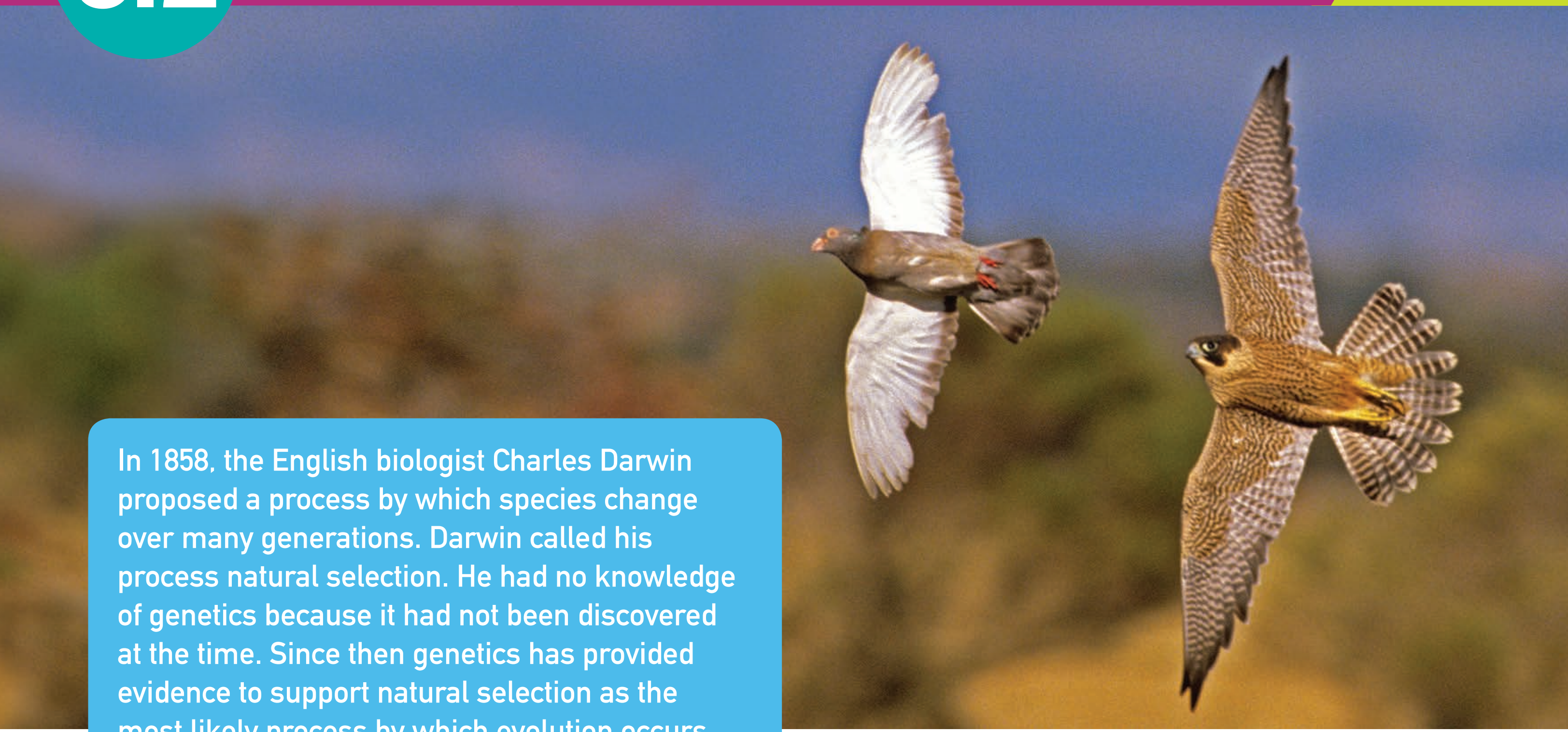


Figure 3.1.14

3.2 Natural selection



In 1858, the English biologist Charles Darwin proposed a process by which species change over many generations. Darwin called his process natural selection. He had no knowledge of genetics because it had not been discovered at the time. Since then genetics has provided evidence to support natural selection as the most likely process by which evolution occurs.

Darwin's ideas of natural selection

The following example will help you understand what Charles Darwin (Figure 3.2.1) meant by natural selection.

Consider a population of mice being preyed upon by owls. The mice have two different coat colours, dark brown and light brown. These colours are inherited. The owls swoop down to catch mice that are in the fields.

Imagine that there are equal numbers of dark-brown and light-brown mice. In areas where the ground colour is dark brown, the owls would find the light-brown mice easier to see. The owls would catch a greater number of light-brown than dark-brown mice. As a result, there will be more dark-brown mice surviving and breeding. The next generation would have more dark-brown mice than light-brown mice.

The dark-brown mice have been 'naturally selected' by the owls, as opposed to artificially selected by humans. Darwin meant that the selection was done by 'nature', not humans. The dark-brown mice had been selected to breed, but it was not intentional. They were favoured by selection to produce the next generation of offspring. Over many generations, this process would continue and the population would gradually become all dark brown and therefore better adapted to its dark brown environment.

This story of the mice shows natural selection at work. Different studies of mice have shown that natural selection also works on real mice, changing their population and characteristics.

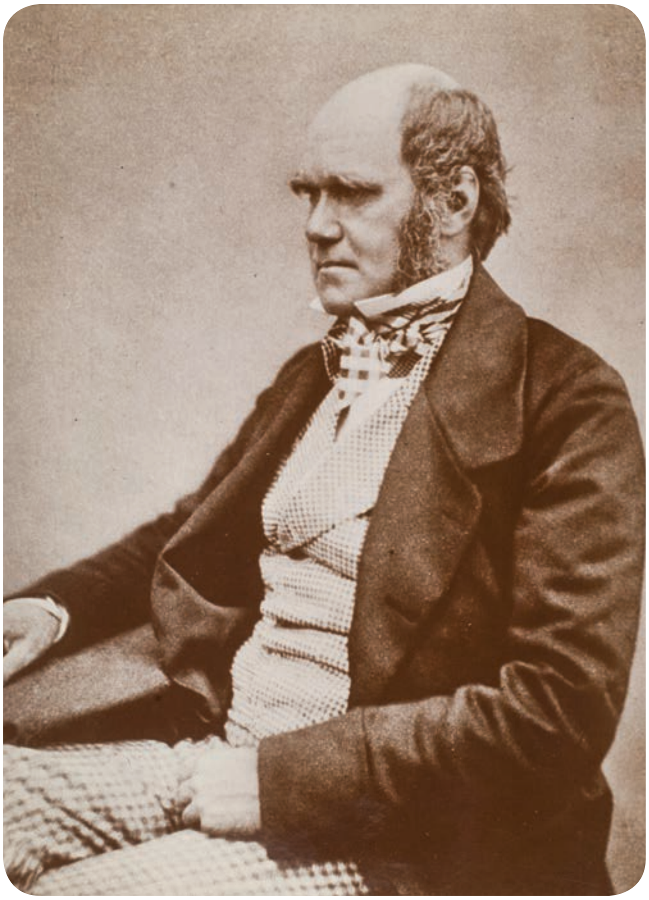


Figure 3.2.1 Charles Darwin (1809–1882) photographed in 1860, aged 51

Figure 3.2.2 In Arizona, USA, a study was performed to find out why rock mice living there has certain coat colours. It was found that by preying on mice that were easiest to see, owls were influencing particular coat colours in different locations. The end result was that each population became better adapted to its environment.

Natural selection defined

Natural selection is the process where an environmental factor acts on a population and results in some organisms having more offspring than others.

Biologists call the environmental factor that acts on the population the **selective agent**. The effect of natural selection on the population is referred to as 'selection pressure'. The selective agent in Figure 3.2.2 is the owl. The selective agent may be a biotic factor (another living thing), such as predation, bacterial infection or competition, or a physical factor, such as temperature, water, soil nutrients or fire (Figure 3.2.3).

Figure 3.2.3 Fire is a selective agent in Australia. Trees with thicker bark may better survive a fire as the bark can protect the living tissue beneath.

Many selective agents act by killing individuals. Such individuals are often less suited to surviving and are referred to as 'poorly adapted' or 'less fit'. For example, predators may find them easier to catch because they are slower runners, have poorer eyesight or are more easily seen. For example, light-coloured mice are less fit to survive on dark soil.

Selective agents do not always act by killing. For example, female birds often select brighter coloured males for breeding. Those males will produce more of the offspring in the next generation (Figure 3.2.4). Darwin called this **sexual selection**, because he thought of natural selection as being something that kills. But nowadays sexual selection is considered to be an example of natural selection because both change the characteristics of a species through selection.

Figure 3.2.4 This male great frigate bird with his air-filled throat pouch is trying to attract the female. Females are attracted to males with the most prominent red pouch.

The individuals that are favoured by the selective agent pass on their features to the next generation. So the next generation inherits those selected features. One outcome of natural selection is that the species gradually becomes better adapted to its environment. For example, the whole population of mice becomes more like the colour of the ground it lives on.

Variation

Darwin concluded that natural selection could only act if there is variation (natural differences) in the population. However, genetics was unknown in his time and so he did not know how or why this variation happened.

Since then, scientists have shown that **variation** is caused by differences in genes, which result in different characteristics. Since genes are inherited, so too are the characteristics they carry. Hence, variation is inherited too. Variation in most organisms is relatively easy to see. For example, humans show variation in height, nose shape, hairiness, baldness, leg length, and hair, eye and skin colour (Figure 3.2.5).

Figure 3.2.5 Variation in different people is due to inherited differences.

INQUIRY science 4 fun

Observing variation

Yes

Do this …

1. Go outside into the garden or the bush. Try to find many plants of the same type (species).
2. Choose a particular feature such as flower structure or colour; leaf shape, size and colour; or fruits (seed cases).
3. Study many examples of your chosen feature, looking for any variation you can see in it.

Record this …

Describe any differences you observed.

Explain what you observed.

Genetics and natural selection

A more modern definition of natural selection can be expressed in terms of genetics. Natural selection is the change in proportion of a particular genetic make-up (genotype) of a species over many generations due to environmental selection of a particular characteristic (phenotype). In simpler terms, this means the proportion of a particular characteristic (phenotype) in a species changes because individuals with a particular genetic make-up (genotype) within it are being favoured to breed.

Evidence for natural selection

The peppered moth

One of the first studies to collect evidence for natural selection was conducted earlier last century in England. Henry Bernard Kettlewell studied the peppered moth, which existed in two forms. The normal colour was white with black specks, although occasionally all-black mutant moths were born.

Kettlewell found that in the cities, almost all the peppered moths were black. In rural areas, they were almost all white. He concluded that this difference was due to a selective agent acting on the populations. The selective agents he observed preying on the moths were birds such as the flycatcher and nuthatch.

Kettlewell explained the process as follows:

- In the cities, all the building and tree trunks had been blackened by soot from over 150 years of industrial pollution. Any white moths resting on the trees could be seen more easily than the black moths (Figure 3.2.6). So the birds removed white moths faster than they removed the black ones. Black moths produce black offspring and so the population eventually became mainly black. So, the black form was considered to be better adapted to its polluted city environment.

Figure 3.2.6 Black and white peppered moths on a dark background

Figure 3.2.7 Black and white peppered moths on a light background

- In rural areas, the air was cleaner and tree trunks were of a lighter colour. This made the white moths harder to see (Figure 3.2.7). The black moths were eaten more often and so the population eventually became nearly all white. Now the white moths were better adapted to their environment.

Kettlewell carried out experiments where he placed the two different colours of moths on tree trunks and then observed birds feeding on the moths. He counted the numbers of light and dark moths eaten. His results showed that the birds ate mostly the dark moths on the light-coloured tree trunks and light-coloured moths on dark tree trunks. Some results are shown in Table 3.2.1.

Table 3.2.1 Natural selection of moths by birds

Place and background colour	Number of moths observed	Percentage dark eaten	Percentage light eaten
Birmingham wood—dark tree trunks	58	26%	74%
Dorset—light tree trunks	190	86%	14%

This experiment supported Kettlewell's observations made earlier in the country.

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Since Kettlewell's experiments, examples of camouflage against background colour have been found in many places around the world in species as varied as mice, snakes and snails. In England, over 100 species of moth demonstrate the same colour changes as observed by Kettlewell. Several of these studies have shown that the dark form of moth has declined in numbers in cities where pollution controls have been in force.

Natural selection highlights how much the environment affects living organisms, causing the characteristics of a species to change over many generations. Natural selection has been demonstrated more recently in many organisms such as bacteria, insects, snakes and cane toads. For example, many bacteria have become resistant to antibiotics and many insects are now resistant to insecticides.

3.3

Natural selection of insects

In the middle of last century, agricultural scientists developed chemical insecticides. These were sprayed onto crops to kill insects (Figure 3.2.8) and reduce crop damage caused by them. The scientists thought they would kill all the insects and that food production would rise greatly. However, these insecticides were only effective for a few years, requiring farmers to increase the concentrations of the insecticides they used. Also, not all the insects that were sprayed with insecticide died. Eventually the sprays had no effect, and none of the insects died. The scientists called this ability of insects to survive the poison spray **resistance** (Figure 3.2.9).

Although triggered by humans, the development of resistance to insecticides by insects is an example of natural selection.

Figure 3.2.8 Spraying crops with insecticides to kill insect pests

Figure 3.2.9 The diamond backed moth is a pest in vegetable crops such as cabbage and broccoli. It was the first crop pest in the world to develop resistance to the insecticide DDT. The moth is now resistant to all insecticides used before the mid-1990s.

The resistance that developed in insects was due to several mechanisms. One was that some insects could destroy the poison in their bodies. They had inherited cell chemistry that could do this. So there was variation in cell chemistry.

The resistant insects survived when the population was sprayed, but the non-resistant insects all died. The resistant insects then bred and produced offspring, most of which inherited resistance. Every time all the farmers sprayed, there would be a larger proportion of resistant insects on the crops. As many farmers sprayed over a large area, the insect population quickly became all resistant. This process is shown in Figure 3.2.10.

Figure 3.2.10 Insects become resistant to insecticides by natural selection.

Natural selection in bacteria

Bacteria are microscopic single-celled organisms. Some cause infectious diseases such as cholera, typhoid and pneumonia. In 1928, Scottish scientist Alexander Fleming found a way to kill bacteria. He discovered that some fungi make special chemicals to defend themselves against bacteria. The chemicals were given the name **antibiotics.** The first one to be isolated was called penicillin. Many more types of antibiotic have since been discovered.

Doctors sometimes prescribe antibiotics to kill any bacteria that are infecting you. This practice became widespread in medicine in the last few decades of the 20th century, and several types of antibiotics lost their effectiveness against many different bacteria. The bacteria had become resistant to them. You can see this in Figure 3.2.11.

Bacteria became resistant to antibiotics by natural selection. In the millions of bacterial cells infecting a person, some may have inherited cell chemistry that can destroy the antibiotic molecules, or may resist the antibiotic in some other way. This is similar to the resistance insects developed to pesticides. When you take the antibiotic, it kills all the bacterial cells that are not resistant. Any resistant ones may survive and reproduce, forming resistant offspring.

Bacteria reproduce by dividing in half, producing two copies of themselves. Each half divides again, often within 20 minutes. Hence, every 20 minutes or so the number of bacteria inside you could double. Eventually there will be enough resistant bacteria to make you ill. At this stage, taking more of the antibiotic will not work. You will need a different antibiotic, one to which the bacteria is not already resistant.

One very dangerous type of bacteria is golden staph, *Staphylococcus aureus*, seen in Figure 3.2.12. Golden staph is resistant to many antibiotics, and is very difficult to kill. It became resistant because of the widespread use of antibiotics in hospitals. Constant antibiotic use in hospitals kept selecting the resistant bacteria to survive. Eventually the species became resistant.

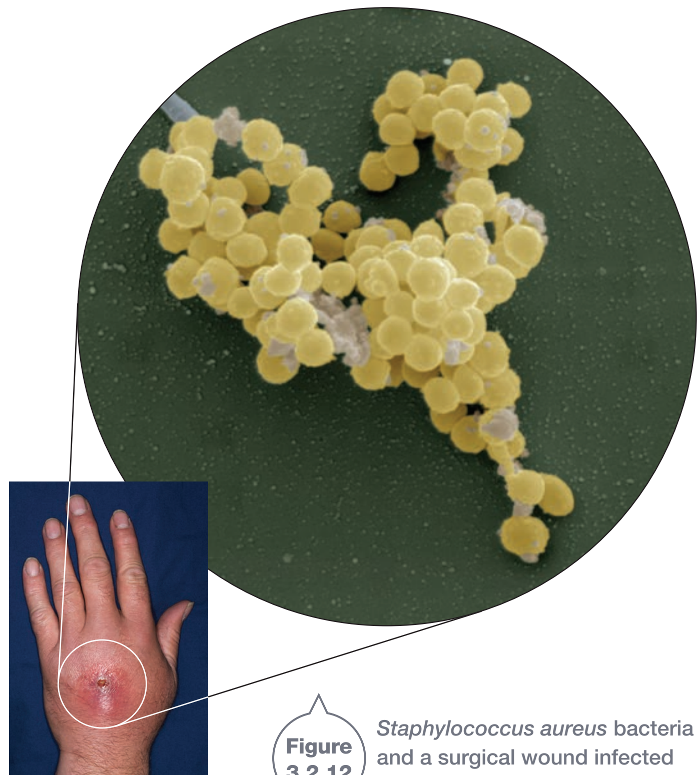

Figure 3.2.12 *Staphylococcus aureus* bacteria and a surgical wound infected with *Staphylococcus aureus*

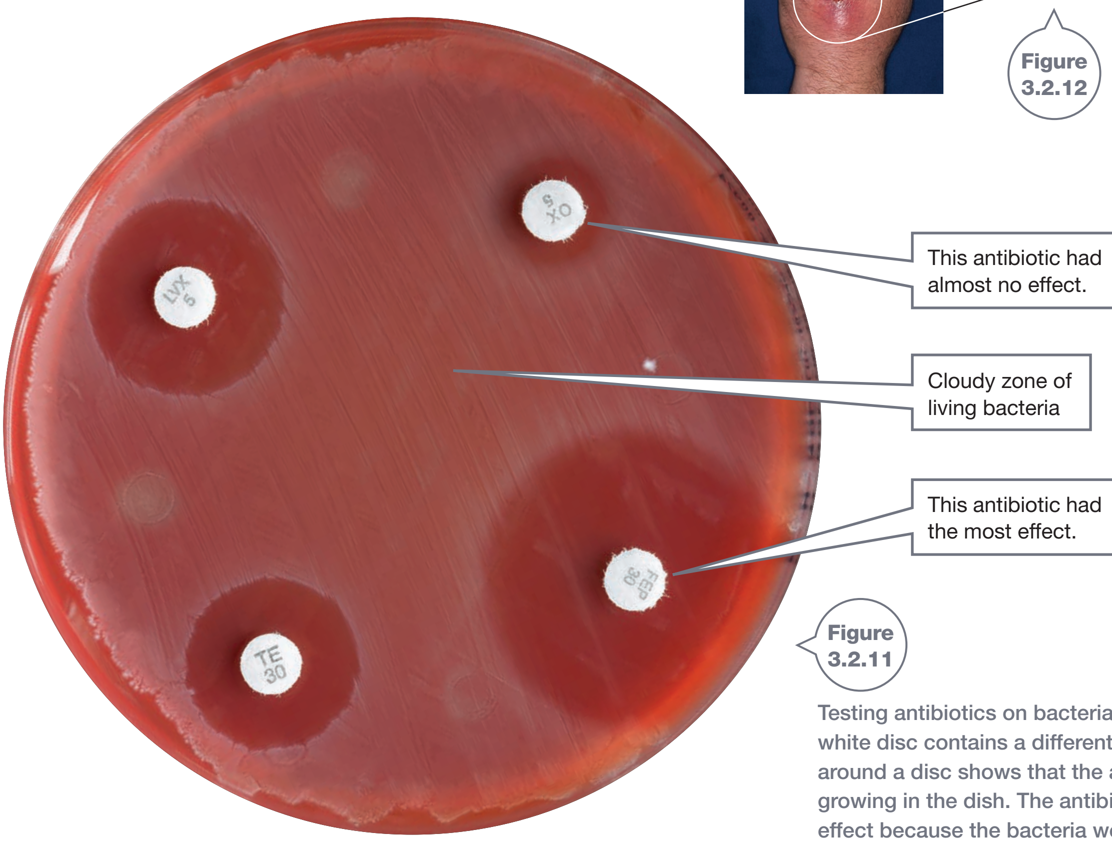

Figure 3.2.11 Testing antibiotics on bacteria growing in a dish. Each white disc contains a different antibiotic. The clear zone around a disc shows that the antibiotic killed the bacteria growing in the dish. The antibiotic at the top right had no effect because the bacteria were resistant to it.

3.2 Unit review

Remembering

1 **Name** the process proposed by Charles Darwin that explained how a species can change over many generations.

2 **List** four different selective agents.

3 **List** five examples of variation in humans.

Understanding

4 **Modify** the following statements to make them correct.

- **a** Natural selection is the process where an individual is acted upon by its environment and produces more offspring.
- **b** A selective agent acts on a population and improves the survival of some individuals more than others.

5 **Modify** the following definition of natural selection to make it correct.

Natural selection is the change in proportion of a particular phenotype of a species over many generations, due to environmental selection of a particular genotype.

6 **Explain** what is meant by *variation*.

7 **Define** resistance to insecticides or antibiotics.

8 **Explain** how light-coloured peppered moths gradually died out in the cities where pollution had changed the environment.

9 **Explain** why variation is necessary before natural selection can occur.

Applying

10 Consider the examples of natural selection in insects and bacteria in this unit.

- **a** **Identify** the selective agents in each case.
- **b** **Identify** the inherited variation in each case.

Analysing

11 **Compare** natural selection and artificial selection.

12 In his famous book *On the Origin of Species*, Charles Darwin said: 'This preservation of favourable variations and the rejection of injurious variations, I call Natural Selection.' **Compare** his definition with the one given on page 79.

Evaluating

13 **Analyse** the data in Table 3.2.1 (on page 81) and **justify** the conclusion made by Kettlewell.

14 **Propose** what would happen to populations of dark- and light-coloured mice living on light-coloured soil.

15 **Evaluate** whether humans have been and are still subject to natural selection.

16 **Evaluate** whether an individual can become adapted during its lifetime.

17 Spraying crops with pesticides has caused the development of pesticide-resistant insects. This is given as an example of natural selection at work despite humans being involved in the spraying.

- **a** **Identify** the agent for natural selection in this case.
- **b** **Assess** whether the example would be better classified as an example of artificial selection.
- **c** **Justify** your answer.

Creating

18 **Construct** a story based on natural selection that could explain how one of the following developed by natural selection: warning colouration in poisonous insects, venom in snakes, wings on dinosaurs.

19 Several early science fiction movies showed humans several million years in the future. They showed us with a huge brain and a head about twice as big. **Construct** an argument opposing this point of view.

Inquiring

1 Research Charles Darwin and discuss his contribution to the understanding of evolution by natural selection. If possible, read the first few pages of Chapter 4 of his book, *On the Origin of Species*. It is available free online.

2 Research and discuss the evidence of evolutionary change in Australian snakes and other predators due to the spread of the cane toad in Australia, and evidence that the toad has evolved to spread faster.

3 Research the famous Australian scientist Howard Florey and explain his contribution to fighting infectious diseases.

4 Research Batesian and Mullerian mimicry in butterflies and moths. Explain the difference between them by using examples such as the monarch or wanderer butterfly.

3.2 Practical activities

1 Natural selection modelled

Purpose

To use a model to investigate natural selection and the effect of camouflage.

Materials

- 2 different-coloured A3 sheets of paper
- 2 sets of 20 toothpicks of two different colours, to match the sheets of paper
- stopwatch
- tweezers
- cup
- bubble wrap or muslin material

Procedure

Part A

1 Work with a partner. One person is the experimenter and the other is the subject. The subject copies the table in the results section into their workbook.

2 The experimenter mixes up the coloured toothpicks and spreads them evenly over one of the sheets of paper while the subject is copying the table. Place a cup 50 cm away from the edge of the paper.

3 The subject stands up. They will have 20 seconds to use the tweezers to pick up as many of the toothpicks as they can, one at a time. Pick them off the paper and put them in the cup at the side of the paper. The experimenter will say when to start and when to stop.

4 When the time is up, the experimenter must count the number of each colour of toothpick the subject picked up. Write the results in your table and on the board.

5 Repeat the experiment with the other coloured sheet of paper.

Part B

6 Repeat the experiment but the subject must put bubble wrap or muslin material over their eyes to reduce their ability to see clearly.

Extension

7 Design and conduct a different method of testing out the effect of camouflage on natural selection, but outside the classroom. Make use of natural objects such as leaves, twigs and flowers.

Results

1 Complete the following table.

	Toothpick		Percentage different colour from paper
	Colour A	Colour B	
Good vision			
Paper colour A			
Paper colour B			
Poor vision			
Paper colour A			
Paper colour B			

2 Your teacher should put a class results table on the board. Enter your results and calculate a class average for each set.

3 Copy the class results into your workbook.

4 If you carried out the extension, report your results.

Discussion

1 In part A, **identify** which was picked up more often: toothpicks the same colour as the background paper, or toothpicks a different colour from the paper.

2 In part B, **identify** which was picked up more often: toothpicks the same colour as the background paper, or toothpicks a different colour from the paper.

3 **Compare** the effect of good vision and poor vision on the results.

4 **Discuss** how this experiment models the effect of camouflage on natural selection.

5 **Evaluate** whether this experiment was effective in modelling the effect of camouflage on natural selection.

6 If you carried out the Extension, **draw** a conclusion based on your results.