Form and Function: Primate Locomotion

Q1: How does the morphology differ in the four specimens and how do those differences reflect their different locomotor repertoires?

(With jargoned osteopathic terminology, I try my best to label the parts in the relevant drawings for easier recognition.)

As can be observed by the skeletal evidence that rests in the scapula, clavicle and humerus in each of the four primate species, it can be seen that all primates retain "relatively mobile shoulder joints for free movement of the upper limb in all directions" (Conroy 1990, 383). The glenoid cavity and humerus form a head-and-socket joint in all primates, and the coracoids process is all that remains of a small bone, which has fused with the scapula to form a projection over the glenoid cavity (Cambridge University Press 2006, 631). Despite these similarities, when examined and compared with one another, these four animals evidently have very different shoulder-bone arrangements.

Mandrill

The mandrill (*Mandrillus sphinx*) is classified as an Old World cercopithecoid (Napier and Napier 1997, 14 & 19). It mainly dwells in forests, with males on the ground, and females plus offspring climbing into the canopy to feed. Mandrills are usually quadrupedal, and their terrestrial gait is digitigrade (having only the toes touch the ground) (*Ibid.*, 135), but as a fair proportion of the species live for some time arboreally, semibrachiation, leaping, and some arm-swinging is not unheard of (*Ibid*, 45). The shoulder area reflects this as the glenoid cavity is somewhat narrower and more restrictive than the other species (Cambridge University Press 1992, 76). The clavicle is relatively shorter as well, and the humeral head is not as enlarged as that in the other species. This shows that it is unlikely that the mandrill carries much weight anteriorly.

Gibbon

Gibbons (*Hylobates*), on the other hand, are wholly arboreal, and live in the canopies of forests (Napier and Napier 1997, 162). Their locomotion is highly specialized as they have long arms, and shoulders with a considerable range of movement. This is probably due to a change in the shape of the thoracic region which is broad from side-to-side, unlike monkeys, where the greatest width is from front to back. Also, the gibbon shoulder may have developed this way so that the species could reach ripe fruit growing under a tree (Stanford, Allen and Antón 2009, 184). The forearm is extremely flexible, enabling the gibbon to hang by one arm and slowly rotate through 360° (*Ibid.*, 162-3). The body itself, when pivoting about a fixed point, acts as a pendulum (Fleagle 1977, as cited by *Ibid.*, 48), and the long arms allow for greater distances to be covered. The scapula is placed dorsally (Cambridge University Press 1992, 76). During suspension and brachiation, the arms are over the animal's head, so a brachiator with rounded joint surface on top of the humeral head, and a scapula rotatable onto its back is favored (Stanford, Allen and Antón 2009, 280-1).

Chimpanzee

Chimpanzees are only partly arboreal. They sleep and feed in fruit trees, but travel on ground (Napier and Napier 1997, 168). When on the ground, they are knuckle-walking, in which the weight of the forepart of the body is carried on the back of their knuckles (*Ibid.*, 48-9). The clavicles are shorter, pointing laterally and cephalically (up, toward the head), as opposed to ventrally (down, toward the abdomen) (Bass 2003, 132). This is relevant to the chimpanzee's terrestrialism as the clavicle is a prominent structural element serving to transfer the weight of the body to the arm (Kardong 2002, 342). The humerus is relatively larger and thicker, and the scapula is longer and lies laterally further down the back, compared to humans (Conroy 1990, 384), meaning chimpanzees can reach for things above them too, in trees, for example, on the occasion that they wish to. Although we humans rarely spend time in trees, we still retain our prominent clavicles and long, thick humeri (Kardong 2002, 342).

Human

As humans, we stand, stride and run (Napier and Napier 1997, 48). The superior margin (or border) is thicker and slopes upward, the scapular spine is thicker, and the coracoid process is thicker, in comparison with the chimpanzee's (Conroy 1990, 384). Human scapulas are dorsally placed (Cambridge University Press 1992, 76), located on the back of the rib cage as opposed to on the side (Stanford, Allen and Antón 2009). This is indicative of more musculature in the shoulders and biceps, as thick bones are required to support them. A ball-and-socket joint is formed where the humerus joins the pectoral girdle. This only permits movement in a single plane (Campbell, et al. 2009, 610), but provides a base of support for the bones of the forelimbs (*Ibid.*, 608). The clavicle is also well-developed, especially around both the acromial end articulating with the acromion process of the scapula, the sternal end with sternum. The acromial end of the clavicle also ends more dorsally, in line with the vertebral column. This is used for aiding with complex movements of the arms, providing it with universal movement of the humerus (Cambridge University Press 2006, 631). Last of all, there is an obvious bicipital/intertubercular groove, where the tendon of the biceps muscle passes (*Ibid.*, 632).

Q2: Although both the chimpanzee and the mandrill are walking on all fours, describe how their anatomy differs. What does this tell you about their evolutionary history ?

Looking at both species' skeletons, the back of the chimpanzee's back is much less pronounced and much rounder, while the mandrill has a fairly longer and narrow head. The frontal bones are slightly unfused in the mandrill, compared to the skeletal evidence of the chimpanzee. The nasal aperture is also broader in the chimpanzee, and the glabella (the part between the eyebrows and above the nose) is also thickened. These are indicative of a wider nasal cavity, and consequently, a more efficient respiratory system (Conroy 1990). The brain capacity was also bigger in the chimpanzees. It has been shown that the average length of a chimpanzee's brain is 10.5cm, a human's, 15cm, and a mandrill's, only 8cm, nearly half the size of ours (Noe, Johnson and Welker 2009).

Chimpanzees have also lost their tail, and have relatively wider, broader chests (Napier and Napier 1997, 19). The arms are longer than the legs, and the natural positioning of the chimpanzee's fingers are flexed inwards for knuckle-walking, while the mandrill's are extended outwards for digitigrades quadrupedalism. The chimpanzee's thumb is relatively longer, demonstrating the possibility that chimpanzees are capable of manipulating objects, while the mandrill's are comparatively shorter. From the cranial evidence, to an examination of the rest of the body, it can be inferred that the mandrills are fairly primitive creatures morphologically, and have branched off into another primate family (*Cercopithecidae*) from the great apes and humans.

Q3: Describe with the aid of illustrations, three features of human skeletal anatomy that specifically relate to bipedalism?

Three of the morphological differences seen between non-bipedal primates and us bipedal humans are the variations of our hips, our legs, and our feet.

Hip

The human hip supports the abdominal organs that tend to be pulled downward by gravity in a bipedal animal (Campbell, et al. 2009, 293). The blade of the ilium is widened to broaden the base of support at the hips (Kardong 2002, 311). This is done as it, being broader from front to back, increases the leverage of hip flexors and extensors. The hip acts as a stiff propulsive lever (Cambridge University Press 1992, 77) swinging the legs forward, and in order for it to operate smoothly, the muscles, and thus, the bony support, have to be larger and thicker. It also increases the mass of the lower portion of the body, bringing the center of gravity to a more posterior position (Conroy 1990, 336). Although efficient bipedalism requires a narrow pelvis, that needs to be balanced against the need for a birth canal wide enough for the large shoulders of a child (Campbell, et al. 2009, 293).

Lower limb

In the femur, the femoral neck becomes longer and thicker, while the acetabulum becomes wider in conjunction with the femoral head (Conroy 1990, 334). The head forms two-thirds of a sphere to allow for greater mobility at the hip joint (Bass 2003, 220). There is also a highly developed greater trochant to ensure the ilium is locked into place (Moore and Agur 2007, 377). As the femur juts out to the side, it ensures that we do not lurch over sideways and have our hips collapse to the opposite side of each stride (Conroy 1990, 332).

The femur is the longest bone in the body (Stanford, Allen and Antón 2009, 294), and longer legs means more distance covered in a given number of strides. The legs are longer than the arms (Cambridge University Press 1992, 78), and this increase of size increases the mass of the lower portion of the body (Conroy 1990, 336). As a percentage of total body weight, the upper limbs of humans are only 60% as heavy as those of chimps, whereas the lower limbs are nearly twice as heavy. This arrangement of body weight contributes to a more stable posture, since the center of gravity is lower in the pelvis (*Ibid.*, 336-7). Special adaptations of the knee prevent over-extension of the leg when it swings forwards (Cambridge University Press 1992, 78). To support the excess body weight, the femoral condyles (bottom of the femur) coalesces in front (Brothwell 1972, 37), and is entirely enlarged, as is the tibia with which it articulates (Stanford, Allen and Antón 2009, 294).

Foot

In humans, perhaps the most obvious adaptation for bipedalism is the hallux (big toe) is aligned with the other digits of the foot (Cambridge University Press 1992, 77-8), so that the limbs are swung beneath the body and can be placed close to the line of travel without catching the projecting toe on the opposite leg (Kardong 2002, 343). The foot forms an arch, broadening the base of support upon which the upper body stands. If the arch were absent, extension of the ankle would not be as far (Kardong 2002, 343). The development of these transverse and longitudinal arches also helps to absorb shocks (Cambridge University Press 1992, 78). They store and return some of the energy during walking, and help to reduce the incidence of fatigue fractures to the biped's lower leg (Stanford, Allen and Antón 2009, 295).

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