OCCASIONAL PAPERS OF THE MUSEUM OF ZOOLOGY

UNIVERSITY OF MICHIGAN

ANN ARBOR, MICHIGAN

NOTES ON THE GLIDING MECHANISM IN THE FLYING SOUIRREL

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THERE has been considerable work done on the anatomy of flying squirrels with some discussion on their phylogeny and relationships (Pocock, 1922, 1923; Peterka, 1936; Bryant, 1945; Layne, 1954; Burt, 1960; McKenna, 1962), but very little in relation to their gliding. Walker (1947–51) and, recently, Muul and Alley (1963) described how *Glaucomys* changes its body shape while gliding. This analysis was based on photographs taken during the glides.

In an attempt to determine the peculiarities in their anatomy, connected with the gliding mechanism, I have undertaken a study on the two New World species—Glaucomys volans and G. sabrinus. Freshly chloroformed specimens, as well as preserved ones, were dissected. The latter were kept in 7 per cent formaldehyde after embalming with the same fluid. Five specimens of G. volans and three of G. sabrinus were dissected, and microtomic sections were made of the Bouin's-fixed gliding membrane to confirm the actual attachment and relationship of the muscles (Pl. I). The presence of the accessory carpal has been observed even in the neonatal volans.

The skeleton of the limbs of *Glaucomys* is grossly similar to that of other sciurids, except for the additional slender cartilage (sometimes referred to as styliform cartilage) that articulates with the lateral half of the fifth metacarpal, the unciform, and pisiform, and extends laterally from the wrist joint to support the anterior margin of the gliding membrane (plagiopatagium).

In the wrist of *Glaucomys* (Fig. 1A) there are nine carpals plus the long slender cartilage here designated accessory carpal, "os accessorire" of Grasse (1955), who observed an additional carpal in the same posi-

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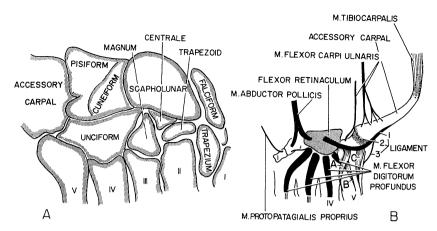


Fig. 1. A, Wrist bones of *G. volans*; B, plantar view of the muscles and ligaments in relation to the accessory carpal of *G. volans* (diagramatic): 1, ligament between the flexor retinaculum and lateral side of the accessory carpal; 2, capsular ligament between the pisiform and accessory carpal; 3, ligament between the lateral side of the fifth metacarpal and accessory carpal; A, M. opponens digiti quinti; B, M. flexor digiti brevis; c, M. abductor digiti quinti.

tion in *Chlamyphorus truncatus* (Xenathra) and in two lagomorphs, *Sylvilagus floridanus* and *Ochotona saxatilis*. Greene (1935) observed a similar structure, though smaller, in *Rattus norvegicus* and named it *ulnar sesamoid*. The cartilaginous rod shares its articulation with the head of the fifth metacarpal.

The accessory carpal and the pisiform are connected by a capsular ligament, and another ligament connects the flexor retinaculum with the lateral side of the accessory carpal. M. flexor carpi ulnaris is divided and inserts on the proximal end of the accessory carpal and the pisiform. The reduced pollex receives a tendon from M. flexor digitorum profundus. M. abductor pollicis splits into two and inserts on the flexor retinaculum and the reduced pollex (Fig. 1B). Because of its cartilaginous structure, the accessory carpal appears to be resilient to deformation during gliding when it forms a nearly curved surface at the anterolateral end of the lateral gliding membrane.

GLIDING MEMBRANE AND ITS MUSCLES.—The lateral extension of skin between the front and hind limbs (the plagiopatagium) is lined internally by a thin layer of transverse muscle fibers, followed by another layer of longitudinal fibers. The former are absent at the lateral margin of the membrane, which is lined solely with a bundle of longitudinal muscle fibers. Anteriorly, between the front limbs and the head, the

lateral margin of the membrane (the propatagium) is lined with a flat muscle, the protopatagialis proprius. At the posterior end the membrane between the hind limbs and the tail (the uropatagium) has an inner support of what I interpret as semitendinosus III, which originates from the transverse process of the seventh caudal vertebra and extends laterally, fusing with the other two parts of the semitendinosus at the proximal end of the tibia; together they insert on the lateral surface of the tibia near the knee.

M. protopatagialis proprius: This muscle originates from the lateral region of the skull, runs posteriad in the neck region and extends toward the wrist to insert by a tendinous end on the reduced pollex. This muscle assists in the control of the movement of the front limbs in relation to the head during glide.

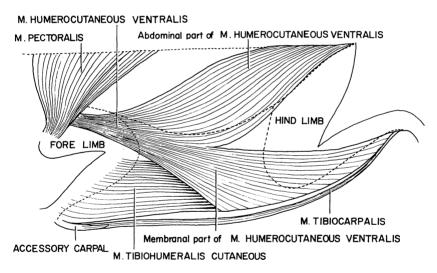


Fig. 2. Cutaneous muscles of the ventral surface of G. volans.

M. humerocutaneous ventralis (Fig. 2): This muscle originates, with the abdominal muscles, on the pubis and inserts on the medial surface of the humerus, between the lesser tuberosity and the deltoid ridge, very close to the insertion of M. pectoralis. As the fibers come out of the shoulder region, they spread on the ventral body surface. The lateralmost fibers run toward the mid-lateral margin of the gliding membrane, the medial fibers toward the ankle, and the innermost fibers to the abdominal region where they cover the abdomen then continue to the inguinal region. Contraction of the muscle pulls the

front limb posteriad. This and the following muscle may be regarded as part of the M. cutaneous maximus of Meinertz (1941), Bryant (1945), and Klingener (1964). Fibers extend over the body and also receive a branch of the brachial plexus.

M. humerocutaneous dorsalis: The fibers of this muscle originate on a broad area on the dorsal skin. They run ventrad to insert on the medioproximal surface of the humerus near M. humerocutaneous ventralis. Contraction of the muscle will pull the front limb posteriad.

M. tibiohumeralis cutaneous (Fig. 2): This thin layer of muscle fibers, present on the side of the body in the gliding membrane, runs longitudinally from the ankle to the front limb. It originates from the laterodistal end of the tibia, spreads out in the whole gliding membrane, and inserts anteriorly by a thin aponeurosis on the whole length of the brachium and antebrachium, extending up to the wrist. Contraction will bring the anterior and posterior limbs closer together.

M. dorsolongitudinalis cutaneous: On the inner surface of the skin of the back region there is a thin layer of muscle fibers extending longitudinally from the anterior to the posterior end with no definite origin and insertion. The muscle fibers are well defined laterally but are absent in the mid-dorsal region. Contraction will shorten the length of the skin.

M. transversus cutaneous (Pl. I): In the thoracolumbar region a thin layer of muscle fibers runs transversely under the M. dorsolongitudinalis. The fibers turn ventrad, before reaching the margin of the gliding membrane, and insert on the ventrolateral skin. Contraction will bring the gliding membrane closer to the body.

M. tibiocarpalis (Pl. I): This muscle originates from the distolateral end of the tibia, along with the M. tibiohumeralis cutaneous, and runs anteriorly, but it is restricted to the margin of the gliding membrane. At the anterior end it inserts on the accessory carpal in the form of a caplike covering. Contraction will cause the front limb to move backwards. I consider the tibiohumeralis, dorsolongitudinalis, transversus cutaneous, and tibiocarpalis parts of the panniculus carnosus; they are in the thoracolumbar region and are supplied by the thoracic nerves.

M. caudocutaneous: This muscle originates from the dorsal surface of the first two caudal vertebrae and inserts on the skin above this region.

I am grateful to Dr. W. H. Burt for the facilities and for critical suggestions regarding this manuscript; and to Dr. Illar Muul for the help in collecting the specimens.

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Accepted for publication December 1, 1965

PLATE I

Microphotograph of transverse section of the gliding membrane of G. sabrinus passing through the lateral margin (upper) and through the accessory carpal (lower). AC, accessory carpal; H, hair follicles; TI, M. tibiocarpalis; TR, M. transversus cutaneous.

