

SUGGESTED TEXTBOOK ANSWERS

Chapter 16 Fossil evidence for evolution

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

Science inquiry

Activity 16.1 Radioisotope methods of dating

A. Radiocarbon dating

What to do

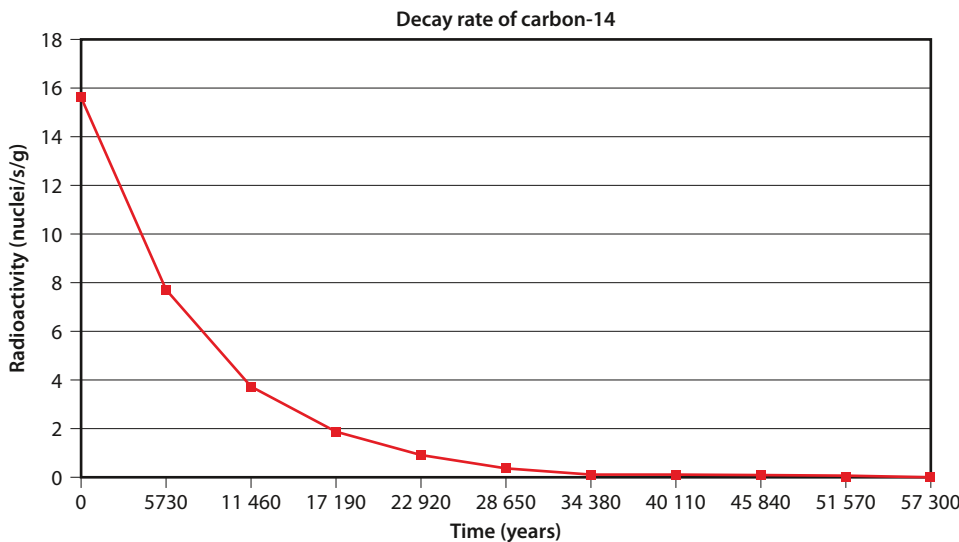
- 1 Draw up a table like Table 16.3 and fill in all the gaps.

Answer:

Half-life	Age (years)	Radioactivity (nuclei/sec/g)	Half life	Age (years)	Radioactivity (nuclei/sec/g)
0	0	15.6	6	34 380	0.24375
1	5730	7.8	7	40 110	0.121875
2	11 460	3.9	8	45 840	0.0609375
3	17 190	1.95	9	51 570	0.03046875
4	22 920	0.975	10	57 300	0.015234375
5	28 650	0.4875			

- 2 On your sheet of graph paper, plot a decay curve for carbon-14 to show the relationship between decay rate and time, up to a maximum of 60 000 years. (Before doing this, you may wish to check page 13 on how to draw a graph.)

Answer:



3 Use your graph to answer the following questions.

- a Charcoal remains from a hearth in a cave occupied by Australian Aborigines were found to have a decay rate of 8.9 nuclei/s/g of charcoal. How old was the charcoal?

Answer: Approximately 4500 years old. (This figure will vary depending on the accuracy of the graph and whether students have plotted a smooth curve or ruled straight lines between the points.)

- b A piece of wood buried in a cave in Europe was found alongside stone tools that were considered to be about 9000 years old. If the wood were the same age as the tools, what decay rate would you expect from the piece of wood?

Answer: Approximately 5 nuclei/s/g

- c If the piece of wood from question b was found to be considerably older than 9000 years, what explanations can you offer for the fact that it was at the same level in the cave deposits as the tools?

Answer: Animals or humans could have buried the tools; or there could have been disruption to the burial process or site of both the tools and wood.

- d If the piece of wood was found to be considerably younger than 9000 years, suggest reasons to account for the fact that it was at the same level in the cave deposits as the tools.

Answer: Animals or humans could have buried the wood; or there could have been disruption to the burial process or site of both the tools and wood.

- e A fossil bone was discovered and when tested had a decay rate of 1.5 nuclei/s/g. How old was the fossil bone?

Answer: Approximately 20 000 years old

- f A piece of fossilised wood was dated using the tree ring method at 4000 years old. What decay rate would you expect it to display when it was subject to carbon-14 analysis?

Answer: Approximately 10.2 nuclei/s/g. Around 10 would be acceptable, possibly even a little less.

B. Potassium-argon dating

What to do

- 1 Explain why there is no argon-40 in layer A.

Answer: The rock is not old enough. The radioactive potassium decays too slowly to have enough argon-40 to detect in a rock of this age.

- 2 Determine the ratio of potassium-40 to argon-40 in layer E.

Answer: $7:2 = 3.5:1$

- 3 Rock layers B, D and F are composed of the same material. What type of material do you think this would be? Explain how it has come to be between the alternating layers of lava.

Answer: Layers B, D and F would be sedimentary rock, which has formed by the compaction of wind or water borne sediments over a long period of time. Later, further eruptions of the volcano resulted in these sediments being covered by lava.

- 4 Explain why there are no fossils in layers A, C, E and G.

Answer: These are lava layers. The lava would have been so hot that it destroyed any remains of organisms, thus no fossils were preserved.

- 5 Layers B, D and F all contain fossils. For this to have occurred, conditions must have been suitable for fossilisation. Describe the conditions that assist the process of fossilisation.

Answer: Fossilisation requires rapid burial and preferably alkaline soils.

- 6 Anthropologists working at this site believe that layer B was formed around 40 to 70 thousand years ago. This date is too early to use the potassium-argon technique. Suggest at least two ways in which they could determine the age of layer B. Explain how each of these methods work.

Answer: Fossils in layer B that contained carbon could be dated by carbon-14 dating. This method of dating material is based on the decay of the radioactive isotope of carbon, carbon-14, to nitrogen. Measuring the amount of radiation liberated by a sample of organic material, the ratio of carbon-14 to carbon-12 can be estimated, and from this, the age of the sample can be calculated. It is only useful for material younger than 70 000 years, but because layer B is within that range, this technique could be used to date fossil material contained within it.

Fission tracks are a radioactive type of dating. The rocks must contain uranium-bearing minerals or glasses. Fission tracks are created in the surrounding minerals when the uranium decays. It is possible to tell how much time has passed since the tracks began. The method can be used to date minerals that are one hundred years to four thousand five hundred million years old.

Activity 16.2 Stratigraphy

What to do

- 1 How do you think these sediments were formed?

Answer: Sedimentation would have occurred over many millions of years. Some layers would have been beneath the sea at some time. Changes in sea level may have resulted in some layers being exposed, then covered again by water. Some layers appear to contain fossils that were terrestrial and therefore may have been buried by wind-borne sediments, or by silt deposited by rivers. Such fossils may have also resulted from human or animal burial. A clear fault line is visible, so earth movements have occurred.

- 2 The various layers in series A and series B no longer align with each other. Explain how this may have happened.

Answer: A shift in the Earth's crust, such as an earthquake, creating a clear fault line, is the most likely explanation.

- 3 Of all the strata shown in series A, B and C, which is the oldest? Explain how you arrived at your answer.

Answer: According to the principle of superposition, the oldest layer is at the bottom of each series, therefore layer 7 of series A is the oldest layer. Series C has the youngest strata, because layer 8 of this series correlates with layer 3 of series B; in turn, layer 6 of series B is younger than most strata in A, because layer 6 of series B correlates with layer 2 of series A.

- 4 Of all the strata shown, which is the youngest? Explain how you arrived at your answer.

Answer: Layer 1 of series C. This was obtained by matching the layers that were the same and then seeing which layer was at the top.

- 5 Layers A2 and B6, and B1 and C6, contain the same types of fossils. Would these be index fossils? List the criteria that must be met for a fossil to be considered an index fossil.

Answer: They are not likely to be index fossils, because index fossils need to be widely distributed and are only present on Earth for a short period of time.

- 6 A fossil in layer A4 was dated at 45 000 years using carbon-14 dating. What can you infer about the relative ages of layers B6 and C8?

Answer: Layer B6: less than 45 000 years old. Layer C8: very much younger than B6; far more recent.

- 7 Could layer A6 be dated using the potassium-argon technique? Give reasons for your answer.

Answer: Only volcanic rock more than 100 000 years old can be dated using potassium-argon. Because this stratum is much deeper than layer A4, dated at 45 000 years, it is possible that it would be of an age suitable for this technique. However, since only igneous rocks can be dated by this method, it is unlikely that it could be used.

- 8 Do you think dendrochronology could be used to determine an absolute date for layer C2? Again, give reasons for your answer.

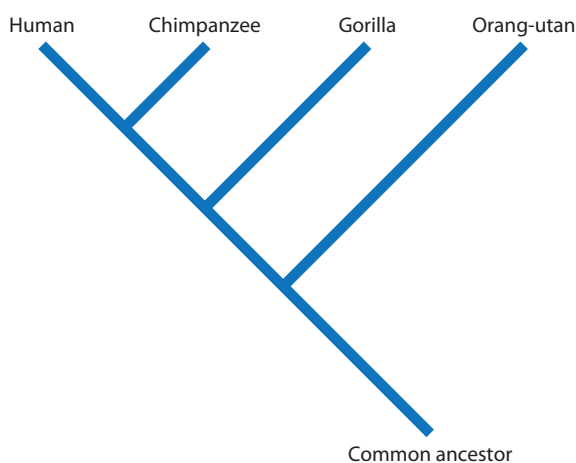
Answer: Dendrochronology could be used for layer C2, because it contains wood and it is a layer that is very much younger than 45 000 years.

Activity 16.3 Phylogenetic trees

What to do

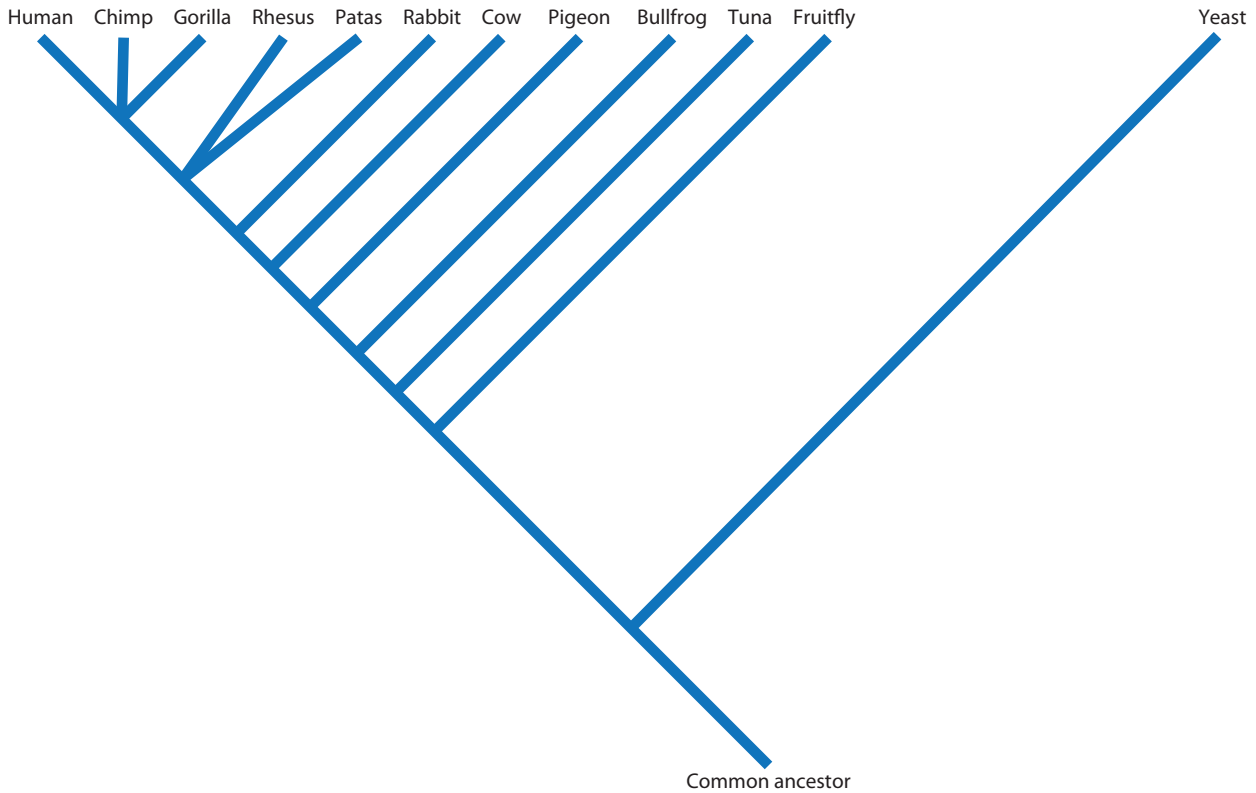
- 1 Refer to Table 15.1 on page 217 which shows the relationship between humans and great apes using DNA differences. Using this information, construct a phylogenetic tree to show diagrammatically the evolutionary relationships.

Answer:



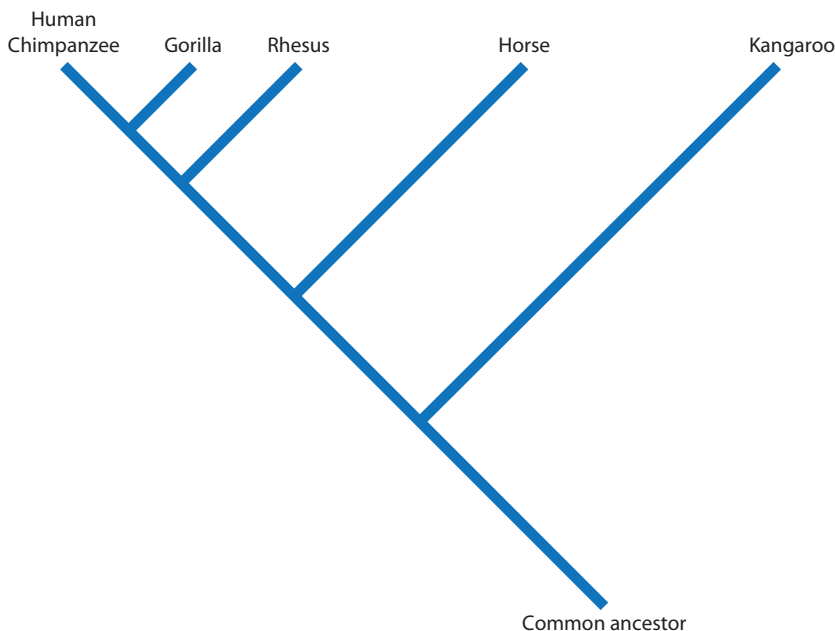
2 Refer to Table 15.4 on page 222. This table shows the differences in amino acids in cytochrome C between humans and a number of other species. The more similarity there is between two molecules, the more recently they have evolved from a common ancestor. Using this information, construct a phylogenetic tree to show the evolutionary relationships between the species listed.

Answer:



3 Refer to Table 15.6 on page 230, which shows the amino acid sequences in the haemoglobin of six mammalian species. Using the data presented in the table, construct a phylogenetic tree to show the evolutionary relationships between the species shown.

Answer:



Studying your data

- 1** How much variation was there among the phylogenetic trees constructed by different class members? Explain any similarities and differences with the ones you have created.

Answer: Responses will vary widely.

- 2** In the three trees you have drawn, does one animal appear to be more closely related to humans?

Answer: In all three of the trees, the chimpanzee should be the species most closely related to humans.

- 3** In which of the three trees do you have the most confidence as a good representation of evolutionary relationships? Why did you select this tree?

Answer: Responses will vary, but most students will probably suggest the first as it is based on DNA differences and it appears to resemble many of the current phylogenetic representations found in the literature.

- 4** When a phylogenetic tree is constructed it can be considered as a way of presenting a hypothesis. Explain why.

Answer: A hypothesis is a possible explanation to account for observations and, in constructing a phylogenetic tree, it is a diagrammatic representation of observations that have been made, or it is based on data that has been collected.

Review questions

- 1 a** Define 'fossil'.

Answer: A fossil is any preserved trace left by an organism that lived a long time ago.

- b** Give examples of five different forms of fossils.

Answer: Footprints, petrified faeces, bones, teeth, shells, impressions, burrows or feeding marks.

- 2 a** Explain the difference between a fossil and an artefact.

Answer: A fossil is a natural trace left by an organism, whereas an artefact is an object that has been deliberately made by humans.

- b** What is an index fossil? Could there be such things as index artefacts?

Answer: Fossils from organisms that were widely distributed geographically, and were only on Earth for a short period of time are called index fossils. These fossils are used for relative dating.

Many types of stone tools or primitive artwork can be considered to be index artefacts. They are indications of a particular culture at a particular time. (In practice, the term 'index artefact' is not used.)

- 3 a** What soil types are best for the preservation of fossils?

Answer: Wet acidic soil that does not contain oxygen (for example, peat) is best for the preservation of soft tissues. Alkaline soils are best for preservation of bones, because there is no acid to dissolve the hard part of the bone.

- b** Why is it that fossilised soft tissue, such as muscle, is rarely found by those searching for fossils?

Answer: Soft tissues are very quickly decayed by bacteria, fungi and other micro-organisms.

- 4 a What do you understand by the terms ‘relative dating’ and ‘absolute dating’?

Answer: Relative dating gives a comparison of age. It indicates the age of something relative to the age of something else; that is, it will indicate which fossil, artefact or rock stratum is older than another. Absolute dating gives the actual age of the material in years.

- b Why is relative dating used when a number of good methods of absolute dating are available?

Answer: All the methods of absolute dating require certain sets of conditions to be met before the method can be used. In cases where the conditions are not met, and it is not possible to get an actual date, relative dating must be used.

- 5 Draw up a table with three columns, listing in the first column the methods of absolute dating described in this chapter. In the second and third columns, list the advantages and limitations of each method.

Answer:

Absolute dating method	Advantages	Limitations
Potassium-argon	Can be used to give precise dates	Not all rocks suitable Only useful for rocks 100 000 to 200 000 years or older Must have rock that is same age as fossil
Carbon-14	Can be used to give precise dates Used for more recent fossils Useful for dating artefacts, provided they contain organic material	Need 3 g of the organic material Only useful for material up to 70 000 years old Carbon-14 varies in atmosphere, so not as reliable as once thought Material to be dated must contain carbon
Accelerator mass spectrometry radio-carbon dating	Only need 100 micrograms of sample Used for more recent fossils Useful for dating artefacts if they contain carbon	Only useful for material up to 70 000 years old Carbon-14 varies in atmosphere so not as reliable as once thought Must contain carbon
Dendrochronology	Good for calculating absolute ages of fossil wood	Timber rarely preserved Only useful for wood younger than 9000 years of age

- 6 a Explain the principle behind radioisotope methods of dating.

Answer: Radioactive material decays at a known rate. Radioisotope dating is based on knowing the half-life of the radioactive isotope. So knowing how much radioactive product is in the fossil and knowing its rate of decay allows the age of the fossil to be calculated.

- b Describe why potassium-argon dating cannot be used to date fossil bones.

Answer: The isotope is found in rocks of volcanic origin. Any bones trapped in volcanic rock would be destroyed by the heat.

- 7 a How is it that the bodies of plants and animals have radioactive carbon-14 in them?

Answer: Carbon-14 is in the atmosphere and is taken up by plants when they photosynthesise. Thus, it is found in plants. These plants are consumed by animals and the carbon-14 is then incorporated into the animals’ tissues.

- b What does it mean to say that carbon-14 has a half-life of 5730 years?

Answer: In 5730 years half of any sample of carbon-14 will have decayed and half will be remaining.

- c** Why is it not possible to use radioactive carbon dating on artefacts?

Answer: Most of the older artefacts do not contain carbon, being made from stone, so this dating technique is not suitable. However, more recent artefacts made from wood or other plant materials, would be able to be dated using radioactive carbon dating.

- d** What is AMS radiocarbon dating?

Answer: Accelerator mass spectrometry (AMS) radiocarbon dating breaks the sample up into all the different types of atoms that it contains. The numbers of atoms of each isotope of carbon can then be counted.

- 8** What is dendrochronology and in what situations would it be useful to a scientist dating fossil material?

Answer: Dendrochronology is another name for tree ring dating. It is useful when timber is preserved. Dendrochronology can date ancient wooden buildings, and can be used for any structure manufactured from timber such as sailing vessels, canoes and rafts, along with huts, tent poles and weapons.

- 9 a** What is the principle of superposition?

Answer: The layers of sedimentary rock closest to the Earth's surface are the youngest. The deeper one goes into a sedimentary deposit the older the material.

- b** Does this principle always apply? If not, explain why.

Answer: No. The layers can be shifted around by earth movements. The Earth's crust can fault and fold. Animals can bury artefacts into deeper soil layers. Human burials and other human activity may result in fossils being found in sediments older than the fossil.

- 10 a** Explain how index fossils can be used to compare strata from different locations.

Answer: Index fossils were widely distributed and only lived on Earth for a short time. This means that dating the strata where they are found is more precise. If the index fossil is found in rocks at different locations the rocks should be of the same approximate age.

- b** Describe the different ways in which fossil pollen grains can be of use to the anthropologist.

Answer: Fossil pollen grains can be of use in the following ways:

- as index fossils
- to gain a picture of the vegetation around the time that the pollen was produced by plants
- as an indicator of climatic conditions at the time the plants (that produced the pollen) were living.

- 11 a** Why is it that fluorine dating cannot give the absolute age of a fossil?

Answer: Fluorine dating cannot be used to give an absolute age as the concentration of fluoride ions in soil varies from location to location.

- b** Do older fossils contain more or less fluorine than younger fossils?

Answer: Older fossils contain more fluoride than younger fossils because they absorb it from the sediment in which they are buried.

- c** Describe a situation where fluorine analysis has shown the component parts of a fossil to be of different ages.

Answer: One of the best examples is the skull and jaw bone found in the same sediment at Piltdown, England. Fluorine dating showed the cranium to be older than the jaw bone so the two could not have belonged to the same individual.

12 a What are phylogenetic trees and why are they used?

Answer: Phylogenetic trees are a diagrammatic representation of evolutionary relationships between groups of organisms that have derived from a common ancestor. They are used to give a simple representation of complex relationships, and are useful for showing possible evolutionary pathways.

b List the techniques described in this chapter and in Chapter 15 that would provide information that could be used to draw a phylogenetic tree for human ancestors.

Answer: Techniques available for providing information for the construction of phylogenetic trees include comparative studies of DNA, mitochondrial DNA, comparative studies of protein sequences, comparative genomics, comparative anatomy, embryology, homologous structures, fossil evidence, and the dating of fossils.

13 If a fossil is said to be of Oligocene age, is this an absolute date or a relative date? Explain your answer.

Answer: This is a relative date, as it places the fossil in time in relation to other fossils. It means that it is older than Eocene and younger than Miocene fossils.

Apply your knowledge

1 Anthropologists excavating the floor of a cave found, at a depth of 50 centimetres, a deposit of charcoal that they concluded was the site of an ancient hearth. Next to the hearth, at the same depth, was a stone tool. Radiocarbon analysis of the charcoal showed that the ratio of carbon-14 to carbon-12 was 0.25 in 10^{12} . Further excavation uncovered, at a depth of 95 centimetres, a fragment of human jaw bone and the thigh bone of another animal. Fluorine analysis showed that the thigh bone had a much higher fluorine content than the jaw bone.

a What would be the estimated absolute age of the stone tool?

Answer: 11 500 years (or 11 460 years, which is precisely two half-lives).

b What would be the relative ages of the stone tool, jaw bone and thigh bone? Explain fully how you arrived at your answer.

Answer: The stone tool would be the youngest, then the human jaw bone, and the animal thigh bone would be the oldest.

The stone tool would be younger than the bones found at a depth of 95 cm using the principle of superposition, because the tool was found at a depth of 50 cm. The human jaw bone and the animal thigh bone were found at the same depth, but fluorine analysis demonstrated the animal thigh bone to be older (by comparison), because it contained more fluorine.

c Can you be certain of the relative dates? Explain why or why not.

Answer: No. If the artefact or fossil that you are using as a comparison is dated incorrectly, then the relative date will also be inaccurate. In addition, the jaw bone and animal bones may have been deliberately buried. One can be sure that the animal thigh bone is older than the human jaw bone.

- 2 The sand dunes around the Australian coast consist of alkaline soil. If an animal was buried in the dunes by drifting sand, would its bones become fossilised, provided they were left undisturbed for long enough? Explain the reasons for your answer.

Answer: Yes. Alkaline soil does not dissolve the minerals in bone. If left for long enough these bones should fossilise.

- 3 In the peat bogs of England, Denmark and other parts of northern Europe, human bodies up to 4000 years old have been found. The hair, skin and other soft tissues have been so well preserved that the fingerprints can still be seen on the skin of the hand, and food in the alimentary canal is complete enough to indicate the nature of the last meal eaten.
- a Describe the types of conditions that must be present in peat bogs to allow preservation of these tissues for such a long period of time.

Answer: Soft tissues are preserved in wet acidic soils, such as peat bogs, when there is no oxygen present.

- b Would you expect the skeletons of these 'bog people' to be preserved? Why, or why not?

Answer: Bones of bog people are rarely preserved because the acid in the bog dissolves the calcium phosphate of the bone.

- 4 Refer to Figure 16.11 (page 242) and describe the reasoning you employed to work out which was the oldest stratum.

Answer: The strata were aligned so that the type of rock and the fossils they contained were matched up. The deepest layer (when all were matched up) is the oldest, in this case it was layer four from site 2.

- 5 Construct a table with four columns titled 'Technique', 'Relative or Absolute', 'Time span' and 'Weaknesses'. List the various dating techniques described in this chapter in the first column, and for each indicate whether it is an absolute or relative dating technique, the period of time (in years) for which the technique is useful, and the weaknesses or problems associated with that technique.

Answer:

Dating technique	Relative or absolute dating	Time span (years)	Weaknesses
Potassium-argon	Absolute	Older than 100 000–200 000 years	Not all rocks suitable Must be of volcanic origin Must be rocks available at same level as fossil
Carbon-14/ Radiocarbon	Absolute	0–70 000 years ago	Only used to date organic material Require at least 3 g sample Amount of carbon-14 in atmosphere varies
Accelerator mass spectrometry radiocarbon	Absolute	0–70 000 years ago	Only used to date organic material Amount of carbon-14 in atmosphere varies
Dendrochronology	Absolute	0–9000 years ago	Trees must have been preserved Wood containing enough annual growth rings must have been preserved
Stratigraphy	Relative	Comparison only	Animals can bury fossils into other strata layers Earth crust movement can confuse layers Cannot give absolute date
Fluorine	Relative	Comparison only	Amount of fluorine in ground varies from one location to another Cannot give absolute date

6 Riversleigh, in north-west Queensland, is one of the world's most important and abundant fossil sites. Fossils found at Riversleigh include kangaroos, wombats, bandicoots, possums, koalas, platypuses, crocodiles, snakes, turtles, lungfish, birds, frogs, snails and insects.

- a From this list of some of the fossils found at Riversleigh, write a description of what the area must have been like when the fossil animals were alive.

Answer: Riversleigh would have been an area that had eucalyptus and other trees (habitat for koalas, possums and so on). These trees could have lined a river or a lake (crocodiles, platypuses). The river or lake may have had a swamp-like area that provided the moist conditions for frogs, insect larvae, snails and lungfish. The surrounding land could have been drier with scrub and bushes (the habitat for wombats, bandicoots and kangaroos).

- b What conditions must have occurred at Riversleigh for so many organisms to have been fossilised?

Answer: The conditions would have contained alkaline soil, which would have allowed fossilisation to occur. It must have been a stable area over a long period of time to allow for the process of fossilisation to occur. Burial must have occurred rapidly, and once buried, the fossils must have been undisturbed by other animals or humans.

7 Some scientists found a few fragments of a fossil skull. Referring to other fossil skulls, they decided it was the skull of an early human. Using their extensive experience, they made a reconstruction of what they thought the complete skull would have looked like. When they published the results of their investigations, many other scientists disagreed with the findings and stated that the fossil fragments were from an ape. List as many possible reasons as you can for the disagreement among the scientists.

Answer: Both ape and human skulls have similar features, and without a whole skull, the scientists would not have had the whole picture. If there was no indication of the foramen magnum or teeth or jaw fragments, identification would have been difficult.

The skull fragments would have been placed in position, based on the experience of the scientists involved. Other scientists with different background and experience may disagree with the way in which the fragments were put together.

Early human skulls were bigger and more robust than modern human skulls, and therefore closer in size to ape skulls.