Chapter 3: Natural selection and evolution

Unit 3.1

1 Body increases in size, legs become longer and number of toes decreases.

2 Budgerigars—different colours and patterns. Dogs—different sizes and shapes

3 Birds seem to be related to a group of dinosaurs called theropods. They both have feathers.

4 a Genetic change in the characteristics of a species over many generations, resulting in a new species.

   b The time between the birth of an individual and when they produce their own offspring.

   c Structures that are controlled by some of the same inherited genes.

5 Fossils show the structure of past organisms; this can be compared with current living species. Many look similar and yet show some differences that suggest they changed over time.

6 Budgerigar breeders choose which parents will mate according to their characteristics. Mutations may be chosen and deliberately passed on. By continually selecting particular features, some of the general characteristics of the species such as size, colour and patterning can be changed.

7 Species with the same basic structure must have many genes the same because genes control structure and function in organisms. Therefore, species sharing genes must have had the same ancestor at some stage.

8 a Plants that were different from the normal plants—mutants

   b Mutation

   c He crossed parent plants with different features and selected offspring that had a combination of the desirable features.
Dolphins and sharks both have a dorsal fin, and streamlined body shape. However, dolphins have lungs and shark have gills, so they are not very closely related.

There are differences in the number of toes and the thickness of the toes. Toes changed from 4 to 1 and the central toe became thicker.

The whole skull enlarges, the jaw grows relatively longer, a gap appears behind the front teeth and the teeth become longer.

Homologous structures look alike and have the same basic structure, such as the similar bone structure in the front limb of mammals, reptiles, birds and amphibians. Analogous structures may look alike, but they have a very different structure. For example, the fins on a shark do not have bones in them like the flippers on a dolphin.

The bat arm (wing) has most of the same bones as a mouse arm, and they are therefore homologous. But the long fingers of the bat support the membrane for the wing and are adapted for flying, whereas a mouse arm is for walking—two entirely different functions.

Cross-breeding is the process of producing offspring different from both parents, but with some desirable features from each. However, inbreeding is the crossing of parents who have similar features, the aim being to make the offspring as similar to the parents as possible.

Breeders waited for different features to appear in the offspring. These features were due to genetic changes. By taking these individuals and breeding from them the features can be passed on and become common and permanent in the offspring.

Birds are the only group of animals alive today that have feathers, and dinosaurs and birds are the only fossil groups known to have had feathers. Scientists say that feathers are homologous structures in birds and dinosaurs. This does not mean that feathers were used for the same purpose in dinosaurs and birds. Homologous structures occur through common genes.
16  a, b  Cross a dark-pink-flowered thorned rose with a white-flowered thornless one (i.e. cross-breed them). Plant the seeds and search among the offspring for any that may have inherited the pink flower and no thorns. Inbreed these, seek out the offspring with desired features and continue the inbreeding process for several generations.

Unit 3.2

1  Natural selection

2  Predation, bacterial infection, competition, temperature, water, soil nutrients, fire

3  Height, natural hair colour, length of legs, eye colour, ear lobe attachment are variations

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

    b  A selective agent acts on a population and affects the chances of reproducing of some individuals more than others.

5  Natural selection is the change in proportion of a particular genotype of a species over many generations due to environmental selection of a particular phenotype (the phenotype is selected by the selective agent, not the genotype)

6  Differences in characteristics due to differences in genes.

7  The ability of organisms to survive insecticides or antibiotics due to inherited mechanisms such as being able to destroy the poison in their bodies.

8  Predatory birds could see the light-coloured moths more easily than the dark moths when the moths were on the blackened trees. So more light moths were removed from the population and the proportion of light offspring (i.e. the proportion of the light-coloured gene) was gradually falling. Eventually the population became mostly dark coloured.

9  Selection acts on differences—the selective agent is selecting one feature (phenotype) over another. If all individuals are the same, then none can be favoured by selection.
10 a Insects—insecticides. Bacteria—antibiotics

b The ability to destroy the poison by the cell chemistry. Also, some bacteria have the ability to prevent the chemical entering the cell.

11 Both natural and artificial selection (directed selection) involve a factor in the organism’s environment acting on the phenotype of the individual, and both change the number of offspring produced (usually by affecting their survival). However, artificial selection (directed selection) involves humans deliberately choosing which individuals will breed and then selecting which offspring will be allowed to breed.

12 Darwin thought about natural selection as something that could kill (‘rejection of injurious variations’), whereas it is now thought of as a process where individuals are favoured in how many offspring they leave rather than whether they live or die. It often amounts to the same thing because an organism that lives longer usually also has more offspring.

13 Kettlewell concluded that the birds mostly ate the dark-coloured moths on the light tree trunks and light-coloured moths on dark tree trunks. The results support this.

14 On light-coloured soil, the population should have a much higher proportion of light-coloured mice than dark-coloured mice. The predators would see the dark mice more easily, and they would be preyed on at a greater rate, removing the dark gene faster than the light one.

15 Humans have been subjected to natural selection. An example is the Black Death in Europe in the 1600s. Many of the population died; those who survived had a higher inherited resistance to the bacteria. We are still subject to natural selection, but medicine has reduced the impact of this. Many survive now who would previously have died.

16 No. Adaptation occurs through natural selection, by change over generations.

17 a The pesticide

b No, it is natural selection.

c Although humans sprayed the chemicals, they did not deliberately choose particular insects to cross-breed.
18 Depends on student answer.

19 This is not likely because the fetal head has to pass through the mother’s pelvis during birth, unless reproduction occurs in a different way outside a mother’s body. The mother’s pelvis would have to be twice as wide as now for the same body height. This would probably interfere with walking.

Unit 3.3

1 Evolution

2 Interbreeding, protein structure, DNA sequence

3 Variation, isolation, selection

4 They don’t recognise each other as the same species, they have different breeding times or breeding rituals, their gametes are incompatible

5 Part of the branchial arches in bird and fish embryos

6 See if two organisms can interbreed to produce fertile offspring under natural conditions. Identify the similarities in the amino acid arrangement in several different proteins they make. Determine the nucleotide sequence of the DNA (identify common genes).

7 Genetic isolation means different groups of the population must be prevented by some mechanism from interbreeding.

8 A donkey and a horse can mate and produce an offspring, but the mule offspring is always sterile.

9 Early fossils show fairly simple organisms; later ones show increasingly complex ones. This makes sense in the light of genetics, because new alleles and genes develop from existing genes by mutation. There is also an increasing number of species from the earliest fossils to the present day. This would be expected if species continually split into several other species over time.

10 If genes can flow freely, then any genetic difference such as a mutation can spread through a whole population. There will not be enough variation in the populations in the two different environments to allow natural selection to change them enough that they become reproductively isolated.
11 The Gcm-2 gene controls how the branchial arches of the chicken embryo develop into parathyroid glands while the same arches in fish develop into gills. Since both are controlled by the Gcm-2 gene, then fish and chickens must be related. They have inherited the same gene, and genes are passed on from ancestors to offspring.

12 Islands are separated by water, which is an effective barrier to gene flow. Any changes due to natural selection in one place cannot reach the other population.

13 Fossils with features of two groups represent a group that is evolving, separating from ancestral groups. The lobe-finned fish would have included a species that evolved into amphibians. At some point, there must be species that had features of both groups as one evolves into another.

14 The process of speciation involving variation, isolation and selection results in the development of new, different species. This increases biodiversity.

15 a Evolution is the changes in the species over time, whereas natural selection is the process by which that happens.
   b Speciation is the splitting of a species into two or more species whereas natural selection is the process by which that occurs.
   c Evolution includes speciation. Evolution links all species by descent from a common ancestor; speciation is the process going on as new species develop from existing ones.

16 a Apes
   b Apes have less difference in the protein—fewer mutations means shorter time span between groups.

17 The proposed evolutionary sequence (with amino acid differences with humans in brackets) is fish (21) → amphibians (18) → reptiles (15) → birds (13) → mammals.

The closest relative based on anatomy is chimps (0), then monkeys (1) and whales (10). So the number of amino acid differences is in the same sequence as the proposed evolutionary pathway.
18 • One species with variation spreads over a wide area.
   • A canyon deep and wide enough to be a geographical barrier develops.
   • Selection occurs differently on each side of the canyon.
   • Mutation and selection continues for a long time. Genetic isolation develops
     as changes in mating habits and body chemistry make them unable to breed
     even if the canyon disappears.

19 The diagram should show the following steps.
   • Variation exists in the frog species.
   • Nullarbor Plain develops—a climatic geographical barrier.
   • Selection occurs differently in Western Australia and Victoria. Different
     selective agents operate.
   • The frogs become genetically isolated as changes in mating habits, such as
     calls, and reproductive biology occur.

Unit 3.4

1 Class Mammalia, order Primates, family Hominidae, genus Homo, species
   Homo sapiens

2 Lemurs, lorises, tarsiers, Aye-aye, potto, New World monkeys, Old World
   monkeys, chimpanzees, gorilla, orang-utan, gibbons

3 Most of them have ‘grasping’ hands, nails rather than claws and forward-facing
   eyes.

4 Humans, chimpanzee, gorilla

5 Chimpanzee and gorilla

6 There were several types. A. afarensis was about 1.3 metres tall and weighed
   about 30 kg. Their brain was about 410 cm³, about the size of a chimpanzee’s,
   but they had a much smaller body weight. They walked upright on two legs as
   shown by the shape of their pelvis and the carrying angle of the femurs.

7 Modern humans evolved in East Africa about 200 000 years ago, migrated out of
   Africa 60 000 years ago and reached all continents by 15 000 years ago.
8 mtDNA is only passed from mother to children. Mitochondria separate into each gamete while meiosis occurs.

9 My biological mother.

10 Perhaps Homo erectus migrated out of Africa and reached Flores some time in the past, where it evolved into a smaller species. Alternatively, Homo sapiens migrated out of Africa, became isolated on Flores and evolved into a smaller version of Homo sapiens. In either case, the brain size is very small relative to the body size of H. floresiensis.

11 Homo ergaster was about the same height as Homo sapiens. The Turkana Boy specimen was 1.6 metres tall and may have reached 1.85 metres as an adult. The Turkana Boy had a tall, slender body adapted for walking long distances, similar to ours. His brain size though was much smaller probably around 910 cm³ when he reached adulthood compared with 1450 cm³ for us.

12 Nuclear DNA comes from copies of the nuclear DNA received from both parents. mtDNA is inherited only from the mother as it is not nuclear DNA. The mtDNA in sperm is destroyed at fertilisation.

13 There is only one fossil, of a skull. Generalising from one skull needs to be done with caution.

14 Two independent methods of genetic analysis, mtDNA and Y chromosome analysis both show agreement on migrations from Africa—based on mutation rates in the two DNA types.

15 a Homo ergaster or Homo habilis migrated out of Africa before 1.7 million years ago.

b The Georgian specimen was very short—much shorter than Homo ergaster, but comparable with Homo habilis. Its brain was much closer in size to that of Homo habilis than Homo ergaster.

16 Upright stance evolved first as shown by Australopithecines, which were upright walkers long before there was any brain size increase.
17 *Australopithecus afarensis* had a range of variation in brain size and this affected intelligence. The more intelligent, larger brained individuals had a greater survival rate because they could solve the problems of survival such as making better tools and finding better food sources. They therefore left more offspring who inherited their larger brain size and intelligence. The differences were eventually enough to classify them as *Homo habilis*.

**Chapter review**

1 Charles Darwin

2 Variation, isolation, selection, reproductive isolation/speciation

3 Fossils, comparative anatomy, DNA and protein sequences, distribution of species, embryology

4 a Homologous structures do not have to perform the same function in different species.

   b Differences in the position of amino acids in a protein show how closely related species are.

   c Organisms that look similar do not necessarily have the same genes causing the similarity.

   d Variation in a species is not caused by natural selection.

   e Natural selection acts on the phenotype of an organism.

5 Early fossils show fairly simple organisms; later ones show increasingly complex ones. There is also an increasing number of species from the earliest fossils to the present day. This is what you would expect if species continually split into several other species over time. Transitional forms are what you would expect if one group changes into another.

6 a Bacteria are resistant to antibiotics, insects are resistant to insecticides.

   b Natural selection has resulted in improved survival and reproductive rates of individuals that have genes giving them resistance to the antibiotic or the insecticide.
Using cross-breeding and inbreeding. Breeders choose which parents will mate. Mutations may be chosen and deliberately passed on. By continually selecting particular features, some of the general characteristics of the species such as size, colour and patterning, can be changed.

Speciation can only occur if groups are genetically isolated from each other. Then any change in one group cannot spread to the other group, which therefore allows enough differences to build up to make them different species.

Analysis of mutations in mtDNA and Y chromosomes have shown that particular mutations arose in Africa and in areas leading from Africa and around the globe in a steady time sequence.

Dark mice living on dark soil are camouflaged from predators by coat colour. If the climate becomes drier and predator numbers decrease, then lighter colours would enable mice to absorb less heat. Lighter colours would be selected for even on dark soil.

Birds (class Aves) did not exist before dinosaurs (class Reptilia). The fossil record shows that some species of dinosaur developed feathers and eventually one became different enough to be classified as a different class—birds.

Grasping hands, forward facing eyes and nails instead of claws.

The pentadactyl limb has changed from five digits supported by three major bones to the body into variations in the shape of the bones, number of digits and number of supporting bones. All changes are related to the function of the limbs in different species.

Without variation, neither can occur.

Homologous structures are those that in related individuals have the same basic structure. Analogous structures are ones that in distantly related individuals appear similar but have a different structure.

They are analogous structures.

Animals such as bacteria and insects have very short generation times, so natural selection acts on many more generations in the same time. This results in features being passed on to offspring much faster so the evolutionary change of adaptation will be much more rapid.
18 As long as the structure is based on homologous components (rather than superficial resemblance) then they must be related, because genes are what build structures and genes are copied from existing genes inherited from ancestors.

19 The structures associated with upright stance and walking—the pelvis, femur, foot and vertebral column structure.

20 Natural selection will remove any individual not adapted to cope with it. Domestic species are nurtured by humans and are not subject to most of the selective agents in the wild.

21 Early Homo had a range of variation in brain size and this affected intelligence. The more intelligent larger-brained individuals had a greater survival rate because they could solve the problems of survival. They therefore left more offspring who inherited their larger brain size and intelligence. Any mutations in genes affecting intelligence would have been selected for.

22 Diagrammatic answer (see below)
Thinking scientifically

Q1 B
Q2 C
Q3 A
Q4 B
Q5 D