SUGGESTED TEXTBOOK ANSWERS

Chapter 18 Evolutionary trends in hominids

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

Science inquiry

Activity 18.1 Hominin skulls

A: Increase in brain size

What to do

2 Construct a table similar to Table 18.2 showing the average cranial capacity of the species, but add an extra column to show how long ago each species ceased to exist.

Answer:

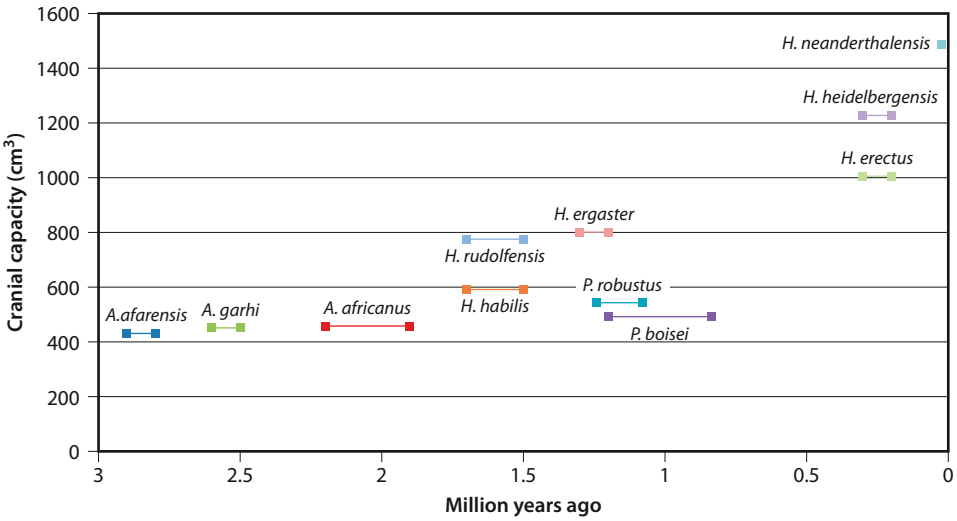
Hominin species	Cranial capacity (cm^3)	Approximate date of extinction
Australopithecus afarensis	430	2.8–2.9 million years ago (mya)
Australopithecus africanus	457	1.9–2.2 mya
Australopithecus garhi	450	2.4–2.5 mya
Paranthropus boisei	491	0.9–1.2 mya
Paranthropus robustus	542	1.0–1.2 mya
Homo habilis	590	1.5–1.75 mya
Homo rudolfensis	774	1.5–1.75 mya
Homo ergaster	800	1.2–1.3 mya
Homo erectus	1004	200 000–300 000 ya
Homo heidelbergensis	1226	200 000–300 000 ya
Homo neanderthalensis	1485	30 000 ya

Date of extinction will depend on the resource consulted. The dates given here are approximately those that students should discover.

3 Draw a graph of average cranial capacity versus the time when extinction of the species occurred.

Answer:

Cranial capacity of Hominins



Studying your data

1 Describe the evolutionary trend that the graph illustrates.

Answer: With evolution, there has been an increase in cranial capacity. Younger hominin fossils tend to have a greater cranial capacity than older fossils.

2 Are there any anomalies in the trend? If there are anomalies, suggest explanations for them.

Answer: There are anomalies in the trend as follows.

- *Paranthropus boisei* and *P. robustus* lived at around the same time, but had differing cranial capacities.
- *Homo habilis* and *H. rudolfensis* also lived at the same time, but their cranial capacities were quite different.
- *H. neanderthalensis* became extinct 30 000 years ago, but had a bigger brain than modern humans.

A possible explanation for these anomalies is that brain size is only a rough measure of intelligence – the number of convolutions in the cerebral cortex is also very important.

B: Decrease in prognathism

What to do

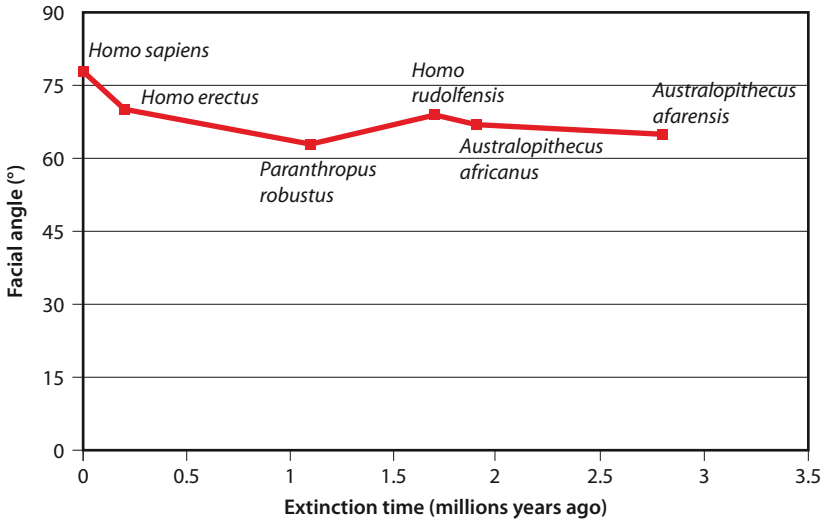
2 Construct a graph of the facial angle (from Table 18.3) plotted against the extinction time. The closer the facial angle is to 90°, the flatter the face.

Table 18.3 The facial angle of various hominin crania

Hominin	Facial angle (degrees)
Australopithecus afarensis	65
Australopithecus africanus	67
Paranthropus robustus	63
Homo rudolfensis	69
Homo erectus	70
Homo sapiens	78

Answer:

Changes in Facial Angle of Hominins



Studying your data

1 Describe the evolutionary trend that the graph illustrates. Are there any anomalies in the general trend?

Answer: With evolution, the facial angle of the skulls has flattened (become closer to 90°). *Paranthropus robustus* is an anomaly in this trend.

2 Does this graph follow the same trend as that drawn in part A? Comment on any similarities or differences.

Answer: Yes, both graphs follow the same trends. The trend in activity A (cranial capacity) is more pronounced.

In summary

Write a summarising paragraph to describe the relationship between an increase in cranial capacity and the trend towards a flatter face. What is the evolutionary significance of these trends?

Answer: As cranial capacity increases over time, so does the trend towards a flatter face in hominins. This is significant, because it suggests that the increasing cranial capacity was in the frontal region of the brain, leading to a more pronounced forehead and a flatter face. The increase in cranial capacity would have allowed the development of more complex cognition.

Activity 18.2 Cranial capacity and phylogenetic trees

What to do

2 Consider which species may have become extinct and which species may have evolved into one or more other species. Draw up a phylogenetic tree to show the possible evolutionary relationships between the species in the table. Remember, there is no such thing as a correct tree. Scientists themselves cannot agree on all the relationships.

Answer: Responses will vary, especially with the evolutionary relationships that students may present. All students should start with *Ardepithecus ramidus* at the bottom of the tree as the common ancestor. Most will probably then show a connection with *Australopithecus afarensis*, from there one would expect students to show branches to the gracile forms of australopithecines, the robust forms, and to early *Homo*. Considerable variation would then be expected on the way students linked the various member of the genus *Homo*.

Studying your data

Compare your phylogenetic tree with the summary you wrote for the previous activity. Does the phylogenetic tree represent the same evolutionary relationships that you described in Activity 18.1?

Answer: Responses will vary, but one would expect some similarity between the summary and the phylogenetic tree.

Activity 18.3 Upright stance and the striding gait

Studying your observations

1 Compare the skull of an ape with that of a human. List the differences in the size and shape of the crania (brain cases).

Answer:

Gorilla skull	Human skull	Chimpanzee skull
Small cranium	Very large cranium compared with chimp and gorilla	Small cranium
Large sagittal crest in male	No sagittal crest	No sagittal crest in either male or female
Absence of forehead	Presence of forehead	Absence of forehead
Students may also mention:	*Students may also mention:*	*Students may also mention:*
Large eyebrow ridges	*Reduced eyebrow ridges*	*Large eyebrow ridges*
Prognathic jaw	*Reduced jaw*	*Prognathic jaw*

2 Locate the position of the foramen magnum. The foramen magnum is the opening in the base of the skull where the spinal cord enters the brain (refer to Figure 18.4 on page 273). Look at the base of each skull and compare the position of the foramen magnum in the ape and in the human. Where is the foramen magnum in the human skull? Where is the foramen magnum in the ape skull?

Answer: The foramen magnum is directly under the cranium in humans. In the ape it is toward the rear of the skull.

3 Which skull is most easily balanced on the vertebral column: ape or human?

Answer: The human skull would balance easily on the vertebral column because the foramen magnum is centrally located under the skull. It allows the skull to balance on the vertebral column with little support.

4 Look carefully at the model of the skeleton, and then refer to Figure18.3 on page 272. Describe the curves of the vertebral column of the ape and the human. What extra curve exists in the vertebral columns of humans? (You may wish to refer to Figure 18.6 on page 273 to answer this question.)

Answer:

Gorilla spine	Human spine	Chimpanzee spine
C-shaped	S-shaped Extra curve in lumbar region of the spine	C-shaped

5 Look at Figure 18.7 on page 274 and compare the shape of the human pelvis with that of the gorilla. Which pelvis is wider? Which is longer? Suggest reasons for the relatively wide pelvis in humans.

Answer: The human pelvis is wider and shorter than that of a gorilla. This is an adaptation for upright stance and bipedalism. The broad bowl-shape contributes to a lower centre of gravity and supports the abdominal organs. It also contributes to the carrying angle of the femurs because the sockets for the heads of the femurs are wide apart.

6 The human pelvis is tilted forward and curves inward, creating a basin shape. List the advantages this arrangement has for upright stance.

Answer: This arrangement lowers the centre of gravity; it supports the abdominal organs when upright, and supports the foetus during pregnancy; it also allows the femurs to join at an angle that is advantageous for bipedalism (the carrying angle).

7 Look carefully at the model of the skeleton again, and then refer to Figure 18.8 on page 274. The narrow pelvis of the ape (Figure 18.7) makes the legs hang vertically. This means the ape must keep its feet apart when standing and, when walking, sway from side to side to maintain balance (Figure 18.14, page 277). Describe how the breadth of the pelvis contributes to the carrying angle of the femurs.

Answer: The breadth of the pelvis allows the femurs to join the pelvis at an angle to the vertical that is advantageous for bipedalism. The femurs come together toward the knee, then the lower part of the legs are more vertical so that the feet are together when standing erect.

This arrangement allows for the striding gait, with one foot being placed in front of the other so that there is no swaying from side to side of the body. The body weight is directly over the foot during each stride; whereas an ape, when walking bipedally, would have to sway from side to side to keep the body weight over the foot that was on the ground.

8 Explain the effect of the carrying angle on the arrangement of the knees, lower limb bones and the position of the feet in humans. What advantage does this arrangement have for human walking?

Answer: The carrying angle allows the femur to be angled, so that the lower limb bones and feet are under the centre of gravity. When the leg is swung forward in walking, the knees lock in the fully extended position. This aids in the striding gait. The knee is hinged and only moves forward and backward to allow walking. The foot is weight-bearing in humans and the enlarged heel bone is able to take the weight of the body when taking a step forward. The carrying angle allows body weight to be directly over each foot while walking; the upper body remains relatively stationary. In contrast, an ape must sway from side to side when walking bipedally. This requires a lot more energy than the striding gait of humans.

9 The vertebral column of humans acts as a weight-supporting column. How does the shape of the lumbar vertebrae contribute to the lumbar curve? Look closely at the angle between the lumbar curve and the pelvis. (You may wish to refer to Figure 18.5 on page 273.) What effect does the lumbar curve have on the position of the trunk and legs in humans?

Answer: The lumbar vertebrae are thicker, wedge-shaped and have flattened processes. They are the largest vertebrae. These features contribute to the five lumbar vertebrae articulating in a way that produces the lumbar curvature. This curvature places the trunk over the centre of gravity and the legs directly beneath it. As a person walks, the centre of gravity moves from one side of the pelvis to the other so that it is always centred above the leg currently on the ground. These features give balance and stabilise the bipedal stance and the striding gait.

10 Refer to Figure 18.11 on page 276 and compare the position of the centre of gravity in humans and apes. Which animal has the lower centre of gravity relative to body size? What features of the skeleton contribute to this difference?

Answer: Humans have a lower centre of gravity compared to body size. This is due to the broad bowl-shaped pelvis, the S-shaped spine, the lumbar vertebrae position, and the legs being relatively long and directly beneath the body.

11 Describe the pathway the body weight in humans follows from the pelvis down to the feet.

Answer: Pelvis → knee → ankle → foot

12 Remove your shoe and run your fingers over the top of your foot from little toe side to big toe side. Can you feel the transverse arch? Referring to Figure 18.10 on page 275 may help. How is this arch different from the longitudinal arch? What is the main function of the two arches?

Answer: The longitudinal arch has a weight-bearing function; whereas the transverse arch is to aid in the transmission of thrust when walking (from heel strike to thrust from the big toe).

13 Look at the model of the skeleton again, and then refer to Figure 18.10. Compare the toes of a gorilla and a human. What differences can you see?

Answer: The big toe of the gorilla is more like the human thumb. It is not in line with the other toes of the foot and is opposable. As such, it can be used for grasping. The human big toe is in line with the other toes of the foot and lacks opposability. It has a major function in the striding gait. The length of the toe bones and distance between joints are also different.

14 When humans stride, the big toe provides the thrust. What features of the big toe assist this? Would an ape be able to use the big toe in a similar way? Explain your answer.

Answer: The big toe has a relatively large surface area in contact with the ground, is in line with the other toes of the foot, and is jointed to allow the push-off motion when walking. Gorillas have an opposable big toe. Because it is not in line with the other toes, it would not be able push off at the start of a stride in bipedal walking.

15 Refer to Figure 18.13 on page 277 and describe how the arches of the foot enable weight to be distributed from the heel to the big toe. Remove your shoes and try this for yourself.

Answer: The transverse arch distributes the body weight across the foot maintaining balance. When striding the longitudinal arch allows the weight to be moved from the heel down the outer part of the foot, across the transverse arch and to the big toe.

16 Take a number of steps in your bare feet. Describe what occurs from the time the left heel hits the ground until the right heel hits the ground. Referring to Figure 18.13 on page 277 may help you with your description.

Answer: Left heel strike → weight rolls down outside of the longitudinal arch → across the ball of the foot → thrust from ball of foot rolling onto big toe → thrust from big toe

This rolling motion happens on both feet, but not at the same time. As the left foot thrusts off from the big toe, the right foot is airborne. The right foot heel strikes the ground and transfers the weight and balance forward.

17 Summarise the main features in the human skeleton that are adaptations for an upright stance and for walking bipedally with a striding gait.

Answer:

Characteristic	Adaptations
Foramen magnum	Located centrally in the base of the cranium Allows skull to sit on top of the spine so that little muscular effort is needed to hold it in place
Jaw bone	Small and non-protruding, so that it enables the skull to balance on the vertebral column Allows skull to sit on top of the spine so humans can stand upright and walk bipedally
Vertebral column	Lumbar vertebrae wedge-shaped producing an S-shaped curve that brings the vertebral column directly under centre of skull Allows spine to be in a position that allows humans to stand upright and walk bipedally
Pelvis	Broad – shallow from top to bottom Provides support for abdominal organs Allows an upright stance rather than carrying organs under the thorax when on all fours Attachment of femurs wide apart contributing to carrying angle Allows striding gait and upright stance
Femurs	Large head to femur that contributes to the carrying angle Allows the movement of the legs to walk bipedally Angle in towards the knee
Knee joint	Outer 'hinge' larger and stronger to take weight of body, thus the ability to stand upright and walk bipedally Knee able to be straightened as part of the striding gait
Legs	Longer than arms, contributing to a low centre of gravity so that humans do not fall over when upright Carrying angle allows the weight of the body to be kept close to the central axis allowing a striding gait
Foot	Large heel bone and aligned big toe form a pedestal on which the body is supported; allows for a heel strike used in bipedal walking The large non-opposable big toe allows for a strong push off Foot has both longitudinal and transverse arches, again allowing for the striding gait

Review questions

1 a In the hierarchy of biological classification, what does the term 'tribe' mean?

Answer: 'Tribe' is the name given to a relatively new level of classification between subfamily and genus. Tribe, like any other classification group, is defined by certain characteristics that all members of the group share.

b List the three tribes in the subfamily Homininae, and give an example of a member of each.

Answer: Hominini – humans; Gorillini – gorilla; Panini – chimpanzees and bonobos

2 a List the components of the skeleton that allow humans to adopt an erect posture.

Answer: Foramen magnum; skull and jaw bone; vertebral column; pelvis; femurs; knee joint; legs; foot

b How do these components differ from the corresponding ones in a quadrupedal animal?

Answer:

- Foramen magnum – centrally located
- Skull and jaw bone – reduced prognathism
- Vertebral column – S-shaped
- Pelvis – broad, shallow, bowl-shaped
- Femur – strengthened, at an angle to the vertical, ball and socket hip joint
- Knee joint – hinge joint can be fully straightened
- Legs – longer than arms
- Foot – transverse and longitudinal arches, inline (non-opposable) large toe

c What are **i** the advantages and **ii** the disadvantages of an erect stance and bipedal locomotion?

Answer:

i Advantages	ii Disadvantages
For food hunting (can see further) For food gathering (pick fruit high in trees) Avoid predators; able to see further and run faster Better to walk longer distances (no longer arboreal) Mechanical advantages for travelling longer distances – reduces energy expenditure Improved cooling of the body, due to greater surface area and greater exposure to wind Hands free for carrying and/or tool use	Can no longer easily escape from predators into the trees Slow moving compared to some quadrupedal species Difficult to cover large distances quickly; therefore small, productive home range needed Difficult to maintain body temperature in cold climates

3 a What is muscle tone?

Answer: Muscle tone is the partial contraction of skeletal muscles.

b How does muscle tone help to support the body against the force of gravity?

Answer: It helps to keep the head erect and the body in the upright stance position, supporting the spine, abdomen, knees and ankles.

4 a What is the carrying angle?

Answer: The carrying angle is the angle of the femur bones to the vertical. The femurs angle in towards the knees so that, when walking, the weight of the body is over the feet at all times.

b Compare the carrying angle of an ape with that of a human.

Answer: Humans have a wider carrying angle than apes; that is, the angle of the femur to the vertical in humans is greater. This allows for bipedalism in humans.

5 **a** How does the wide pelvis and carrying angle of the femur enable humans to walk without the body swaying from side to side?

Answer: The wide pelvis and carrying angle allow the body to rotate about the lower leg and foot, and centre the weight distribution over the foot so that the body does not sway from side to side when walking. Apes must sway from side to side so that the body weight is above the foot that is on the ground.

b What contribution do the arms make to stabilising the body during walking?

Answer: The arms swing to compensate for the natural rotation of the body when walking. The legs and arms work in opposition: as the left leg goes forward, the left arm swings back, while the right arm is swinging forward. The arm movement also helps keep the shoulders in the correct position: at right angles to the direction in which the body is moving.

6 What is an endocast? What can it tell us about the size and shape of the brain?

Answer: Endocasts are impressions of the inside of a skull made of rock or some other solid material. They occur naturally or can be made by scientists when a skull is found. They give a model of the brain, showing its size and the shape of the brain surface, including any convolutions if originally present.

7 Describe the major anatomical and functional developments that have occurred in hominin brains over the past four million years.

Answer: Hominin brains have increased in cranial capacity; show an increase in the number and complexity of convolutions; show an increase in frontal lobe size with development of a forehead; have increased in cognitive and reasoning ability.

8 Human dentition is said to be unique.

a List the differences between the teeth of a human and those of an ape, such as a gorilla.

Answer: Human canines look more like incisors – they are not longer than the other teeth. Ape canines are approximately twice as long as the incisors. Human molars are comparatively smaller than apes. Humans have a parabolic dental arcade, whereas in apes it is U-shaped.

b How has the dental arcade changed in hominins when compared with that of an ape?

Answer: Hominins have a parabolic dental arcade, rather than a U-shaped arcade like an ape. In hominins there is no diastema to accommodate the long canines that protrude beyond the other teeth.

9 Describe the change in the shape of the face of hominins over the past four million years or so.

Answer: Hominins have a flatter face that is less prognathic (a reduced jaw); a chin has developed along with a more prominent nose and a distinct forehead.

Apply your knowledge

1 For humans to be able to stand upright, a number of adaptations have taken place. Changes have occurred to the skull, vertebral column, pelvis, legs and feet. Describe how each of these has contributed – and how they have interacted – to enable humans to adopt an erect stance.

Answer:

- Skull: Foramen magnum is centrally located to allow the skull to sit on top of the vertebral column. A flattened face ensures that there is about the same weight in front of, and behind, the foramen magnum so that the skull can balance on the spinal column.
- Vertebral column: S-shaped curve to allow the skull to sit on top of spine and allow upright stance with the torso held erect, instead of the continuous curve possessed by apes.
- Pelvis: A broad bowl-shape; supports the abdominal organs; a lower centre of gravity for upright stance; attached to a S-shaped spine; wide to contribute to the carrying angle.
- Legs: Carrying angle of femur requires broad pelvis with ball and socket hip joints; the knees are structured with a hinge joint so that the legs can carry the mass of the body upright and bend for walking; the knee can straighten as required in the walking process; the femur is also very strong. Legs are longer than arms.
- Feet: Connected to the legs with joints to allow the pivotal motion for walking, arched feet to stand upright and carry body mass; feet allow upright stance to be balanced; inline large toe and large, strong heel bone provides a pedestal when standing erect and takes the weight of the body at the start of each stride.

All of the adaptations described above interact and contribute to the ability to stand erect.

2 As a result of various conditions, the normal curves of the vertebral column may become exaggerated. Use references to describe the conditions known as scoliosis, kyphosis and lordosis.

Answer:

Scoliosis:

- An abnormal sideways curve of the spine that makes the spine look tilted when viewed from the rear
- View from side usually shows a hump.
- May result from skeletal malformations present at birth, muscular problems, or in a great many cases the cause is unknown
- Pain, and in severe cases, breathing problems may result.
- It is likely that genetic factors are involved in many cases.
- Treatment can include physiotherapy, surgery, or if bone growth is not complete, bracing of the spine.

Kyphosis:

- Abnormal curvature of the spine in the thoracic region
- When the spine is viewed from side there is a front bending curve, in the cervical or thoracic area; appearance is hunchbacked.
- Most cases are mild, but very severe forms may be treated by spinal fusion therapy.

Lordosis:

- Abnormal inward curve in the small of the back
- When the spine is viewed from side there is a pronounced inward curve (sway back, hollow back or saddle back) in the lumbar region.
- Caused by uneven thicknesses in the intervertebral discs
- Usually treated by exercise to strengthen hip muscles

3 If you have seen chimpanzees or gorillas walking bipedally, you will have noticed that they sway from side to side as they walk. Explain why they cannot stride as humans do.

Answer: These primates do not have the adaptations for bipedalism that humans do. They are essentially quadrupedal animals walking upright for only short periods of time. The narrow pelvis and lower limb bones do not allow the striding gait to be used. This is mainly because there is no carrying angle and the ape must sway from side to side to keep the centre of gravity over the foot that is on the ground.

4 What assumptions are made when scientists infer the degree of intelligence from the cranial capacity of a skull?

Answer: The cranial capacity of the skull gives an indication of brain size. It is assumed that the whole of the cranium is occupied by the brain and is not occupied by extra fluid or other matter. It is also assumed that increased brain size is proportional to increased intelligence.

5 The human canine tooth is much smaller than that of the other hominids, especially in the males of the species. Describe the evolutionary processes that would have taken place in hominins to produce the current size of that tooth in humans today.

Answer: Natural selection would have caused the evolutionary trend toward smaller canine teeth. In early hominins there would have been natural variation in the size of the canine teeth. As the diet moved towards softer foods, the hominins with the smaller canines would have been more successful and have had an increased chance of survival. When these hominins reproduced they would have passed on the favourable allele for smaller canine teeth. This would have occurred over many generations – a period of time during which the diet became softer and contained an increasing amount of cooked meat . The ensuing trend was toward smaller canine teeth, resulting in the current canine size in modern humans.

6 The primitive ancestor of the hominins is thought to have moved through trees by brachiation. Outline the characteristics that a brachiator, such as the gibbon, would possess that are likely to be of advantage for bipedal locomotion.

Answer: Rotating shoulder joints – allow free movement about the shoulder joint during brachiation. This allows the arms to swing aiding balance in bipedal locomotion. A flattened chest and long forelimbs allow arm swinging in brachiation and swinging of arms for balance when bipedal.

7 The term 'hominid' used to have the same meaning that 'hominin' now has. 'Hominid' was used to refer to the various members of the human family tree. Scientists who study human origins have changed the classification scheme by introducing a new level, the tribe (see Figure 18.2 on page 271). 'Hominid' is now defined in a much broader way so that it refers to all great apes and their ancestors. 'Hominin' refers only to present-day humans and our extinct ancestors. Why would scientists make changes to the classification scheme for apes and humans? Suggest as many reasons as you can.

Answer: Modern biotechnological techniques, including molecular studies of DNA and proteins showed that humans, chimps and gorillas are closer to each other than to orang-utans. To fit this new evidence, two sub-families were created: the Ponginae, which includes the orangs; and the Homininae, which includes humans (and their ancestors), chimps and gorillas. However, it was desirable to discuss humans and their ancestors as a separate group, so the tribes Gorillini (gorillas), Panini (chimps) and Hominini (humans and their ancestors) were created.

8 This chapter has discussed the evolution of erect stance and bipedal locomotion, and a large brain, under separate headings. In the previous chapter, the development of the human hand and the precision grip were discussed. However, it is unlikely that these features would have evolved independently of each other. Discuss a possible evolutionary sequence that would account for the development of each of these characteristics.

Answer: The order in which these characteristics evolved is contentious. Students may argue that bipedal locomotion freed the hands so that the precision grip had survival value and gradually developed through natural selection. Those individuals with larger brains were able to better use the precision grip and so larger brains developed. Another likely scenario is that all the characteristics gradually evolved together, although students should make it clear that bipedalism was well established before the brain made any substantial increase in size.