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COMPARATIVE MORPHOLOGICAL STUDIES ON THE GIRDLES AND LIMB BONES OF THE GENUS *PANTHERA* OKEN (CARNIVORA : MAMMALIA)

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(With 4 plates)

INTRODUCTION

Skeleton of animals has attracted the attention of anatomists since long, mainly because it forms the solid framework of the body in relation to which other structures are oriented. However, all components of the skeletal framework have not received equal treatment. For instance, though the craniology of various mammalian groups has been extensively studied, information about the appendicular skeleton, specially that of Carnivora, is still meagre. Mivart (1881), Kelson (1946), Hopwood (1947), Davis (1949), Hildebrand (1954), Cantuel (1955) and Ondrias (1961) have given accounts to the morphology of skeleton in different carnivores, but none has dealt with the differential character of the various species. The present study was undertaken towards filling up the lacuna in our knowledge of carnivore osteology.

As a first step, four species of the genus *Panthera,* namely *Panthera leo* (Linn.) (the Lion), *P. tigris* (Linn.) (the Tiger), *P. pardus* (Linn.) (the Leopard) and *P. uncia* (Schreber) (the Snow Leopard) were selected for study. The fifth species of the genus, the neotropical *P. onca* (the Jaguar) could not be studied for want of material.

The investigation has been confined to the morphology of the long bones and girdles in the four Indian species of this genus, and attempt has been made to correlate the diversity in structure with the habits and habitats of these species, and to assess the degree of specialisation achieved in each.

The Lion is an inhabitant of semi-forested areas with plenty of scrub ; it is a powerful leaper but does not climb trees. The Tiger chiefly lives in grasslands, and reedy swamps,

though may be, occasionally, associated with dense forests. It is not arboreal, but it can swim well. The Leopard can climb trees with great ease. It lives mainly in forests but may also be found in broken, rocky hill-sides and scrub-covered country. The Snow Leopard is denizen of a different type of habitat. It does not inhabit forests, but occupies rocky mountains above tree-line where it can move about with great facility. It descends to lower levels from its normal haunts upto the forest-zone (2,000 m) during the acme of the winter.

MATERIAL AND METHOD

Most of the skeletons studied belonged to the Zoological Survey of India, but some were received on loan from the American Museum Natural History, New York, and the Zoological Institute, Academy of Sciences of U.S.S.R., Leningrad.

In all, 40 skeletons were examined, as detailed below. Of these 2 unsexed examples of *P. leo,* 2 ♂ and 1 ♀ of *P. tigris* were from captive specimen of Zoological Gardens, and the others were of wild animals.

P. leo,	2 ♂ , 2 ♀, 2 unsexed
P. tigris,	9 ♂ , 9 ♀, 2 unsexed
P. pardus,	5 ♂ , 4 ♀, 1 unsexed
P. uncia,	2 ♂ , 2 ♀.

The skeletons of both the sides were examined. In order to avoid the variation due to age, only those skeletons where the epiphysial sutures were closed or obliterated, were studied. Morphological characters are mentioned for the genus first, followed by those for the different species.

OBSERVATIONS

SCAPULA

(Pl. 1, figs. 1-8)

Flat, more or less triangular ; spine somewhat straight, slightly inclined towards infraspinous fossa ; coracoid border rounded, more convex at lower end ; junction between vertebral and coracoid borders distinct marked by a prominent rounded thick area ; coracoid process generally pointed, hook-like slightly projecting out, subscapular surface more concave, with five or six prominent ridges for muscular attachment.

The main feature by which the scapula can be specifically differentiated is its outline and the contour of spine. The spine is somewhat linear in the Lion and slightly overhangs towards infrascapular fossa. In the Tiger and the Leopard, it is broad in the middle, more so in the former. It is more inclined towards the fossa in the Tiger but almost erect in the Leopard. The spine is also linear throughout but more inclined towards the fossa in the Snow Leopard. In the Tiger and the Leopard, the acromion is slender and curved at the end like a hook, more so in the latter. It is broad and almost straight in the Lion and the Snow Leopard. The metacromion is broad and fan-shaped in the Tiger, but slender and hook-like in the Leopard. It is elongated and massive on the base in the Lion and the Snow Leopard. The coracoid margin is uniformly curved without forming any angle in the Lion and the Leopard, whereas an obtuse angle is formed just below the middle in the Tiger and almost at the middle in the Snow Leopard. On the costal side, the scars for *m. serratus magnus* and *m. lavator anguli scapulae* are placed just behind the spine. It is somewhat rectangular in the Tiger, elongated or diamond-shaped in the Leopard, and rhomboidal in the Lion. In the Snow Leopard the shape is intermediate between those of the Lion and the Tiger. The coracoid process is stumpy in the Lion and rudimentary in the Snow Leopard. It is fairly well-developed and directed backward in the Tiger, but small and slightly curved in the Leopard.

HUMERUS

(Pl. 2 figs. 1-4)

Massive, more or less cylindrical ; bicipital groove wide ; deltoid ridge prominent, placed more towards outer margin ; surface for *m. infraspinatus* well developed ; greater and lesser tuberosities heavy and broad ; olecranal fossa narrow and deep with prominent external edge ; supinator ridge fairly well developed.

The humerus of the Leopard is almost linear. It is slightly curved inward in the Snow Leopard, and more so in the Lion. In the Tiger, this curvature is intermediate between those of the Lion and the Snow Leopard. The deltoid tuberosity is strongly developed in the Tiger and the Leopard, more so in the former. It is less developed in the Lion and least in the

Snow Leopard. The outer and inner margins of the deltoid tuberosity meet posteriorly to form the crest. This fusion takes place above the middle of the shaft in the Lion, at the mid-point in the Tiger, in between the two in the Leopard and a little below the middle in the Snow Leopard. The humeral crest is more prominent in the Tiger and the Leopard than in the Lion and the least in the Snow Leopard. The prominent teres tubercle is placed equidistant from the outer and inner margins in the Lion and the Snow Leopard ; towards the inner margin in the Tiger, but in the Leopard it lies between the inner margin and the middle point.

RADIUS

(Pl. 2, figs 5 & 6)

Shaft rather flattened, slightly curved, head oval or kidney-shaped, lateral border flattened, medial border relatively sharp, styloid process elongated and fairly well developed.

The scars for the *m. pronator teres* and *m. supinator brevis* are situated almost in the middle axes in the Lion and the Snow Leopard, slightly proximal to it in the Tiger and distal to it in the Leopard. In the Lion and the Snow Leopard, prominent ovate tubercle for *m. biceps* is placed close to the lateral border, but in the Tiger, nearly half of it lies on the volar surface and the rest on the lateral border. In the Leopard, it has shifted more towards the volar surface. The styloid process is elongated and pointed in the Tiger but less so in the Snow Leopard. In the Lion and the Leopard, it is broader at the base and appears less elongated.

ULNA

(Pl. 2, figs. 7-9)

Shaft heavy, strongly built, more or less straight, tuberosity for radial surface highly developed ; olecranon provided with a single process towards its outer extremity.

The ulna can be specifically differentiated by the nature of a deep fossa, situated in front of a smooth area on the proximal end of the olecranon, where the *m. triceps* are inserted. In the Leopard, the lateral margin is tumid, more promi-

nent and placed upwards than the medial margin. In the Lion, the lateral and medial margins are equally strong and the former is more anteriorly situated than that in the Leopard. In the Tiger, the lateral margin is thick, and more anteriorly projected than in the Lion ; whereas the medial margin is thin and less elevated than the lateral margin as in the Leopard. In the Snow Leopard, the thick and prominent medial margin is projected more anteriorly than the thick lateral.

INNOMINATE

(Pl. 3, Figs. 1-4)

Ilium slightly concave on outer surface, crest convex, arched and parabolic ; outer surface of acetabulum projected out, obturator foramen uniformly narrow towards anterior end ; acetabular process of ischium less developed in male than in female ; pubis slender in female but stout in male.

The ischiatic process which forms the acetabulum is depressed in the Lion and slightly less so in the Snow Leopard. It is elevated in the Tiger and the Leopard but to a lesser extent in the latter. The outer border of the acetabulum is broad in the Lion and the Leopard, and narrow in the Tiger and the Snow Leopard. The acetabular notch is prominent in the Tiger, less so in the Snow Leopard and the Leopard, and the least in the Lion. It is directed downward, inside the acetabulum in the Lion, upwards in the Tiger, and more or less straight in the Leopard and the Snow Leopard. The obturator foramen is oval in the Lion and the Snow Leopard, somewhat elliptical in the Tiger, and perfectly elliptical in the Leopard.

FEMUR

(Pl. 4, fig. 1 & 2)

Shaft sub-cylindrical, more or less straight, head broadly rounded ; dorsal surface of neck thick and straight ; greater trochanter straight ; trochanteric fossa shallow and wide ; lesser trochanter fairly well developed, knobbed, placed a little away from trochanteric fossa ; linia aspra well developed.

In the Lion, the shaft is more arched at the distal end than that of the Tiger and the Snow Leopard, but in the Leopard,

it is almost straight. The head is broad and wide in the Lion but less so in the Snow Leopard. In the Tiger and the Leopard, it is stumpy. The trochanteric fossa is broader in the Lion and the Snow Leopard than those in the Tiger and the Leopard.

In the Lion the lateral ridge is well developed. The distance between the lesser trochanter and the head is maximum in the Tiger, minimum in the Lion and intermediate between the two in the Leopard and the Snow Leopard. The greater trochanter is placed a little higher than the head in the Lion and in others it is almost at the same level as the head. The points of origin of the *m. gastrocnemius* on the inner surface above the condyle are well defined in all the species studied.

TIBIA

(Pl. 4, figs 3-5)

Crest flattened, highly developed, with a prominent ridge on outer side ; popliteal notch fairly well developed, with prominent outer tuberosity.

The crest of the tibia is prominent in the Lion and arched towards the outer side with a deeper concavity on the lateral surface than that of the Tiger. In the Leopard, it is less prominent than that of the Tiger, and it is least prominent in the Snow Leopard. The furrow for the attachment of *m. gastrocnemius* on the inner surface of the tibia is prominent and deep in the Leopard, slightly less so in the Tiger, and rather shallow in the Lion and the Snow Leopard.

FIBULA

(Pl. 4, fig. 6 & 7)

Shaft slender, reduced ; outer surface concave ; proximal end bluntly expanded ; distal end flattened with notched extremity.

Of the long bones of *Panthera* studied, the fibula shows much individual variation. It is stronger in the Tiger than in the Lion. It is heavier in the Snow Leopard than in the Leopard. The head of the fibula in the Lion is more expanded than that of the Tiger. In the Snow Leopard it is less developed than that of the Tiger, and least so in the Leopard.

DISCUSSION

Limbs have dual function of locomotion and supporting the body, the girdles serving as a bridge between the axial skeleton and limbs.

The appendicular skeleton in species of the genus *Panthera* has the same general plan and components, but the latter exhibit certain structural modifications to suit the particular habits and ways of life of each species.

The four species of larger cats of the genus *Panthera,* dealt with here, are all predators who have the ability for swift and sustained running, as well as capability to stalk their prey noiselessly and slowly. Not only can they successfully stalk their prey and overpower it, but they can also escape swiftly when sensing danger. Additionally, forelimbs of the big cats are capable of paralysing even larger prey with a powerful blow, capable of dislocating the cervical vertebrae and of tearing away large chunks of flesh from the body of the victim.

The elongated scapulae of the Lion and Leopard, and the deltoid crests placed towards the proximal end of the humerii, are specialisations for speed, as they assist in large angular movement, necessary for quick progression, through the muscles attached over them. In addition, the presence of moderately developed scars in the radius of the Lion indicate moderately developed extensor muscles ; the latter are responsible for the fast running of the animal. The cursorial habits of the Lion and Leopard are further emphasised by the weak pubis and downwardly directed acetabulae (Howell, 1944) and by the development of large femoral head and the reduction of fibulae which restrict their movement in the lateral and sagittal planes (Hildebrand, 1954). Moreover the well-developed greater trochanter in all the four species studied indicates the presence of a powerful gluteal group of muscles, which are essential for running and leaping.

Combined with the capacity for fast running, all these cats are also capable of jumping, a faculty in which the hind limbs are more involved than the fore-limbs. The comparatively longer ischio-pubic region of the pelvis as compared to the ilium in them apparently facilitates in jumping. Among the four species of *Panthera,* the Leopard is structurally best adapted for jumping because of a well-defined trochlear groove indicating fairly well-developed gastrocnemius muscle which assists

in giving the animal necessary poise preparatory to the rapid final leap. The Tiger, the Snow-leopard and the Lion, in which the tibial grove has undergone gradual reduction, are structurally less proficient in ability to jump than the Leopard.

Finally, among the four species, the Leopard shows the greatest ability for climbing which is reflected in the moderately erect scapular spine which gives facility for raising of thorax. The power to rotate the forearm, indicated by the well developed scars for the flexor muscles, is another feature of importance in climbing exhibited by the Leopard.

In conclusion, it can be said that the appendicular skeleton in the four species of the genus *Panthera* is strong and distinctly oriented for powerful muscle attachments that give these cats the power to run fast, jump and, as in the case of the Leopard, to climb. The specific differences in the axial skeleton can be correlated to their particular habits and in spite of much individual variations the morphological characters furnish easy and reliable clues to specific identity of each cat.

SUMMARY

The morphological characters of the girdles and limb bones of four species of the genus *Panthera,* viz. *P. leo, P. tigris, P. pardus* and *P. uncia* have been studied. Certain features which aid in differentiating these species, are presented here and the salient ones have been summarised in a tabular form. Further an attempt has been made to correlate these differences with their habits.

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