SUGGESTED TEXTBOOK ANSWERS

Chapter 15 Evidence for evolution

The following are suggested answers only. Other answers to the same questions may also be correct.

Science inquiry

Activity 15.1 Amino acid sequencing

What to do

2 Record your data in a table.

Answer:

Species comparison	Number of differences in the amino acid sequences of haemoglobin
Human and chimpanzee	0
Human and gorilla	1
Chimpanzee and gorilla	1
Human and rhesus monkey	2
Chimpanzee and rhesus monkey	2
Gorilla and rhesus monkey	1
Human and horse	5
Human and kangaroo	7

3 Using only the data from this section of the haemoglobin molecule, rank the species in order from the one closest to humans to the one most distant.

Answer: Chimpanzee → gorilla → rhesus monkey → horse → kangaroo

Studying your data

1 Based on this segment of the haemoglobin molecule, which species of mammal appears to be the most closely related to humans?

Answer: Chimpanzee

2 Which animal appears to be the least closely related to humans?

Answer: Kangaroo

3 Which of the other pairs of species show close relationships?

Answer: Chimpanzee and gorilla; gorilla and rhesus monkey

4 These sequences of amino acids are generally very similar but not identical. If these species were all descended from a common ancestor how would the changes in the sequences of the different species have come about?

Answer: Mutation and then natural selection

5 Do you think the differences in the amino acid sequences between the species would affect the function of haemoglobin?

Answer: No. Although the sequence of amino acids in the haemoglobin molecule is different the basic structure of the whole molecule is the same and its function of binding the oxygen molecules is the same.

In summary

Using the information from the sequences of amino acids in haemoglobin, describe the evolutionary relationships between the species in terms of the evolution of humans.
Answer: Chimpanzees, gorillas, rhesus monkeys and humans are more closely related and have a more recent common ancestor. The kangaroo and horse would also have a common ancestor with chimpanzees, gorillas, rhesus monkeys and humans, but further back in time than the primate common ancestor.

Review questions

1 Using an example, explain how the study of DNA in different species has added to the evidence for evolution.

Answer: All species of organism have the same DNA code, which indicates that all living things evolved from a common ancestor. When speciation occurs (that is, an ancestral species giving rise to two or more new species), the new species would have very similar DNA. As the species change, there would be more and more differences between their DNA. Species that are closely related will have more similarities in their DNA; more distantly related species will show greater differences.

For example, the genome of chimpanzees shows that they share over 98% of human DNA. Humans and orang-utans have approximately 97.5% of their DNA in common, so orang-utans are more distantly related to humans than chimpanzees.

2 **a** What are endogenous retroviruses?

Answer: Endogenous retroviruses are a viral sequence that has become part of an organism's genome.

b How do retroviruses become endogenous?

Answer: A retrovirus copies its RNA into the DNA of the host cell. The retrovirus only becomes endogenous if copies of its RNA are inserted into the DNA of a germ cell, which through meiosis becomes a sperm or an egg.

c What is the value of endogenous retroviruses in a study of evolution?

Answer: All offspring of the infected individual will have a copy of the ERV in the same place in the same number chromosome. Subsequent generations will all be affected in the same way. This makes the study of endogenous retroviruses important in determining evolution, because the ERVs will show relationships between species. Species with the same ERVs will be closely related.

3 Describe how each of the following has facilitated DNA sequencing.

a Polymerase chain reaction

Answer: If only very small amounts of DNA are available, the polymerase chain reaction can be used to produce large amounts of the DNA so that it can be used in the sequencing of a genome.

b Gel electrophoresis

Answer: Gel electrophoresis is used to establish a DNA profile, which can then be compared with other profiles to trace relationships between individuals and groups.

c Bacterial enzymes

Answer: Restriction enzymes derived from bacteria are used to cut the DNA molecule into smaller fragments, which can then be separated by gel electrophoresis. The DNA can then be sequenced.

4 a What is mitochondrial DNA (mtDNA)?

Answer: Mitochondrial DNA (mtDNA) is DNA located in the mitochondria of cells.

b Describe how mtDNA has been used to provide evidence for evolutionary relationships between species.

Answer: mtDNA is inherited only from the mother. The mtDNA is a copy of that which was in the female parent's egg cell. mtDNA mutates more often than nuclear DNA, and the amount of mutation of mtDNA is roughly proportional to the amount of time that has passed. Similarities and differences in the mtDNA of species can thus show evolutionary relationships.

c Give an example where mtDNA has provided information about such a relationship.

Answer: Studies of mtDNA have shown that most modern Europeans are descended from hunter-gathers who settled in Europe during the last Ice Age.

mtDNA evidence has also shown that the last common ancestor of Neanderthals and modern humans lived approximately 600 000 years ago.

5 Describe how the sequence of amino acids in proteins can be used to determine the degree of similarity between species.

Answer: By comparing the type and sequence of amino acids in similar proteins from different species, the degree of similarity can be established. The greater the similarity between the sequence of amino acids in the proteins of species the more closely related they are.

6 a What are ubiquitous proteins?

Answer: Ubiquitous proteins are proteins that appear to be in all species. They carry out the same functions regardless of the species in which they are found.

b Why has cytochrome C been so valuable in providing evidence for evolution? Give examples of species that contain cytochrome C.

Answer: Cytochrome C is a ubiquitous protein that has changed very little over millions of years of evolution. It has common amino acid sequences among many species and provides evidence for evolution and relationships between species. The more similarity there is between the cytochrome C from different species, the more recently the species have evolved from a common ancestor. Cytochrome C is found in plants, animals and many unicellular organisms.

c Besides cytochrome C, what other proteins have been used to provide evidence about relationships between species.

Answer: Haemoglobin is another protein that can be used to show relationships between species.

7 a How has bioinformatics assisted biologists in refining evolutionary relationships?

Answer: Bioinformatics is the use of computers to describe the molecular components of living things and in doing so has allowed evolutionary biologists to trace the evolution of a large number of organisms by measuring their DNA. This has been a change to the more traditional approach of studying physical taxonomy or the use of physiological observations.

b What role has comparative genomics played in the study of evolutionary changes among organisms?

Answer: Comparative genomics compares the genomes of different species. Regions of similarity and difference between genomes can be identified. Using this technique precise relationships between species can be determined.

8 How does a study of embryology assist in supporting the theory of evolution? Give examples to illustrate your answer.

Answer: Embryology compares the early stages of development of organisms. It is useful because the embryonic stages between species are more similar than the adult stages, thus indicating evolutionary relationships. For example, all vertebrate embryos have gill arches and gill pouches, indicating that they all diverged from a common aquatic ancestor.

9 a What are homologous organs?

Answer: Homologous organs are organs that possess a similar structure, even though their functions may differ; for example, the fore-limbs of vertebrates.

b Using an example, describe how homologous structures provide evidence for evolution.

Answer: Species with organs that have a similar structure are likely to have evolved from a common ancestor. For example, the same limb bones appear in various forms throughout the vertebrates – the forelimbs of amphibians and reptiles, the wings of bats and birds, the leg of a horse, the flipper of a whale or seal and the human arm. These similarities between the classes of vertebrates indicate that they have all diverged from a common ancestor.

10 a What is a vestigial organ? Describe four human vestigial organs.

Answer: Vestigial organs are structures that have, over the course of evolution, been reduced in size and appear to have no function. Vestigial organs possessed by humans include:

- coccyx – formed from fused vertebrae for a tail
- appendix – which is a reduced caecum that appears to have no function
- male nipples
- wisdom teeth – not needed for chewing.
- body hair – not required for maintaining body temperature
- muscles attached to external ear – most people are no longer able to move their ears.

b Describe the significance of vestigial organs to the theory of evolution.

Answer: Vestigial structures, which appear to have no function, show that in ancestors they did function. However, over time, and as the result of changing environments, these organs were no longer necessary and their size and function gradually decreased.

11 Explain how the geographical distribution of species provides evidence for evolution.

Answer: The geographical distribution of species shows which groups were separated and have evolved independently. This demonstrates how evolution has occurred, resulting in related species having different characteristics.

12 Describe how Darwin explained the way different populations of finches became established as separate species on the Galapagos Islands.

Answer: Darwin suggested that the first finches to reach the Galapagos Islands from the mainland of South America would have shown variation in beak shapes. Then, with different environments and food sources on each of the islands, different beak types on different islands were selected for. Those with a favourable beak shape for the food source on a particular island had a survival advantage. This favourable beak shape would be passed on to offspring. Over many generations, natural selection would have favoured those characteristics (not just beaks) that aided survival on that particular island. This eventually resulted in each island developing its own species with distinctive characteristics.

Apply your knowledge

1 When ancestral species evolve into two or more separate species, those new species would exhibit considerable similarity in their DNA. What causes the DNA to change over time? How has the information from DNA been used by scientists to speculate on the relationships between species?

Answer: DNA may change over time due to mutation. Mutant forms are then subject to natural selection or genetic drift or any other evolutionary process. Because the DNA would be the same in the ancestral species and, because only some of the DNA would change over time, the relationship between the new species can be determined by scientists by comparing the similarities in their DNA. Changes to the sequence of bases in a DNA molecule can also arise because of the insertion of endogenous retroviruses.

2 Modern technology has provided the means to compare DNA and protein sequences. How has this changed the traditional way of looking at the relationships between humans and apes?

Answer: Experimentation with the DNA strands from different primates suggests an increasing genetic distance between humans and the other primate groups as one progresses from chimpanzees, to gorillas, to orang-utans, to gibbons and to Old World monkeys. This indicates that humans and chimpanzees are much more closely related than structure alone would appear to suggest. Therefore, modern classifications reflect this closer relationship.

3 Explain why mtDNA is only of use when looking at the relationships within a species or between closely related species.

Answer: mtDNA has only 37 genes, so species that are not closely related may have so many mutations that relationships would be difficult to determine. Also, mtDNA has a higher rate of mutation than nuclear DNA, so that it is only possible to look at the relationships within a species or in groups that have only relatively recently become separate species.

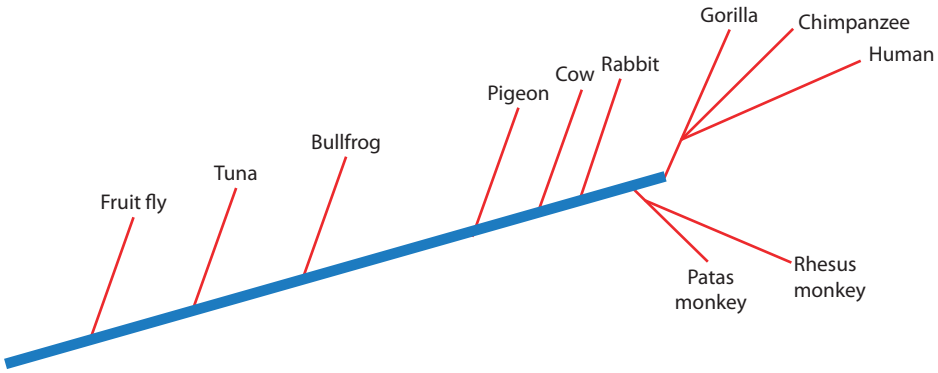
4 Explain why scientists select ubiquitous proteins for their biochemical research on the relationships between species.

Answer: Ubiquitous proteins are used to determine relationships between species because:

- they are found in all organisms
- they are completely independent of an organism's specific function
- they are independent of the environment in which the organisms live
- they carry out the same function in all species.

5 Refer to Table 15.4, which indicates the degree of difference in the amino acids in cytochrome C between humans and some other species. Using this information, construct a family tree to illustrate a possible relationship between those species.

Answer: A possible family tree could be:



6 Why would scientists use a comparative study of haemoglobin in different species in a search for data to support their theories of primate evolution?

Answer: Haemoglobin is common to all primates. The idea that there is a common primate ancestor means all primates would have started with the same haemoglobin and, as they have formed separate species, there have been gradual changes in the haemoglobin. Comparing these differences will demonstrate the relationships. The more similar the haemoglobin, the more closely and recently related the species.

7 Comparative genomics has been used effectively to examine relationships between species. There have also been successful applications of comparative genomics in other fields of biological science. Find out what these successes have been.

Answer: Comparative genomics has also been used for studying evolutionary changes among organisms, helping to identify genes that are conserved or common among species, as well as genes that give each organism its unique characteristics. For example, comparison of the fruit fly genome with the human genome revealed that the two organisms appear to share a core set of genes. Researchers have also found that two-thirds of human genes known to be involved in cancer have counterparts in the fruit fly.

In addition to its implications for human health, comparative genomics may benefit the broader animal world and ecological studies as well. As sequencing technology grows easier and less expensive, it will find wide applications in agriculture, biotechnology, and zoology as a tool to tease apart the often-subtle differences among animal and plant species.

8 In this chapter, the forelimb was used as an example of homologous structures. What other structures found in vertebrates could be used to illustrate homology?

Answer: Muscle structures and arrangements; skeletal structures other than limbs; tail bone in primates – tail and coccyx; alimentary canals. Ear bones in mammals are homologous to gill and jaw bones in fish.

9 Homologous organs are so called because they have a similar structure. However, the basic structure may be modified substantially to carry out a different function. Describe the changes that have taken place to the vertebrate forelimb for it to become:

a a flipper

Answer: In a flipper, the humerus is shortened and thickened; the shortened and thickened ulna and radius have a minimal gap between them; the phalanges are modified: 1 is reduced, 2 is lengthened, 3 is slightly reduced, and 4 and 5 are significantly reduced; all phalanges are thickened. See also the diagram of bones in a flipper in Figure 15.6 on page 225. These changes have made the bones capable of providing the strong support needed for a flipper.

b a wing

Answer: In a bat's wing, all the bones are reduced in thickness and elongated; the metacarpals and phalanges make up the main structures of the wing that the skin is stretched across; the bones are thickened and shortened; the humerus, ulna and radius make up the main part of the wing with significantly reduced and fused metacarpals and phalanges.

In a bird's wing, the humerus, radius and ulna are arranged in a similar way to humans, but the metacarpals and phalanges are mostly fused together to give the wing more strength. See also the diagram of bones in a wing in Figure 15.6 on page 225.

c an arm.

Answer: In a human arm, the humerus, ulna and radius are thickened and lengthened; the metacarpals and phalanges are also elongated; in humans, the first digit has developed a saddle joint so that the thumb is opposable. See also Figure 15.6 on page 225.

10 In 1893 a German anatomist, Robert Weidersheim, compiled a list of 86 vestigial organs. On his list were the valves in veins, the tonsils, the pituitary gland and the thymus. Why must scientists be very careful about describing an organ as vestigial?

Answer: They must be careful in describing an organ as vestigial in case its function has not yet been discovered. Also, the function of some so-called vestigial organs can change over time and the new function may become important to the organism.

11 More than 135 years ago, Darwin predicted that fossils of the ancestors of modern humans would be found in Africa. What evidence would Darwin have used as the basis for making that suggestion?

Answer: Darwin studied the relationship between species. His interpretation of the primate data at the time led him to believe that humans were related to monkeys and apes. His studies were based on physiological, anatomical and behavioural comparisons. He thought that fossils of human ancestors would be found in Africa because he considered humans to be more similar to African apes (gorillas and chimpanzees) than to Asian apes (orang-utans and gibbons).