Acta med. Nagasaki. 20 : 29-71

On the Extensor Muscles of the Forearm in Formosan Monkey (*Macaca cyclopis*)

Seiji NAGASHIMA *

First Department of Anatomy, Nagasaki University School of Medicine, Nagasaki, Japan

Received for publication, February 19, 1976.

INTRODUCTION

The purpose of the present study is an attempt to determine of the anatomical standard condition of the extensor muscles of the forearm in Formosan monkey.

W. L. STRAUS (1941) and many other investigators have examined the musculature of the forearm of Primates, but many of these studies involved only a small number of cases so that some of their conclusions may possibly be associated with errors due to the effect of individual differences or variations. Thus, in order to avoid such difficulties it seems to be necessary to examine a comparatively large number of animals of a single species and statistically analyze the findings.

Based upon such a concept, studies of a large number of cases of Formosan monkey (*Macaca cyclopis*) had been made in this department under the supervision of Professor J, SATOH and are presently being continued in an attempt to determine the normal condition of the various organ systems of the species. The present study was done as part of that project.

This paper will examine the origin and insertion of the extensor muscle group of the forearm as well as their nerve supply and relation to surrounding muscles. The findings will be discussed in comparison with the findings for Primates and man reported by other investigators.

In an earlier work in this laboratory by A, HADANO (1955) a statistical study was made of the findings from the examination of 100 limbs of Formosan monkey, but the results are still unpublished. His records, however, are all maintained in this department so that some of his findings including his observations on variations will be included here.

* 長 嶋 聖 司

MATERIAL AND METHOD

The material in the present study consisted of both arms of 15 animals (male 7, female 8) selected at random from the collection of adult Formosan monkey, the so-called J, SATOH's specimens that are preserved in this department. These animals had been fixed by 10 per cent formalin solution injected into the femoral artery and stored in the solution of the same concentration. The examinations were made in as much detail as possible using a dissecting knife and tweezers, and observations were carried out carefully. The inspection of the nerves and minute portions was always done using magnifying lenses with an illumination attachment.

FINDINGS AND DISCUSSION

The muscles of the forearm can be classified into the extensor and flexor muscle groups, which are enclosed within the antebrachial fascia. The extensor muscle group of the forearm includes the following 11 muscles, which can grossly be separated into the superficial and deep layers by their location. These muscles are all supplied by muscular branches from the radial nerve.

A: Superficial layer group
- 1) M. brachioradialis
- 2) M. extensor carpi radialis longus
- 3) M. extensor carpi radialis brevis
- 4) M. extensor digitorum communis
- 5) Mm. extensores digitorum quarti and quinti proprii
- 6) M. extensor carpi ulnaris

B: Deep layer group
- 7) M. supinator
- 8) M. extensor pollicis longus
- 9) M. extensor digiti secundi proprius
- 10) M. extensor digiti tertii proprius
- 11) M. abductor pollicis longus

Fascia antebrachii

The antebrachial fascia, which arises as a continuation of the brachial fascia, encloses both the extensor and flexor muscles of the forearm. In the elbow region, it not only is a sheath, but also plays a role in the origin of the superficial layer of muscles

of the forearm. Further, it also serves as the insertion of the M. biceps brachii because the tendon of the M. biceps brachii, after changing to aponeurosis, radiates into the antebrachial fascia at the level of the cubital fossa. In the area of the upper posterior surface and distal medial surface of the ulna which are not covered by muscle, the antebrachial fascia is particularly well developed and attaches directly to that bone.

The antebrachial fascia is much more firmly adhered to the M. brachioradialis and the M. flexor carpi ulnaris than to any other muscle in the superficial muscular layer of the forearm, and these muscles serve as a boundary to separate the fascia into the dorsal and palmar divisions. The dorsal portion of the antebrachial fascia is far more well developed than the palmar division, and the intermuscular septum, which is continuation from this fascia, extends between the Mm. extensores digitorum quarti and quinti proprii and the M. extensor carpi ulnaris for attachment to the ulna. The latter palmar portion of the antebrachial fascia consists of comparatively loose aponeurosis and does not form any intermuscular septum.

The distal part of the antebrachial fascia becomes strengthened by transverse fibers near the wrist and forms the palmar carpal ligament and the dorsal carpal ligament (the extensor retinaculum), and the latter is formed a number of separate compartments for tendons from the extensor muscles of the forearm on the back of the wrist.

1. M. brachioradialis (figures 1-3)

This muscle is the best developed among the extensor muscle group of the forearm. It is located on the radial surface of the forearm and functionally belongs to a flexor rather than a extensor.

The origin of this muscle is from the lateral brachial intermuscular septum that extends between the M. triceps brachii and the M. brachialis, and from the lateral edge of the distal part of the humerus.

The portion arising from the intermuscular septum can be classified as follows according to the state of origin:

(i) The intermuscular septum is adhered to neither the M. triceps brachii nor the M. brachialis so that the origin of the M. brachioradialis is clearly from the intermuscular septum (14/30);

(ii) The intermuscular septum is adhered to the M. triceps brachii so that this muscle appears to arise from the M. triceps brachii (9/30);

(iii) The intermuscular septum is adhered to the M. brachialis so that this muscle appears to have origin from the M. brachialis (4/30);

(iv) The M. brachioradialis arises entirely by tendon so that it appears to have tendinous origin rather than from the intermuscular septum (3/30). In one of the limbs with such a condition of origin, the level of the origin was the middle of the humerus, and in the other two limbs that involved both sides of one case,

the origin was from the proximal third of the humerus.

It was difficult to determine at what level this muscle arose in the arm in types (ii) and (iii). Therefore, examination was made of the level at which the intermuscular septum changes to muscle. It was found that this transition occurs predominantly at about the middle of the humerus (24/30), with the remaining few cases equally distributed between those with origin at a level higher than the middle (3/30) and those with origin at a lower level (3/30).

Furthermore, the brachial fascia, which overlies the M. brachialis in the area slightly below the middle of the upper arm, is seen radiating into the anterior edge of the M. brachioradialis. In view of this, the brachial fascia should also be considered to contribute to the origin of the M. brachioradialis.

Next, the portion of this muscle that arises from the lateral edge of the lower part of the humerus has muscular origin from the distal third to distal fourth of the humerus. Moreover, the origin becomes slightly wider toward the lower part, and its radial side is adjacent, but not adhered, to the M. extensor carpi radialis longus.

There is a narrow space formed between the portion arising from the intermuscular septum and that part having muscular origin from the humerus. The dorsal antebrachial cutaneous branch of the radial nerve (the superficial branch of the radial nerve in Gorilla - PREUSCHOFT, etc.) passes through this space and runs between the M. triceps brachii and the M. brachioradialis to emerge to the subcutaneous region of the radial surface of the distal part of the upper arm.

The M. brachioradialis, after having arisen as described above, forms a muscular belly, which bulges in arc-like fashion toward the radial side, and runs downward to insert into the lower part of the radius. During its course downward it lies over, proximally, the insertion of the M. pronator teres and, distally, the origin of the M. flexor digitorum profundus as well as being in contact with the M. flexor carpi radialis on the palmar surface, while it overlies the Mm. extensores carpi radialis longus and brevis on the dorsal side as it descends along the M. extensor digitorum communis.

The insertion takes place by tendon into the styloid process of the radius and the area slightly above. However, this muscle remains muscular until just before its insertion and the insertion involves an area which is comparatively long in length so that in about half of the cases, the superficial aspect was still muscle fiber even though the deep aspect had begun to attach by tendon.

A variation related to this muscle was noted in three limbs in which muscle fibers of the M. brachialis radiated into and strengthened the brachial fascia, which in turn radiated into the anterior edge of the M. brachioradialis. In one of these limbs, the fascia that is strengthened by the M. brachialis was found to first fuse with a fascia, which received tendon fibers from the insertions of the M. pectoralis major and the M. deltoideus, and then radiate into the anterior edge of the M. brachioradialis.

The M. brachioradialis is frequently absent in Mammals (STRAUS, CARLSSON, etc.), but is generally never absent in Primates with the exception of some kinds of Prosimia in which this muscle is reported to be absent (*Ptilocercus* - CLARK ; some *Tupaia* - CARLSSON).

The humeral origin of this muscle in Primates is generally from the lateral edge of the lower part of the humerus, and the findings in my cases of Formosan monkey were not in exception to this.

LOTH states that the more proximal the humeral origin the more primitive is the condition and that the level of the origin tends to be shifted downward depending upon the phylogenic stage. Although the literature contains descriptions of some cases among Primates in which the origin may be as high as the surgical neck of the humerus or the M. deltoideus (STRAUS, MURIE and MIVART, FICK, SULLIVAN and OSGOOD, HEPBURN, SONNTAG, etc.), the origin in many cases of Primates is usually half-way up the humerus. The level of origin in man is more distal than in other Primates, and is usually said to be lower than the middle of the humerus. In a study of human fetuses, however, the upper limit of the origin was found to be higher than the middle of the humerus in some cases (IWAMI, 4%). Moreover, there seems to be racial differences in the level of the origin, Negroes having origin from a higher level which is a more primitive state in comparison with Europeans or Japanese (CHUDZINSKI, LOTH, INOUE).

This muscle, at its origin, is frequently reported to be adhered to such adjacent muscles as the M. brachialis (*Lemur* - STRAUS ; Gibbon - HEPBURN ; Chimpanzee - BEDDARD, MILLER, SONNTAG, etc. ; Gorilla - PIRA, etc.), the M. triceps brachii (Chimpanzee - BEDDARD), the M. deltoideus (Gorilla - PIRA), the M. supinator (Chimpanzee - BEDDARD), or the M. extensor carpi radialis longus (*Hapale* - BEATTIE). No adhesion, however, was found between the muscular portion of this muscle and any other muscle in my cases of Formosan monkey except in the area of the intermuscular septum.

The insertion of this muscle in Primates, similar to that in my cases of Formosan monkey, is reportedly to be usually upon or a little above the styloid process of the radius, but there are observations showing the insertion to be higher such as at the middle of the radius (*Perodicticus* - STRAUS ; Gibbon - BARNARD, BISCHOFF, STRAUS) or at a point well above the styloid process of the radius (Orang - FICK ; Gibbon - HEPBURN) so that, in general, the insertion of this muscle upon the radius in Gibbon is higher than in other Primates. Some authors (PREUSCHOFT, PIRA, SULLIVAN and OSGOOD, LANGER, FICK, BISCHOFF, etc.) describe the insertion to be the antebrachial fascia in addition to upon the radius in Anthropoid apes with the exception of Chimpanzee, but such attachment to the fascia was not seen in Formosan monkey, and neither was there penetration of this muscle at its origin by the superficial branch of the radial nerve such as frequently noted in Gorilla (PREUSCHOFT, etc.) or as rarely seen in man (WOOD).

2. M. extensor carpi radialis longus (figures 1-3)

This muscle, located between the M. brachioradialis and the M. extensor carpi radialis brevis, arises muscularly from the lateral edge of the humerus, between the lower fourth of the humerus to the lateral epicondyle. The origin is unrelated to the intermuscular septum, and there is no adhesion with the M. brachioradialis on its lateral side or with the M. extensor carpi radialis brevis on its medial side. This muscle is located subcutaneously near its origin, but is covered by the M. brachioradialis at just below the elbow joint. This muscle changes to tendon usually at about the middle of the forearm, at least before the M. extensor carpi radialis brevis changes to tendon. The tendon of this muscle descends, accompanied by the tendon of the M. extensor carpi radialis brevis, to about the lower fifth of the forearm where it passes beneath the M. abductor pollicis longus. After passing through the second compartment of the dorsal carpal ligament together with the tendon of the M. extensor carpi radialis brevis, it immediately runs beneath the tendon of the M. extensor pollicis longus to its insertion upon the radial side of the dorsal surface of the base of the second metacarpal bone.

The origin of this muscle in both Primates and man is just distal to that of the M. brachioradialis, and is from the lateral epicondyle and the area immediately above upon the humerus. The insertion is the dorsal surface of the base of the second metacarpal bone. The condition in Formosan monkey was not in exception to this, but many investigators describe the origin in Anthropoid apes to be similar to that in man with origin from the lateral intermuscular septum as well as from the humerus (Anthropoid apes - HEPBURN; Gorilla - PREUSCHOFT; Chimpanzee - SONNTAG; Orang - SULLIVAN and OSGOOD, SONNTAG). Other investigators, however, make no mention of origin from the intermuscular septum even in these same species (Gorilla - PIRA, RAVEN, SOMMER; Chimpanzee - BEDDARD, MILLER; Orang - BEDDARD, etc.). Among Primates other than Anthropoid apes, mention of origin from the intermuscular septum is seen in some kinds of Catarrhina (*Rhinopithecus* and *Cynopithecus* - PATTERSON), but otherwise no description of such a condition can be found on casual review of literature. Therefore, at least the additional origin from the intermuscular septum, as a rule, seems to be a pattern found in Anthropoid apes and man. Furthermore, variations reported include case with origin by two heads in man (MORI) and case with separation of the muscular belly near the origin into two parts among Gorilla (PIRA), but neither were such abnormalities of the origin nor any association with the intermuscular septum seen in my cases of Formosan monkey.

The insertion of this muscle in Primates and man is usually said to be the base of the second metacarpal bone, but the following variations have been reported :

(i) Insertion into the greater and lesser multangular bones (Chimpanzee - MICHAËLIS);

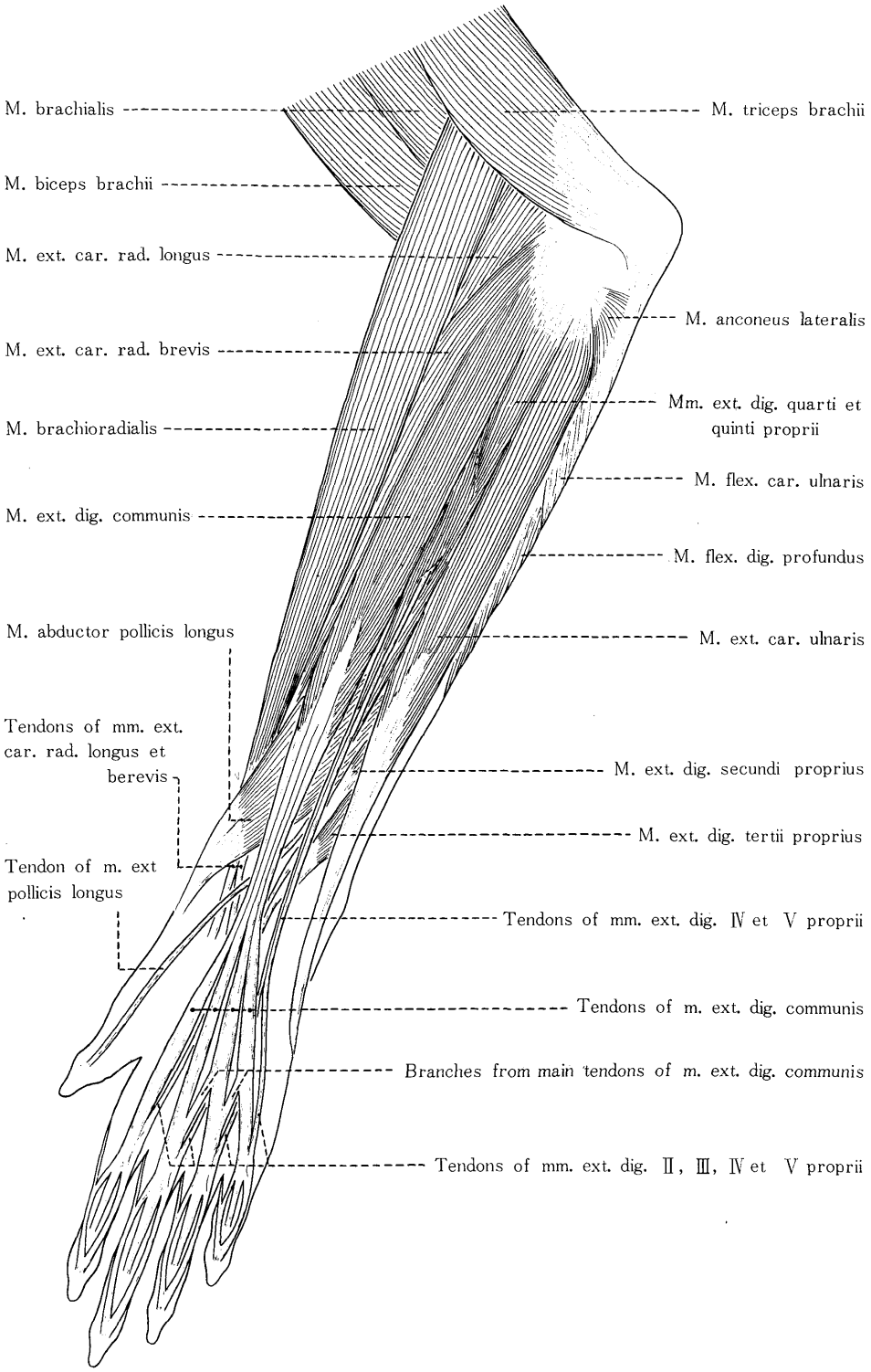


Fig. 1. Superficial muscle group (a)

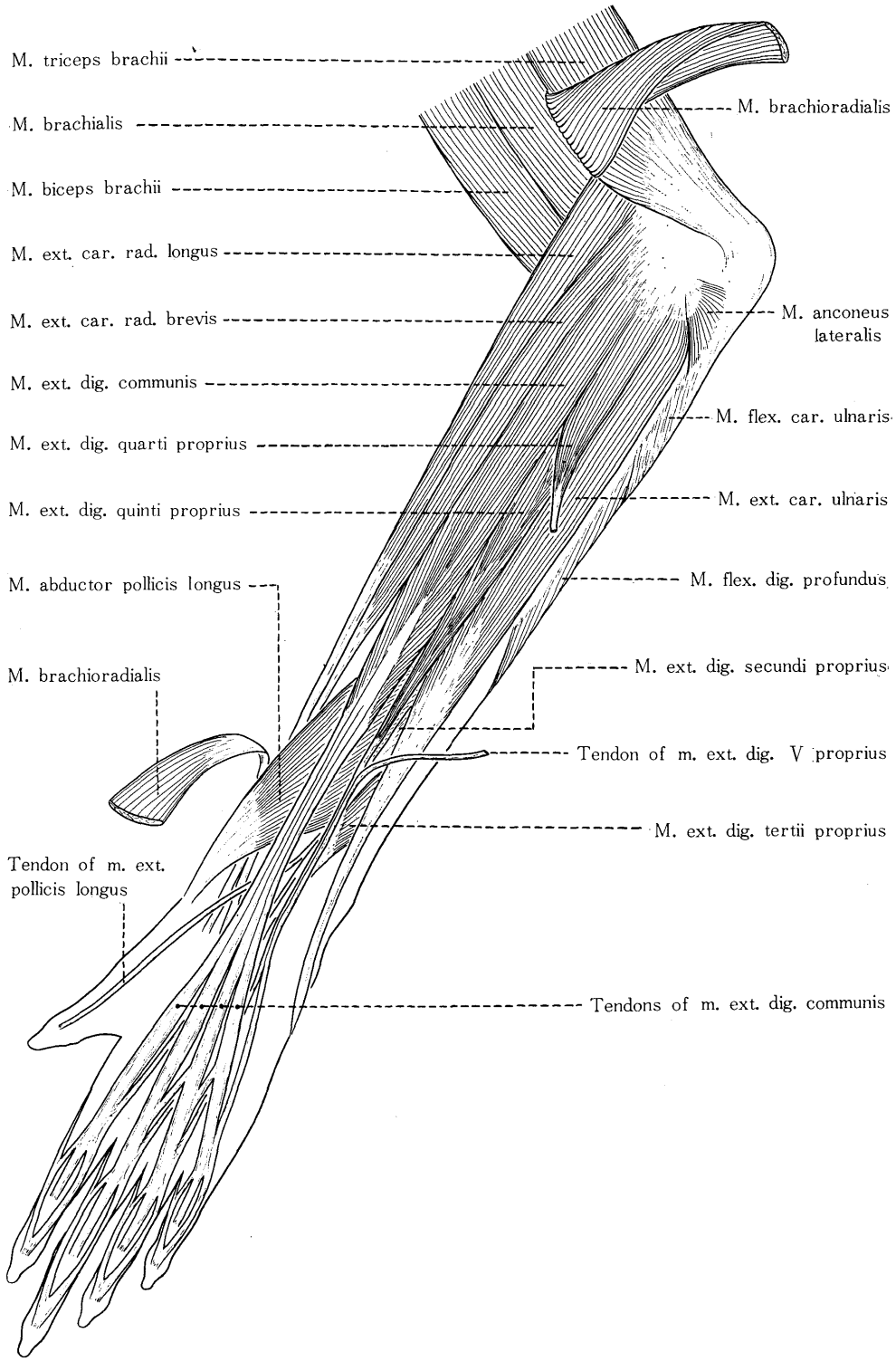


Fig. 2. Superficial muscle group (b)

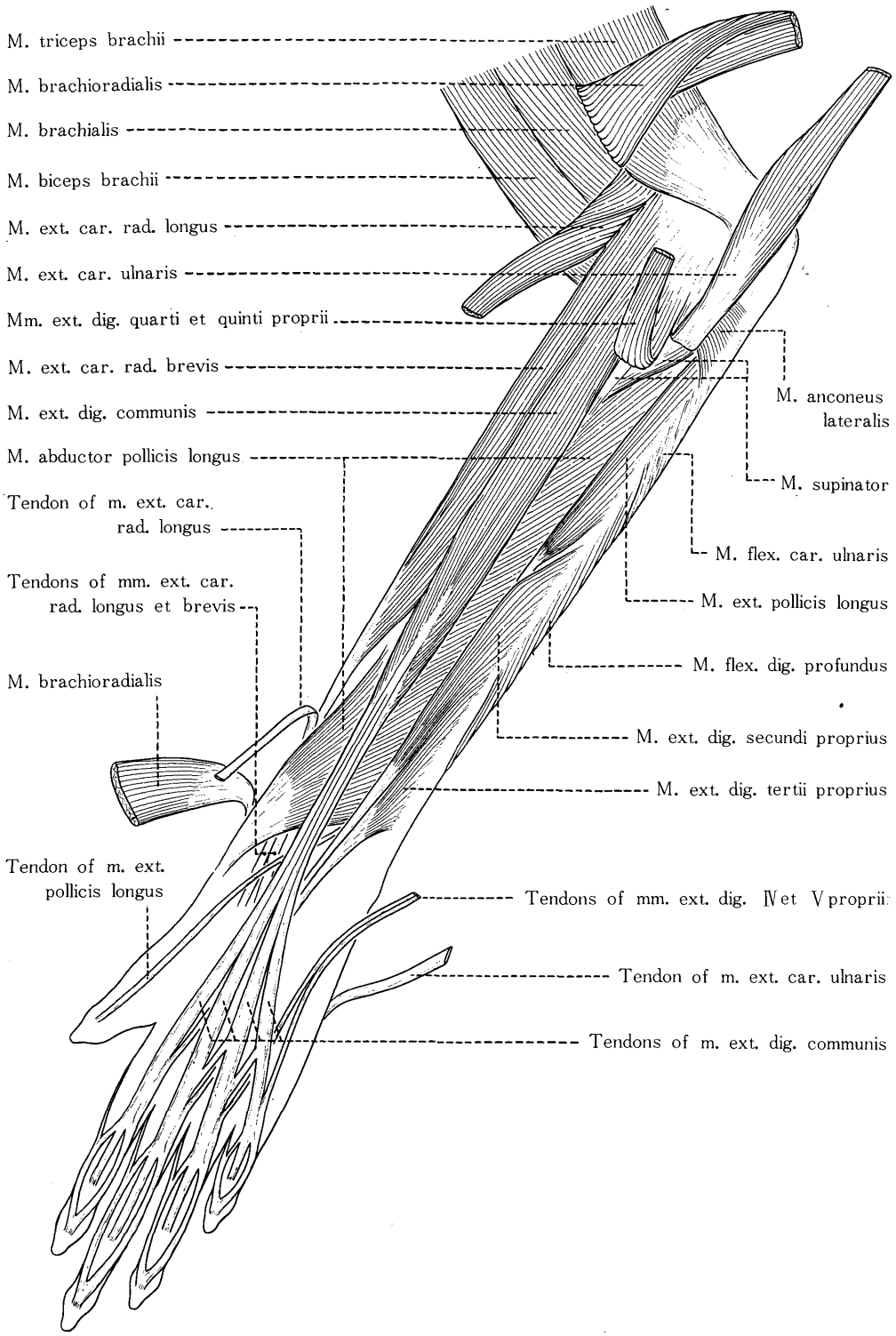


Fig. 3. Superficial muscle group (c)

(ii) Insertion into only the first metacarpal bone (Marmoset - BEATTIE) ;
(iii) Insertion into only the third metacarpal bone (Orang - MICHAËLIS) ;
(iv) Separation at the level of the muscular belly into two parts which insert, respectively, into the second metacarpal bone and the shaft of the radius (Gorilla - PIRA) ;
(v) Separation of the tendon of insertion into two parts which attach, respectively, upon the second and third metacarpal bones (Orang - PRIMROSE as cited by MICHAËLIS ; Chinese - WAGENSEIL) ;
(vi) Separation of the tendon of insrteion into two parts that attach to the first and second metacarpal bones (*Colobus* - POLAK as cited by STRAUS ; Gibbon - STRAUS in 50%, HEPBURN ; man - LEDOUBLE, WOOD, etc.).

3. M. extensor carpi radialis brevis (figures 1-3)

This muscle is about the same size as the foregoing muscle and arises from the lateral epicondyle of the humerus, adjacent to the origin of the M. extensor carpi radialis longus. The superficial aspect of this muscle at the origin is muscular, but the ulnar side is tendinous and firmly adhered to the radial surface of the origin of the M. extensor digitorum communis. Examination of the area and extent of this adhered portion showed that it most frequently extends for about 4 to 5 cm from the origin (22/30). This muscle is located in contact with the M. extensor carpi radialis longus on its radial side, and with the M. extensor digitorum communis on its ulnar side, while beneath it is the M. supinator. This muscle descends on top of the M. supinator to slightly below the middle of the forearm where transition to tendon occurs, and it then passes beneath the M. abductor pollicis longus accompanied by the tendon of the M. extensor carpi radialis longus. After passing through the second compartment of the dorsal carpal ligament, it runs beneath the tendon of the M. extensor pollicis longus to its insertion upon the radial side of the dorsal surface of the base of the third metacarpal bone.

A variation had been found in one case by HADANO in which a small accessory muscle bundle arose at about the middle of the forearm from the ulnar side of this muscle, and ran obliquely across the front of the intrinsic belly of this muscle to the radial side where it attached to the ulnar side of the tendon of the M. extensor carpi radialis longus in the area of the forearm.

This muscle has been reported to be smaller than the M. extensor carpi radialis longus in some cases of *Lemur* and Gorilla (MURIE and MIVART, PIRA), but these are said to be exceptional cases, with this muscle in Primates usually being more powerful than the M. extensor carpi radialis longus (SULLIVAN and OSGOOD, PREUSCHOFT, STRAUS, etc.). Apparently these two muscles, however, were of about equal size in my cases of Formosan monkey.

This muscle in Primates generally arises from the lateral epicondyle of the humerus adjacent to the origin of the M. extensor carpi radialis longus, and inserts into the base of the third metacarpal bone. What is more, additional origin has been reported to occur from the intermuscular septum and the articular capsule in Gorilla (PREUSCHOFT, RAVEN, etc.), from the articular capsule in Orang (HEPBURN, STRAUS, etc.) and from the external lateral ligament in Chimpanzee (HEPBURN, SONNTAG, etc.).

The insertion of this muscle is said to usually be the base of the third metacarpal bone, but the following variations have been reported :

(i) Insertion into only the first metacarpal bone (Orang - MICHAËLIS);

(ii) Insertion into only the second metacarpal bone (Marmoset - BEATTIE; Gibbon - STRAUS; Gorilla - PREUSCHOFT);

(iii) Insertion into the second and third metacarpal bones (*Cebus* - STRAUS; Gorilla - PREUSCHOFT, RAVEN; Orang - BEDDARD; man - WOOD, WAGENSEIL, etc.)

(iv) Insertion into the third and fourth metacarpal bones (man - FROHSE and FRÄNKEL);

(v) Insertion into the Mm. interossei (Orang - FICK).

A small accessory tendon is more frequently reported to be sent off from the tendon of insertion of the M. extensor carpi radialis brevis to the inserting tendon of the M. extensor carpi radialis longus (the foregoing type iii), but the small extra muscle bundle that had been found in one case of Formosan monkey presumably represents the occurrance of this condition at a higher level upon the forearm, that is, at the level of the belly of the muscle.

Next, a review was made of the relationship between this muscle and the M. extensor carpi radialis longus in Primates and man. Among Prosimia, these two muscles may form a single muscle in some cases of *Tupaia* (CARLSSON) and *Ptilocercus* (CLARK), while other investigators have reported fusion of the muscular belly, intercommunication of the muscle fibers or fusion of the tendon (*Papio* - STRAUS; Gorilla - PREUSCHOFT; man - IWAMI, KŌ, INOUE, SANO, WOOD, etc.). HOWELL and STRAUS say that they form a single muscle in some Mammals, and state that the separation into two muscles represents a progressive feature. Furthermore, STRAUS reported that these two muscles in Primates present a conservative state, and that they are essentially clearly separate muscles.

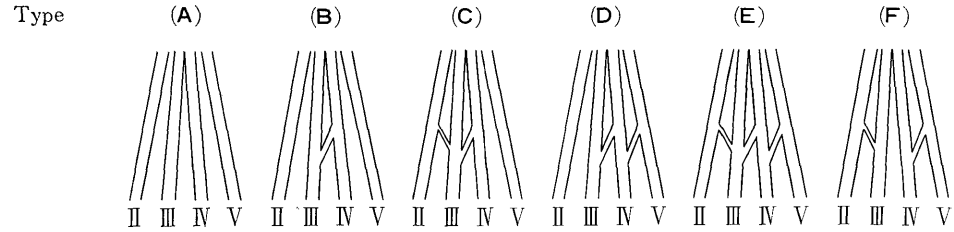
In man, splitting of the tendon of insertion of both of these two muscles has been frequently reported (WOOD, INOUE, SANO, KŌ, etc.). Moreover, as cited by STRAUS, WOOD observed that the M. extensor carpi radialis intermedius which situated between these two muscles in considable frequency and M. extensor carpi radialis accessorius which arised from the humerus for insertion to the base of first metacarpal bone or the proximal phalanx of the first digit in rare cases, and STRAUS considered these to be variations of the progressive types in which these two muscles tend to be more differentiated and have extentions of their insertions.

4. M. extensor digitorum communis (figures 1-3)

This muscle, which is firmly fused with the Mm. extensores digitorum quarti and quinti proprii on its ulnar side, arises mainly tendinously from the lateral epicondyle of the humerus, and is also partially adhered to the M. extensor carpi radialis brevis on its radial side. Moreover, the antebrachial fascia is intimately adhered to this muscle, and some of the muscle fibers take origin from it.

The muscle belly is inseparable in the proximal region, but may be separated, at about the middle of the forearm, into three parts, the radial and ulnar muscular portions that are situated in the superficial layer and the central muscular portion that is located in the deep layer. The belly of the muscular portions in the superficial layer usually undergo transition to tendon in the lower three fourths of the forearm. The portion on the radial side becomes the tendon that runs to the second finger, while the muscle belly on the ulnar side becomes the tendon to the fifth finger. The central muscle belly in the deep layer changes to tendon before the former two, at about the middle of the forearm, and separates, before it reaches the wrist, into two tendons that run to the third and fourth fingers, respectively. In rare cases, this central muscle bundle was separable into two small muscular portions (2/30).

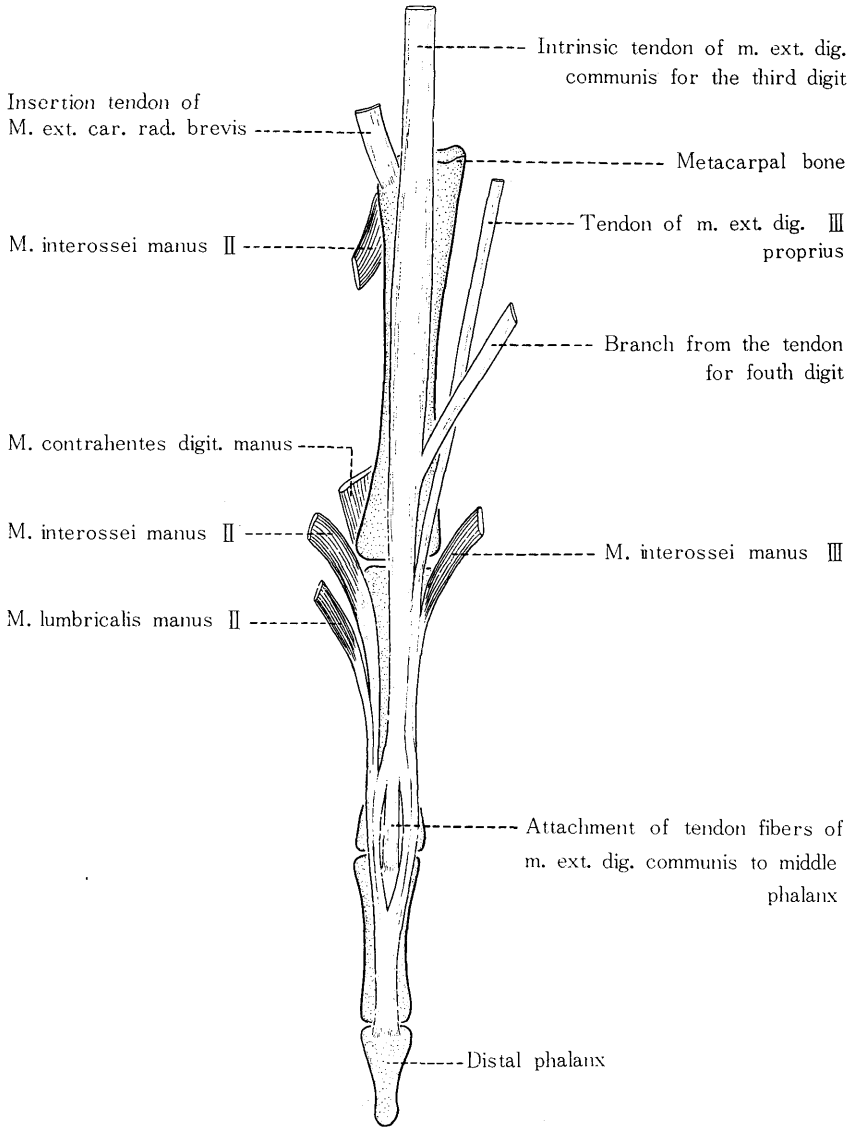
Fig. 4. Types of the branches from the main tendon of M. ext. dig. communis



	(A)	(B)	(C)	(D)	(E)	(F)
Hadano (78 limbs)	10 cases (12.8%)	14 cases (17.9%)	3 cases (3.8%)	43 cases (55.1%)	7 cases (9.0%)	1 case (1.3%)
Nagashima (30 limbs)	———	———	———	16 cases (53.3%)	12 cases (40.0%)	2 cases (6.7%)

These tendons run through the third compartment of the dorsal carpal ligament, and become flattened and increase in width as they descend along the dorsal surface of the metacarpal bones. They overlie the tendons from the Mm. extensores digitorum secundi, tertii and quarti proprii. Furthermore, branches (which is subdivision tendon from main tendon) are exchanged between adjacent tendons during their course, and even in areas where such branches are not found, these tendons are connected to each other by a thin fibrous membrane, which seems to correspond to the interdigital membrane mentioned by LANGER and FICK.

Fig. 5. Structural components of the dorsal digital expansion in third digit (left hand).



In a study of 100 limbs that had been made in this department by HADANO (1955, unpublished report), the structure of the terminal tendons on the back of 78 hands were examined statistically and classified into six types (Figure 4). The results of the present study, however, could be classified into only three of the types in the classification of HADANO. That is, if the terminal tendons of this muscle were to be called the first, second, third and fourth tendon, respectively, the most frequently found pattern was that in which the third and fourth tendons sent off branches to the second and third tendons, respectively (16/30, type D of HADANO). The type in which an additional branch other than the above is sent off from the first tendon to the second tendon was

seen comparatively frequently too (12/30, type E of HADANO). The most common pattern noted in the present study was the same as that found most frequently by HADANO. On the formation of the terminal tendons in the region of the metacarpal bones, therefore, type D can be considered to be the most common condition in Formosan monkey. Although type E was noted at a comparatively high frequency in my cases, it had not been very frequent in the study of HADANO, but the reason for this may perhaps be ascribed to a difference in viewpoint due to the fact that the branch sent off from the first tendon to the second tendon is generally weaker and thiner than the other branches.

Each of these tendons, at the metacarpophalangeal joint, becomes the intrinsic tendon of the corresponding finger for the four ulnar digits and continues downward. At above the proximal phalanx, they are joined by the corresponding tendons from the Mm. extensores digitorum secundi, tertii, quarti and quinti proprii, the Mm. lumbricales manus and the Mm. interossei manus to form the aponeurotic dorsal digital expansion of each corresponding finger. Examination of the course of the intrinsic tendons of the M. extensor digitorum communis showed that, at the lower part of the proximal phalanx, they each separate into three parts, a central portion and two parts on each side of this. The central part inserted into the base of the middle phalanx, while the two on each side ran to the base of the distal phalanx, upon which they inserted after having become united (Figure 5).

This muscle in Primates is generally closely related with the M. extensor digitorum minimi (or quarti and quinti) proprius, and they usually have a common origin. There are some reports which describe them to appear to be a single muscle in their form (*Nyctycebus*, *Loris*, *Perodicticus* - MURIE and MIVART; Orang - BARNARD, etc.). There was a close relationship between these two muscles in my cases of Formosan monkey, and these two muscles were firmly fused to each other at their origin.

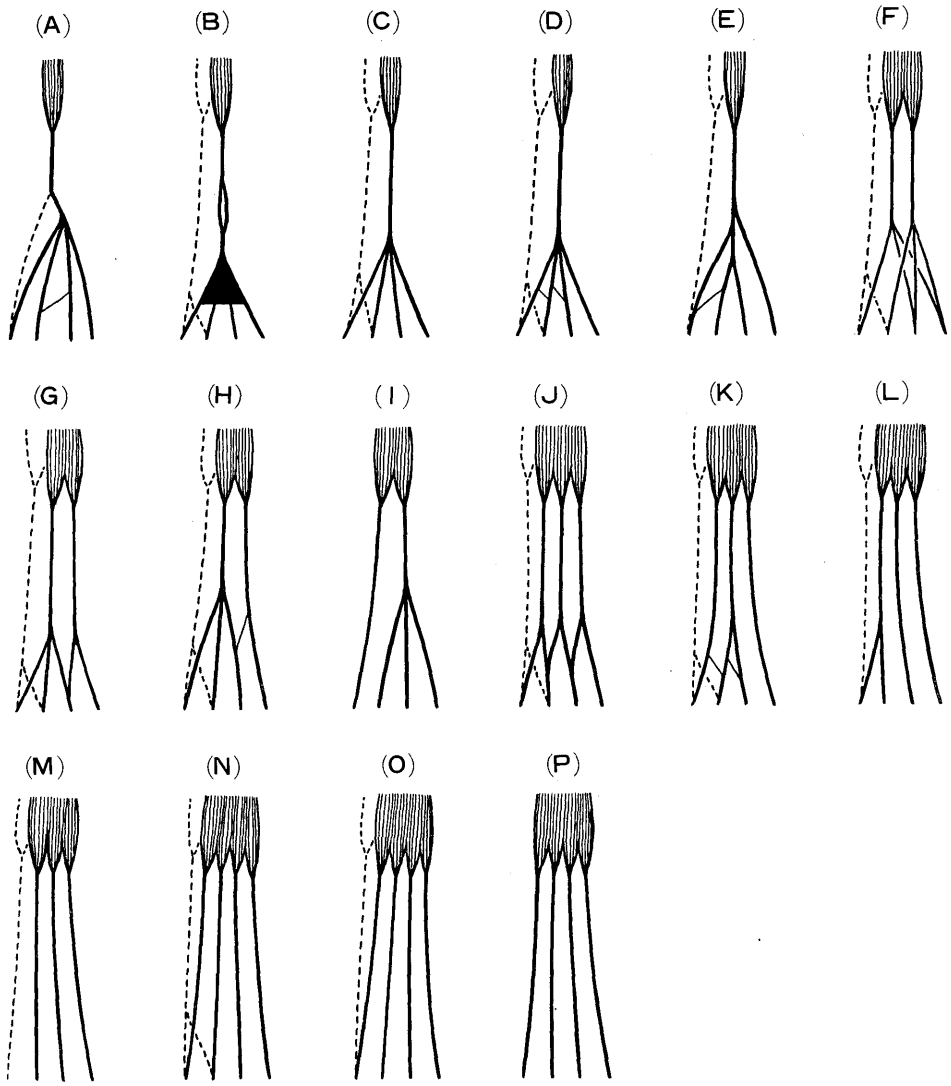
The origin of this muscle from the bone in Primates generally involves only the lateral epicondyle of the humerus, but additional origin has been reported to occur from the radius (*Perodicticus*, Gorilla - STRAUS), the ulna (Gibbon - STRAUS; Orang- SULLIVAN and OSGOOD), and from the radius and ulna (Orang - STRAUS, SONNTAG; Chimpanzee - STRAUS, MACDOWELL; Gorilla - STRAUS). In Gibbon, double origin from the humerus and the ulna is usually said to be the normal condition (STRAUS, 67%). Only Formosan monkey has been shown to have the origin to be limited to the lateral epicondyle of the humerus, with no case having origin from any other site.

This muscle in Primates varies considerably among genera or species as well as between individual cases even among the same species in the number of divisions that the muscular portion is separated into, the pattern that is shown by the structure of the main tendon and their branches on the back of the hand, and in the distribution of the tendons to each finger.

The separation of the muscular portion and the interrelationship between the main tendon and their branches are illustrated diagrammatically in Figure 6 based upon the

reports of earlier investigators. This muscle in Formosan monkey is separated into three muscular divisions, and the terminal tendon from the second (central) muscular portion is subdivided into two parts, which insert into the third and fourth fingers, respectively.

Fig. 6. Diagrams of the relationship between M. ext. dig. communis and M. ext. dig. (quarti and) quinti proprius in Primates.



Note: A) *Nycticebus tardi.* (Mivart), B) *Lemur catta* (Murie), C) *Tupaia minor* (Clark): *Galago crassi.* (Murie): *Callimico geordii* (Hill), D) *Galago crassi.* (Murie): *Cynocephalus babuin* (Michaëlis), E) *Pan paniscus* (Miller), F) *Cheiromys mada.* (Murie), G) *Ptilocercus lowii* (Clark), H) *Simia satyrus* (Sonntag), I) *Troglodytes niger* (Michaëlis), J) *Tupaia minor* (Clark), K) *Macaca cyclopis* (Nagashima), L) *Gorilla gorilla* (Preuschoft): man (Inoue 99%, Mori 90%, Wagenseil 47%), M) *Troglodytes niger* (Wilder), N) *Simia morio* (Beddard), O) man (Wagenseil 32%, Sano), P) *Troglodytes calvus* (Beddard)

In Gorilla and man, there is also generally separation into three muscular portions, but it is said that the third muscular portion (on the ulnar side) gives off the terminal tendons to the fourth and fifth fingers, while the tendons to the second and third fingers are given off independently (PREUSCHOFT, INOUE, MORI). Furthermore, as a variation in man, it has been seen some cases of high divisions having five or six muscle bellies (Chinese-WAGENSEIL ; Negro-LOTH). Other cases have been reported in which there is sparation into four muscular portions that respectively send off the tendons to the corresponding fingers (Chimpanzee, Orang - BEDDARD; Ainu - SANO) or separation into two muscular portions, of which that on the radial side gives off the tendons to the second, third and fourth fingers, while the one on the ulnar side sends off the tendon to the fifth finger (Chimpanzee - MICHAËLIS). Some reports mention marked individual differences even among the same species (*Tupaia* - CLARK). Thus, the great variability in the condition does not permit any rules to be identified that describe the changes by the phylogenic stage in the strict sense, but it seems, in general, that there is more separation of the muscle belly in higher monkey and apes (including man) than in lower monkey as well as a tendency for more simplification of the pattern of distribution of the main tendons and their branches upon the back of the hand.

The muscle belly that forms the tendon to the second finger is said to show a tendency to separate at a higher level than the others in man and Catarrhina monkey (WAGENSEIL, WOOD, STRAUS, PATTERSON, etc.), but there was no case among Formosan monkey in which separation of the muscle belly to the second finger occurred at a particularly high level.

Next, the pattern of ultimate distribution of tendons from this muscle and from the M. extensor digiti (quarti or) quinti proprius, which usually has a common origin with this muscle, is shown in Table 1 as based upon reports by earlier investigators. Among Prosimia, the tendon of insertion to the second finger may be absent in some instances such as in *Perodicticus*, but they are generally found to be distributed to the second to fifth fingers. Among Platyrrhina monkey, the findings are similar to that in Prosimia with the expception of Marmoset in which BEATTIE noted the separation into five tendons that inserted, respectively, into the first to fifth fingers. Even in Catarrhina monkey, they are distributed to the four ulnar digits, and their distribution is stable and similar to that in Prosimia and Platyrrhina. However, HOWELL and STRAUS in their report "The Anatomy of the Rhesus Monkey" (1971) mentioned that they are distributed to the four radial digits, but this is felt to be a mistake of the "radial" for the "ulnar" because a report by STRAUS (1941), which quoted the same data, describes the distribution as being to the second to fifth fingers. Moreover, the distribution in Anthropoid apes and man as a rule is also to the second to fifth fingers as in other Primates. The tendon of insertion to the fifth finger is small or reduced in Gorilla and Gibbon as in man, and although it is frequently absent in Chimpanzee, it is never absent in Orang, which has been shown to present findings similar to that in lower monkey. Furthermore, review of the literature for the frequency of absence of the tendon to

Table 1. Distribution of tendons from the M. ext. dig. communis (A) and from the M. ext. dig. (quarti and) quinti proprius (B) for the digits.

author	material	(A)	(B)
1) PROSIMIAE			
Clark (1924)	*Tupaia minor*	2 3 4 5	4 5
Carlsson (1922)	*Tupaia javanica*	2 3 4 5	4 5
Straus (1941)	*Tupaia*	2 3 4 5	4 5
Clark (1926)	*Ptilocercus lowii*	2 3 4 5	4 5
Murie & Mivart(1872)	*Lemur catta*	2 3 4 5	4 5
Cuvier (by Murie)	*Lemur varius*	2 3 4 5	4 5
Straus (1941)	*Lemur variegatus*	2 3 4 5	4 5
Beddard (1891)	*Hapalemur griseus*	2 3 4 5	4 5
Murie & Mivart (1872)	*Cheiromys madagas.*	2 3 4 5	4 5
Owen (1866)	〃	2 3 4 5	4 5
Zuckerkandl (1900)	〃	2 3 4 5	4 5
Murie & Mivart (1872)	*Loris gracilis*	2 3 4 5	5
〃 (〃)	*Nycticebus tardigradus*	2 3 4 5	5
Mivart & Murie (1865)	〃	2 3 4 5	5
Straus (1941)	*Perodicticus potto*	3 4 5	(5)
Forster (by Straus)	〃	3 4 5	—
Van Campen (by Murie)	〃	3 4 5	—
Murie & Mivart (1872)	*Galago crassicaudatus*	2 3 4 5	4 5
〃 (〃)	*Galago allenii*	2 3 4 5	4 5
Woollard (1925)	*Tarsius spectrum*	2 3 4 5	4 5
Straus (1941)	*Tarsius saltator*	2 3 4 5	4 5
Burmeister (by Murie)	*Tarsius spectrum*	2 3 4 5	4 5
2) PLATYRRHINAE			
Straus (1941)	*Cebus malitiosus*	2 3 4 5	4 5
Hill (1959)	*Callimico geordii*	2 3 4 5	4 5
Beattie (1927)	*Hapale jacchus*	1 2 3 4 5	4 5
Straus (1941)	*Oedipomidas geoffroyi*	2 3 4 5	4 5
3) CATARRHINAE			
Straus (1941)	*Macaca mulatta*	2 3 4 5	4 5
Jacobi (1966)	〃	2 3 4 5	4 5
Kimura (1970)	*Macaca irus*	2 3 4 5	4 5
Nagashima (1976)	*Macaca cyclopis*	2 3 4 5	4 5
Patterson (1942)	*Cynopithecus niger*	2 3 4 5	4 5
Straus (1941)	*Papio cynocephalus*	2 3 4 5	4 5
Champneys (1872)	*Cynocephalus anubis*	—	4 5
Michaëlis (1903)	*Cynocephalus babuin*	2 3 4 5	4 5
Patterson (1942)	*Rhinopithecus roxe.*	2 3 4 5	4 5
4) HOMINOIDEA (Anthropoid apes)			
a) Gibbon			
Bischoff (1870)	*Hylobates leuciscus*	—	5
Hepburn (1892)	*Hylobates spec.*	2 3 4[(5)]	5
Straus (1941)	*Hylobates lar*	2 3 4	5
〃 (〃)	*Hylobates moloho*	2 3 4 (5)	5

b) Orang			
Barnard (1875)	*Simia satyrus*	2 3 4 5	4 5
Langer (1879)	〃	2 3 4 5	4 5
Chapman (1880)	〃	2 3 4 5	(4) 5
Hepburn (1892)	〃	2 3 4 5	4 5
Beddard (1893)	*Simia morio*	2 3 4 5	4 5
Fick (1895)	*Simia satyrus*	2 3 4 5	(4) 5
Michaëlis (1903)	〃	2 3 4 5	(4) 5
Sonntag (1924)	〃	2 3 4 5	4 5
Sullivan (1927)	〃	2 3 4 5	4 5
Straus (1941)	*Pongo pygmaeus*	2 3 4 5	4 5
Duvernoy (by Pira)		—	4 5
c) Chimpanzee			
Wilder (1863)	*Troglodytes niger*	2 3 4	5
Macalister (1871)	*Pan spec.*	2 3 4 5	5
Champneys (1872)	*Troglodytes niger*	(R) 2 3 4[(5)]	5
		(L) 2 3 4 5	5
Chapman (1879)	〃	—	5
Hepburn (1892)	*Pan spec.*	2 3 4 5	5
Beddard (1893)	*Troglodytes calvus*	2 3 4 5	absent
Michaëlis (1903)	*Troglodytes niger*	2 3 4 5	absent
McDowell (1910)	*Anthropo. niger*	2 3 4 5	5
Sonntag (1923)	*Anthropo. troglodytes*	2 3 4 (5)	5
Straus (1941)	*Pan spec.* No. 156	2 3 4 5	4 5
〃	〃 No. 319	2 3 4	5
〃	〃 No. 372	—	5
〃	〃 No. 191	—	5
Miller (1952)	*Pan paniscus*	2 3 4 5	5
Moore(by Champneys)		2 3 4	—
Vrorik(by Champneys)		2 3 4	—
d) Gorilla			
Chapman (1878)	*Troglodytes gorilla*	2 3 4 (5)	5
Bischoff (1880)	*Gorilla gorilla*	2 3 4 (5)	5
Hepburn (1892)	〃	2 3 4 (5)	5
Sommer (1907)	〃	2 3 4 (5)	5
Pira (1913)	〃	2 3 4 (5)	5
Straus (1941)	〃	2 3 4[(5)]	5
Raven (1950)	〃	2 3 4 (5)	5
Preuschoft (1965)	〃 Tier A	(L) 2 3 4 (5)	5
〃	〃 Tier B	(R) 2 3 4 (5)	5
〃	〃 〃	(L) 2 3 4 (5)	5
〃	〃 Tier C	(R) 2 3 4 (5)	5
〃	〃 〃	(L) 2 3 4 (5)	5
〃	〃 Tier D	(R) 2 3 4	5
〃	〃 〃	(L) 2 3 4 (5)	(4) 5
Duvernoy (by Pira)		2 3 4 (5)	5
Macalister (by Pira)		2 3 4 (5)	(4) 5
Deniker (by Pira)		2 3 4	5

Note ( ) : small or reduced tendon, [( )] : slip from the tendon for IV digit
— : unknown

Table 2. Frequency of the absence of tendon for fifth digit in man.

Japanese			
Koganei	(1903)	32/301	(10.6%)
Inoue	(1934)	5/100	(5.0%)
Iwami	(1951)	5/50	(10.0%)
Hayashi	(1952)	6/300	(2.0%)
Nishi	(1953)	48/751	(6.4%)
Kō	(1958)	24/200	(12.0%)
Mori	(1964)	—	(4.0%)
Ainu			
Sano	(1931)	0/10	(0.0%)
Chinese			
Wagenseil	(1936)	36/131	(27.5%)
Negro			
Loth	(1912)	4/118	(3.4%)

the fifth finger in man is shown in Table 2, and there seems to be a difference by race.

Although the tendon that runs to the first finger from this muscle is usually not present in Primates as well as in man, rare cases with a tendon running to the first finger have been found among man (WOOD, WA GENSEIL) and Marmoset (BEAT TIE).

In Primates the insertion of the intrinsic tendons from this muscle to each finger is usually said to be upon the middle and distal phalanges. However, HOWELL and STRAUS have reported that the osseous insertion in *Macaca mulatta* is markedly different from man and shows "no marked continuation to the terminal phalanx", but the findings in Formosan monkey (*Macaca cyclopis*) were fundamentally the same as in man (GRAY'S Anatomy) with insertion upon the terminal phalanx as well as upon the middle phalanx. These findings are consistent with the description by JACOBI (*Macaca mulatta*) and KIMURA (*Macaca irus*).

In the metacarpal region, the main tendons of this muscle in Formosan monkey are not only interunited by the branches but also by a fibrous membrane. The tendons on the back of the hand in *Lemur* (MURIE and MIVART), *Perodicticus*, *Oedipomidas*, *Papio* and occasionally in Gibbon (STRAUS) are directly connected with each other to form a "wide tendon" or a "common aponeurosis". Such a condition is said to be found only to a limited extent in Anthropoid apes and man, and it simply remains in the form of the jancturae tendinum (STRAUS). Furthermore, the interunion between the tendons in Anthropoid apes has been described as being by the interdigital membrane by LANGER, FICK, MICHAËLIS, etc., and it is said to be more developed so as to reduce the independent nature of the each tendon of this muscle in lower monkey. The findings in Formosan monkey were similar to this.

5. Mm. extensores digitorum quarti and quinti proprii (figures 1-3)

These two muscles, which are in the superficial layer on the dorsal side of the forearm, are firmly fused with each other and arise as a single muscle from the radial epicondyle of the humerus. Adjacent to these two muscles is the M. extensor digitorum

communis on their radial side and the M. extensor carpi ulnaris on their ulnar side. These muscles are separated from the M. extensor carpi ulnaris by an intermuscular septum, which is a continuation from the antebrachial fascia, but they are firmly fused tendinously with the M. extensor digitorum communis on their radial side at their origin.

In the upper quarter of the forearm, these two muscles are firmly fused with each other and appear to be a single muscle. The portion, which gives off the tendon to the fifth finger (the M. extensor digiti quinti proprius), is in the superficial layer of the muscle as a whole, and it forms a slender, fusiform muscle belly that undergoes transition to tendon usually at about the upper third of the forearm (24/30). The portion that gives off the tendon to the fourth finger (the M. extensor digiti quarti proprius) is located in the deeper layer than the former, reaches the maximum width at about the upper third of the forearm, and changes to tendon about three quarters down the forearm (22/30). In Formosan monkey, the tendon from the M. extensor digiti quinti commences earlier than that from the M. extensor digiti quarti, and is overlayed by the buldging part of muscle belly of the M. extensor digiti quarti situated in the deeper layer as it descends to about the middle of the forearm where it emerges to the superficial layer (Figure 1).

The tendons from these two muscles descend parallel to each other and pass through the fourth compartment of the dorsal carpal ligament to the upper region of the back of the hand where they become separated. One of them, the tendon from the M. extensor digiti quarti proprius, descends beneath the tendon to the fifth digit from the M. extensor digitorum communis, while the other, the tendon from the M. extensor digiti quinti proprius, descends along the ulnar side of the tendon from the M. extensor digitorum communis. At above the proximal phalanx of the fourth and fifth fingers, these tendons join, respectively, with the ulnar part of the corresponding tendons from the M. extensor digitorum communis so as to contribute to the formation of the aponeurotic dorsal digital expanson. The fibers of these tendons extend further to the base of the terminal phalanx.

The muscles in Primates and man that correspond to the Mm. extensores digitorum quarti and quinti proprii of Formosan monkey may take either of the following forms. One in which the Mm. extensores digitorum quarti and quinti proprii are present with fusion between them at their origin and with tendons being sent off to the fourth and fifth fingers, or the other where only the M. extensor digiti quinti proprius (the M. extensor digiti minimi) is present, and just the tendon to the fifth finger is sent off with no tendon being sent off to the fourth finger. The former, as a rule, is the condition noted in Prosimia, Platyrrhina, Catarrhina monkey and Orang, while the latter is that found in Anthropoid apes other than Orang (such as in Gibbon, Chimpanzee, Gorilla) and in man.

The muscles that correspond to these muscles may sometimes take a form, such as described in the preceding section, in which they appear to be united into a single muscle with the M. extensor digitorum communis (*Nycticebus* - MIVART and MURIE,

etc.), and in rare instances they may be absent (Chimpanzee - MICHAËLIS, BEDDARD; man - INOUE in 1%).

Although the Mm. extensores digitorum quarti and quinti proprii have been reported to be clearly separated in *Oedipomidas* among Platyrrhina (STRAUS), these two muscles are fused in most Primates, and further arise by a common origin with the M. extensor digitorum communis directly from the radial epicondyle of the humerus. However, in man and Gorilla, it is rather rare for these two muscles (more usually the M. extensor digiti quinti proprius) to have direct osseous origin, and they arise more frequently from a component of the M. extensor digitorum communis or the intermuscular septum (or septa) in this area, or from both (STRAUS, PREUSCHOFT, PIRA, RAVEN, HEPBURN, HOLLINSHEAD, etc.). Such a condition of origin has been also reported rarely in Prosimia (*Perodicticus*, *Tarsius* - STRAUS) and Anthropoid apes except Gorilla (such as in Gibbon - HEPBURN; Orang - SONNTAG; Chimpanzee - STRAUS, MILLER). However, the descriptions by many investigators that these muscles arise from the M. extensor digitorum communis or from its component presumably simply means that the close relationship between these muscles and the M. extensor digitorum communis and their fusion at their origin makes such a description possible at casual inspection rather than to mean that one part of the M. extensor digitorum communis separates to become the M. extensor digiti quinti (and quarti) proprius. Furthermore, some cases among Primates have been reported to have a second head of origin that arises from the ulna in addition to origin from the radial epicondyle (*Cebus*, Gibbon and man - cited by STRAUS) or origin from only the ulna (Gibbon, Orang - STRAUS; Chimpanzee - MACDOWELL), but the origin in Formosan monkey occurred only from the radial epicondyle, adhered to the M. extensor digitorum communis.

The distribution of the tendons from these muscles to the fingers in Primates was described in the preceding section (Table 1). Although the tendon of insertion to the fourth finger may be occasionally absent, tendons run as a rule to the fourth and fifth fingers in Prosimia, Platyrrhina, Catarrhina and Orang. Contrarily, in Anthropoid apes other than Orang and in man, the tendon of insertion to the fourth finger is absent, and only the tendon to the fifth finger is present as a rule so that the form of having the Mm. extensores digitorum quarti and quinti proprii is not taken. Nevertheless, the presence of the tendon of insertion to the fourth finger, which is the rule in lower monkey, can be found in a few cases even in Chimpanzee(STRAUS), Gorilla (PREUSCHOFT, MACALISTER) and man (INOUE in 3%, ADACHI in 1.5%, GRUBER in 6%, WOOD in 10.8%, etc.).

There is no agreement on the source of these muscles. Some claim them as having differentiated from the M. extensor carpi ulnaris (STRAUS), from the deep extensor layer (LECHE, SOMMER, BROOKS, EISLER, GRÄFENBERG), or from the M. extensor digitorum communis (RIBBING, HOWELL, INOUE), as cited from the reports by STRAUS and PIRA. The findings in Formosan monkey showed these muscles to be located in the superficial layer and always firmly fused to the M. extensor digitorum communis, but completely separated from the M. extensor carpi ulnaris by the interposed intermuscular

septum so that even though this had not been a phylogenic study it seems reasonable to consider them to have been derived from the M. extensor digitorum communis.

6. M. extensor carpi ulnaris (figures 1-3)

This muscle, which is located the most ulnar among the extensors of the forearm, arises from the radial epicondyle of the humerus. It has no common origin with any of the other extensor muscles of the forearm nor any ulnar origin.

The intermuscular septum is interposed between this muscle and the Mm. extensores digitorum quarti and quinti porprii, while the antebrachial fascia attaches to the ulna on its ulnar side so that only this muscle is completely separate and independent of the other muscles. As this muscle runs downward, its radial side is adjacent to the Mm. extensores digitorum quarti and quinti proprii, while the upper part of its ulnar side (in the area of the elbow) is adjacent to the M. anconeus lateralis, but it soon comes into contact with and runs along the M. flexor digitorum profundus.

At about the distal third of the forearm is seen the commencement of the tendon to which the muscle fibers of this muscle attach in bipenniform fashion. There is soon complete change to tendon that passes through the fifth compartment of the dorsal carpal ligament to the back of the hand, from where it runs covered by the M. abductor digiti quinti to its insertion upon the ulnar edge of the base of the fifth metacarpal bone, but there may be some cases in which the tendon of insertion extends further to the ulnar side of the palmar surface (5/30).

This muscle in both Primates and man shows little variation and it is comparatively stable. The origin as a rule is usually from the lateral epicondyle of the humerus and the dorsal aspect of the ulna except in Catarrhina monkey. The presence of the ulnar origin and its extent differs somewhat by the suborder. That is, the origin is as a rule from both the lateral epicondyle and the ulna in Prosimia and Platyrrhina monkey, but the area of the ulnar origin is frequently limited to the proximal region or the olecranon (STRAUS, CLARK, WOOLLARD, HILL, BEATTIE, etc.). Occasional exceptional cases have been reported in which there was origin from an extensive area on the ulna (*Perodicticus* - STRAUS; *Chiromys*-ZUCKERKANDL) or the absence of the ulnar origin (*Ptilocercus*-CLARK; *Oedipomidas* - STRAUS). In contrast to this, although there may be exceptional cases with additional origin from the olecranon (*Rhinopithecus* - PATTERSON), this muscle in Catarrhina monkey as a rule arises from only the lateral epicondyle of the humerus and there is no origin from the ulna (HOWELL and STRAUS, STRAUS, JACOBI, KIMURA, CHAMPNEYS, etc.). My cases of Formosan monkey were not in disagreement with this. In Anthropoid apes and man, the origin is from the lateral epicondyle and the ulna as in Prosimia and Platyrrhina, but the ulnar origin usually involves a wider area and extends from the middle to distal part of the ulna (STRAUS, SULLIVAN and OSGOOD, BEDDARD,

PREUSCHOFT, PIRA, etc.).

The tendon of this muscle attaches to the base of the fifth metacarpal bone in all Primates and is very stable. Only few abnormalities have been reported, including a case with an accessory tendon to the pisiform bone (*Lemur xanthomystax* - MURIE and MIVART) and a case with extension of the tendon of insertion to the proximal phalanx of the fifth finger (Chimpanzee - MACALISTER). In man, however, cases with extension of the tendon of insertion to the phalanges (WOOD, LEDOUBLE, etc.) or cases with an accessory tendon given off to the fifth finger (IWAMI, INOUE, etc.) have been noted at a considerable frequency.

Furthermore, STRAUS has mentioned that there are differences by the genus in the condition of insertion upon the base of the fifth metacarpal bone, and he described the insertion as taking place into the dorsal surface in his cases of *Macaca mulatta*. The insertion in my study of Formosan monkey was not the dorsal surface but the ulnar edge with some cases having extension to as far as the palmar surface.

7. M. supinator (figures 7-9)

This muscle consists of two layers, a slender, flat superficial layer and a fan - shaped, thick deep layer. It extends from the extensor surface to the flexor surface of the forearm. On the extensor surface, it is covered by the M. extensor digitorum communis and its distal edge lies adjacent to the M. abductor pollicis longus. On the radial surface, it is covered by the M. extensor carpi radialis brevis and its distal edge is adjacent to the attachment of the M. pronator teres. On the other hand, on the flexor surface, it is covered by the M. pronator teres and lies adjacent to the origin of the M. flexor digitorum profundus.

The origin of this muscle is from the lateral epicondyle of the humerus, the articular capsule of the elbow and the supinator crest of the ulna. The surface of the upper half of this muscle is covered by aponeurosis, which undergoes transition to muscle fiber about haly-way down the muscle. The muscle bundle that arises muscularly from the supinator crest of the ulna forms the deep layer, which runs obliquely at a sharp angle (almost at right angles) toward the radial side where it inserts upon the dorsal and radial surfaces of the radius in the area no lower than the upper fourth of the forearm.

The remaining muscle bundle arises tendinously from the lateral epicondyle of the humerus and the articular capsule of the elbow. Although one part may contribute to the formation of the deep layer, this muscle bundle mainly forms the superficial layer of this muscle and runs downward generally parallel with the radius.

The deep branch from the radial nerve, which enters into this muscle from the radial side, passes through the space between these muscle bundles of the deep and superficial layers to emerge upon the dorsal side of the forearm.

The insertion of this muscle involves the dorsal, radial and palmar sides of the

radius, but most frequently extends to the middle part of the radius (26/30). Incidentally, the ratio between the length of the radius and the length of the area of insertion of the M. supinator, that is, $\frac{\text{Length of the attachment of the M. supinator}}{\text{Length of the radius}} \times 100$ was 46.3 on the average.

In Mammals below the Primates, according to PARSONS, the muscle that corres - ponds to this muscle generally consists of a single layer which arises from the humerus, and transitional stages on the appearrance of the deep layer are observed in *Lemur* which it is very small, and quite distinct from the superficial one, while in the monkeys and apes it is larger, and becomes more and more closely united with the superficial layer. Although this muscle in Primates is said to be comparatively stable (HOWELL and STRAUS), it usually consists of two layers in Catarrhina monkey and higher Primates.

This muscle in Primates, with the exception of some cases of Anthropoid apes, always has origin from the humerus, but the question of whether there is additional origin from the ulna and the matter of transmigration are of considerable interest. That is, the origin is from only the lateral epicondyle of the humerus with no origin from the ulna in Prosimia and Platyrrhina except in a few exceptional cases. In contrast to this, there is as a rule origin from both the humerus and the ulna as well as the formation of two layers in Catarrhina, Anthropoid apes and man. That is, there is seen the formation of two layers in association with origin from two sites. However, even in Prosimia and Platyrrhina monkey, there occasionally are exceptional cases that have origin from the ulna in addition to that from the humerus (*Tupaia* - CLARK; *Perodicticus*, *Cebus* - STRAUS; *Callimico* - HILL), but even in such cases the muscle, according to CLARK, was not divisible into two laminae, and HILL has also described it as being a single stratum so that there does not seem to be the formation of two layers. In these cases, the part with origin from the ulna seems to have been a bridge formation to the band that arises from the humerus. Therefore, the findings noted by CLARK and HILL may represent the transitional type to the pattern seen in Catarrhina monkey and higher Primates and in man in which there is origin from two sites and the formation of two layers. Furthermore, Anthropoid apes (particularly Chimpanzee) are said to have a wide area of origin from the ulna (MILLER, STRAUS) and some cases of Orang (BARNARD, STRAUS) and Gorilla (STRAUS) among Anthropoid apes have been noted to have lost the humeral origin and have origin from only the ulna. In view of these findings, it seems that transmigration or change of the site of origin of this muscle occurs in association with phylogenic advance, in which the primitive pattern of origin from only the humerus changes to one in which there is accessory origin from the ulna, and this ulnar origin, which initially develops as an accessory origin, gradually becomes more powerful and extensive until ultimately the humeral origin is lost and only the ulnar origin remains.

The insertion of this muscle varies little, and the attachment is entirely to the radius in Primates. The condition is similar in Formosan monkey, but the ratio between the length of the radius and the length of the area of insertion upon the radius was 46.3.

The paucity of literature prevented a comparison with other Primates, but the comparison with man clearly showed that the insertion extended far more distally in Formosan monkey (Japanese-INOUE 30.5, MORI ♂ 36.2 ♀ 35.2, IWAMI 39.3; Ainu-SANO 43; Europian - CHUDZINSKI 43; Negro - CHUDZINSKI 44). PIRA has regarded cases having extension of the insertion to the distal region of the radius as being the primitive form. Although some cases among Mammals have insertion upon the entire length of the radius, most reports by earlier investigators describe the insertion in Primates to be upon the middle or upper third of the radius.

If an assumption were to be permitted based upon these results, it seems that, in association with evolution, the origin of this muscle shifts to a lower location while the insertion moves upward so that this muscle tends to become more localized.

In general, the deep branch of the radial nerve (or the posterior interosseous nerve) passes beneath this muscle when it consists of only one layer (CLARK, CARLSSON, ZUCKERKANDL, PARSONS, etc.), whereas this nerve passes through between the superficial and deep layers when there is the formation of these two layers, and the findings in my cases of Formosan monkey were in agreement with this.

8. *M. extensor pollicis longus* (figures 7-9)

This slender muscle, which lies covered by the M. extensor carpi ulnaris, is located on top of the M. abductor pollicis longus. The origin is by muscle from the radial side of the dorsal surface of the ulna between the level of the distal tip of the supinator crest to the upper third of the forearm. This origin extends almost to the level of origin of the M. extensor digiti secundi proprius, but there is no fusion or adhesion with this latter muscle.

This muscle changes to a slender tendon at about the middle of the forearm that passes through the third compartment of the dorsal carpal ligament together with the tendons of the Mm. extensores digitorum secundi and tertii proprii. It then immediately crosses over the tendons of the Mm. extensores carpi radialis brevis and longus to the radial side from where it descends to emerge subcutaneously on the radial side of the tendon of the M. extensor digitorum communis. Furthermore, this tendon is bound by connective tissue to the articular capsule of the first metacarpophalangeal joint. The tendon continues downward along the dorsal surface of the phalanges of the first finger to its insertion upon the dorsal surface of the base of the distal phalanx.

The cases with variations noted by HADANO included a case in which the belly of this muscle separated into two parts that descended parallel to each other, and one of them attached to the base of the distal phalanx of the first finger while the other inserted upon the base of the first metacarpal bone, and another two cases in which the tendon soon after passing through the dorsal carpal ligament gave off an accessory tendon which ran to the middle part of the second metacarpal bone.

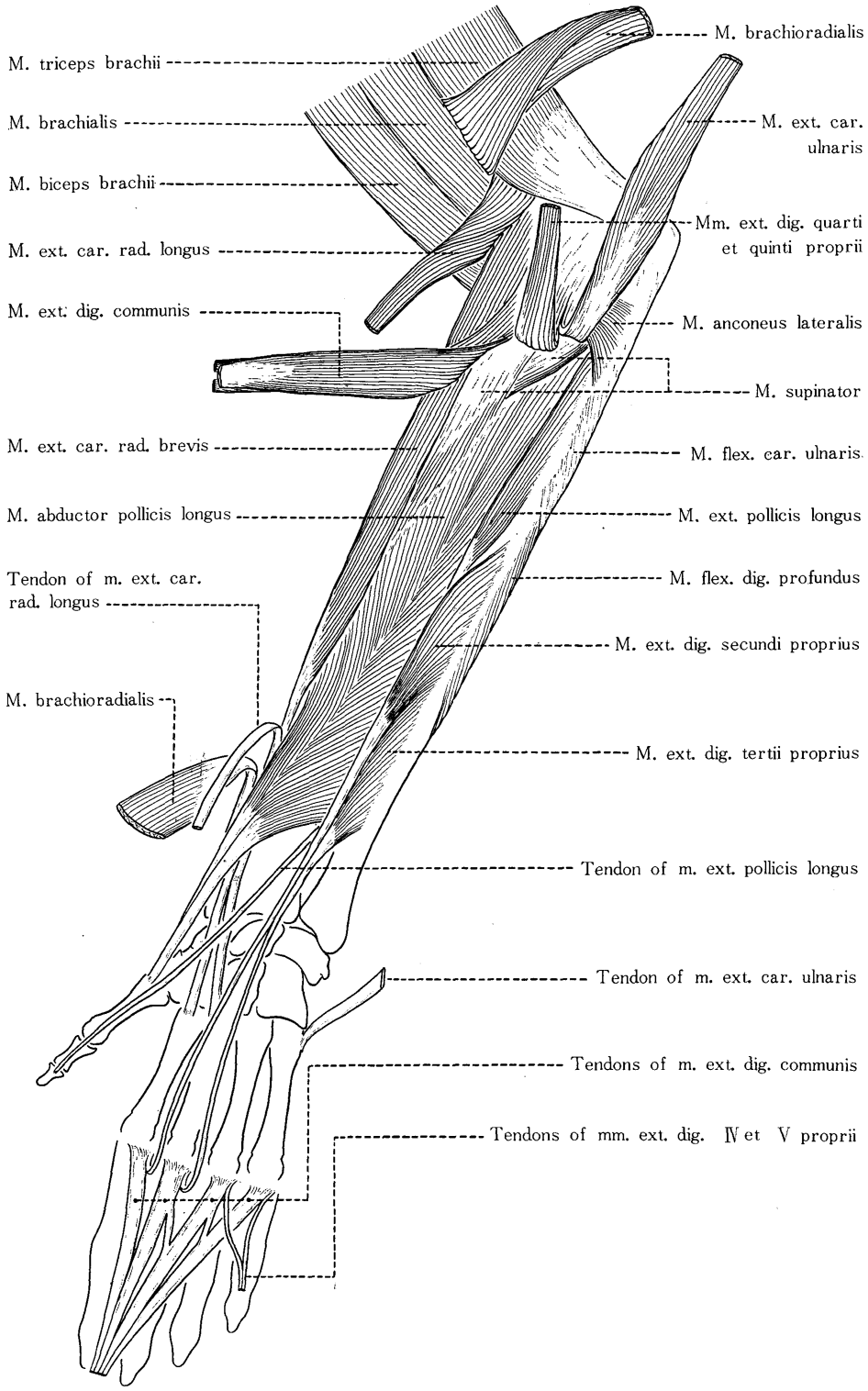


Fig. 7. Deep muscle group (a)

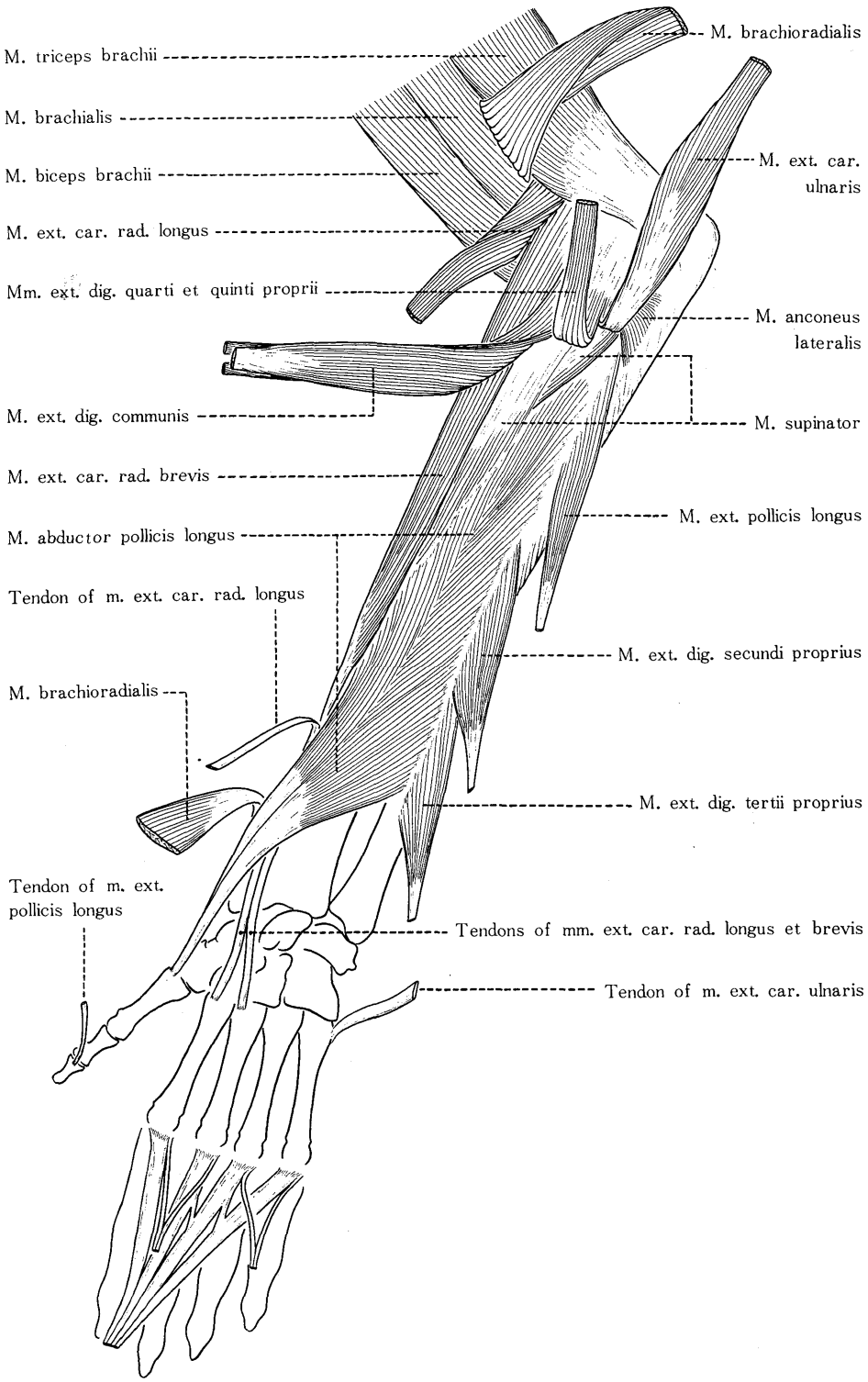


Fig. 8. Deep muscle group (b)

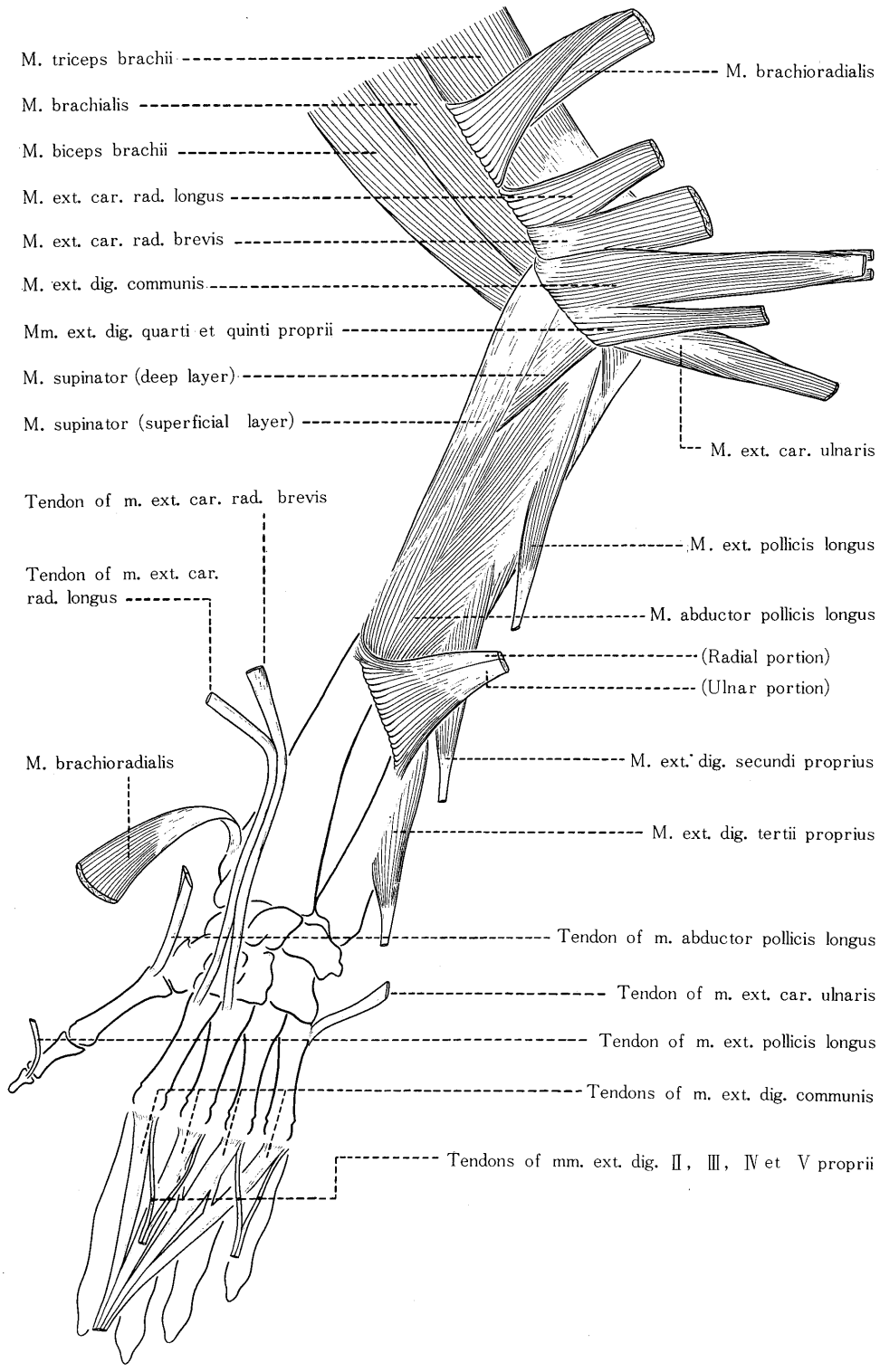


Fig. 9. Deep muscle group (c)

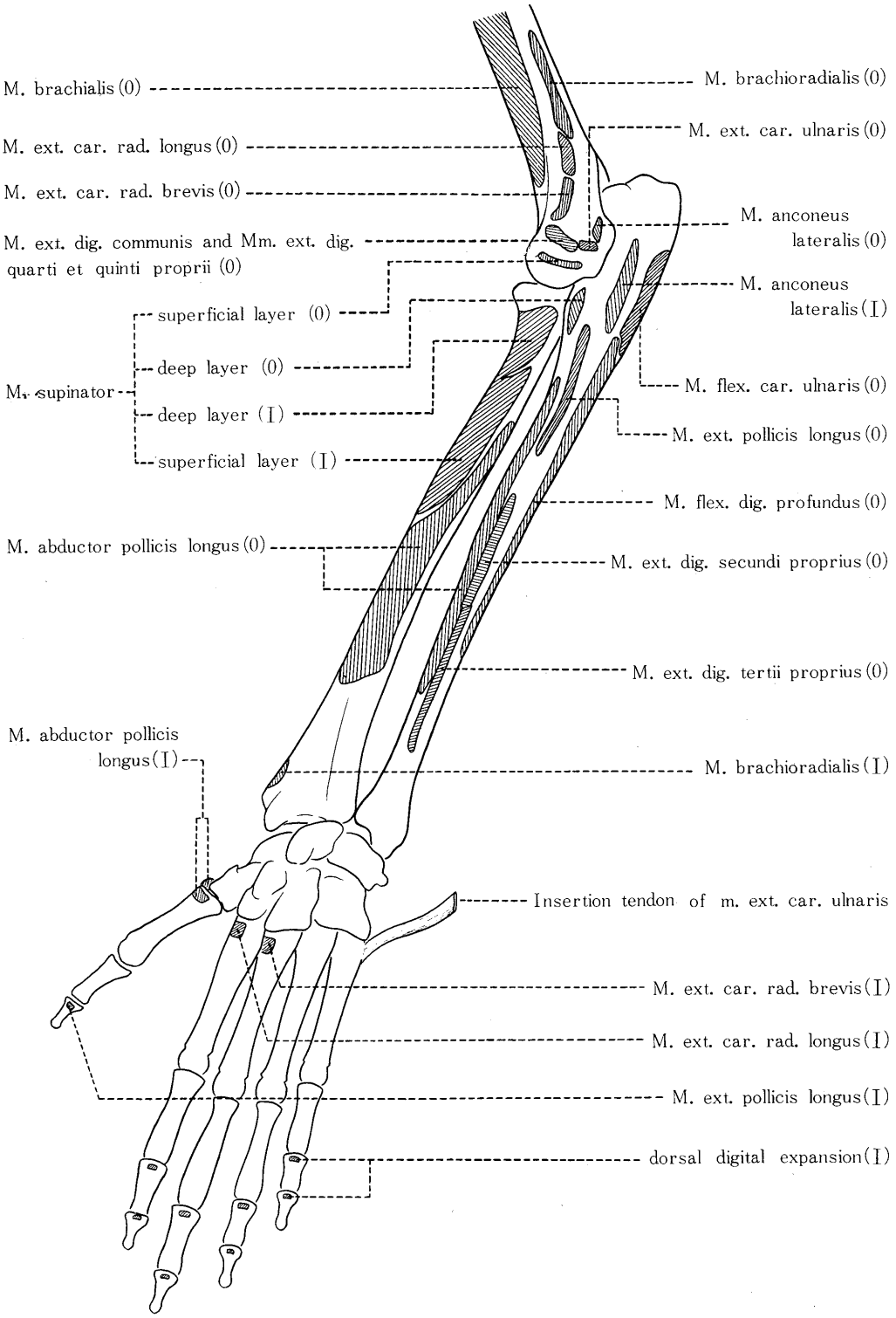


Fig. 10. Origin (O) and Insertion (I) areas of muscles

Of the extensor muscles in the deep layer of the forearm, the muscle that arises from the upper part of the ulna and runs to at least the thumb (the muscle corresponding to the M. extensor pollicis longus in Formosan monkey) and the muscle that arises from the distal part of the ulna and runs to one or more of the other fingers (that which corresponds to the Mm. extensores digitorum secundi and tertii proprii in Formosan monkey) have collectively been called the M. extensor digitorum profundus by STRAUS and many other investigators (HILL, BARNARD, CLARK, etc.).

The M. extensor pollicis longus, which corresponds to that part of the M. extensor digitorum profundus having origin from the upper region, is stable in its state of origin in Primates, but it often is found to have accessory origin from the interosseous membrane in addition to its usual origin from the ulna. In general, its origin is from the ulna in Prosimia, Platyrrhina and Catarrhina, while it is as a rule from the ulna and the interosseous membrane in Anthropoid apes and man.

Next, the insertion of this muscle in Primates and man is stable, and it attaches to the base of the distal phalanx of the first finger, but there may be some cases with insertion upon the proximal phalanx as well as upon the distal phalanx in Anthropoid apes (STRAUS, RAVEN, SUTTON, etc.). Furthermore, there are frequently reports that describe the separation of the tendon of insertion into two parts with an accessory tendon running to the second finger as observed in Formosan monkey (*Tarsius* - WOOLLARD, STRAUS; Gorilla - PREUSCHOFT, HEPBURN ; man - KANEFF, INOUE, etc.).

9. M. extensor digiti secundi proprius (figures 7-9)

This muscle, located in the same layer as the M. extensor pollicis longus, arises muscularly from an area that extends from immediately below the M. extensor pollicis longus to the level adjacent to the M. extensor digiti tertii proprius on the radial side of the dorsal surface of the ulna. This origin is linear in form and involves the area between about the middle part to the lower three fifths of the forearm. Although there is no adhesion or fusion with the M. extensor pollicis longus located above, there always is muscular adhesion with the M. extensor digiti tertii proprius below. Moreover, the adhesion or fusion between these two muscles is extensive with involvement of practically the entire length of the muscular belly in a comparatively large number of cases (10/30). In particular, exchange of muscle fibers was found in three cases, and these two muscles appeared to be a single muscle and were indivisible until transition to tendon occurred.

This slender, fusiform muscle runs downward along the radial side of the ulna and transition to a slender tendon occurs immediately before it reaches the wrist. This tendon passes through the third compartment of the dorsal carpal ligament together with the tendons from the M. extensor pollicis longus and the M. extensor digiti tertii proprius. On the back of the hand, this tendon runs beneath the tendon of the M. extensor digitorum communis to the upper part of the proximal phalanx where it contributes to the

formation of the dorsal digital expansion by joining with the ulnar side of the tendon of the M. extensor digitorum communis that runs to the second finger. The tendon fibers continue down to the distal phalanx.

A variation was noted in one case in which the tendon of insertion during its course separated into two parts, with attachment to the aponeurosis of the fifth finger as well as to the second finger.

10. M. extensor digiti tertii proprius (figures 7-9)

This is a small, fusiform muscle located in the same layer as the M. extensor pollicis longus and the M. extensor digiti secundi proprius. This muscle arises muscularly from the radial aspect of the dorsal surface of the ulna, and is adhered muscularly to the M. extensor digiti secundi proprius as previously mentioned. The origin is linear in form and extends over the lower three fifths to the lower fifth of the forearm. The muscle belly descends along the radial side of the ulna to a short distance above the wrist where it changes to tendon. This tendon passes through the third compartment of the dorsal carpal ligament together with the tendons of the M. extensor pollicis longus and the M. extensor digiti secundi proprius. On the back of the hand, it lies covered by the tendon of the M. extensor digitorum communis. At the upper part of the proximal phalanx, it participates in the formation of the dorsal digital expansion by joining with the ulnar side of the tendon that runs to the third finger from the M. extensor digitorum communis, and the tendon fibers of this muscle extend further to the base of the terminal phalanx (Figure 5). A variation noted by HADANO in one case consisted of an accessory tendon that was sent off to the fourth finger soon after this tendon passed through the dorsal carpal ligament.

The Mm. extensores digitorum secundi and tertii proprii which correspond to the distal portion of the M. extensor digitorum profundus are usually adhered or fused to each other in Primates, and their osseous origin is stable and limited to the distal part of the ulna. The only exception that has been found is the presence of accessory origin from the radius in *Tarsius* (MURIE and MIVART). In contrast to this, the insertion of these muscles is reported to be extremely variable, and STRAUS has developed a classification into eight types according to the relationship with the fingers upon which the insertion takes place. Reports by earlier investigators suggest that the most common pattern in Primates is insertion upon the second and third fingers, but the insertion in lower monkeys is frequently more extensive and involves the second to fifth fingers or the second to fourth fingers so that the range of fingers upon which the insertion takes place seems to become reduced with evolution. The M. extensor digiti tertii proprius in many cases of Chimpanzee (SONNTAG, BEDDARD, STRAUS in 68%, etc.) as well as in Gorilla (PREUSCHOFT, PIRA, HEPBURN, STRAUS in 100%, etc.) and man has undergone involution and only the M.

extensor digiti secundi proprius (M. extensor indicis proprius), which sends off the tendon of insertion to the second finger, is usually present. According to STRAUS, however, insertion upon the second, third and fourth fingers in Gibbon (92%) and upon the second and third fingers in Orang (66%) is the normal condition.

In man, as just mentioned, this muscle usually gives off the tendon only to the second digit, but cases with additional insertion to the third digit have been occassionally observed by some investigators (STRAUS 10%, INOUE 6%, etc.), and in some of such cases it was not mere fasciculus of the M. extensor indicis proprius but an independent muscle which arose from the lower part of the ulna (so-called the M.extensor medii proprius).

The condition in which the M. extensor digiti secundi proprius sends off an accessory tendon to the fifth finger, noted as an abnormality in Formosan monkey, has been described in *Nycticebus* (MURIE and MIVART) while the pattern in which an accessory tendon is sent off to the fourth finger from the M. extensor digiti tertii proprius has been mentioned in *Callithrix* (STRAUS).

11. M. abductor pollicis longus (figures 7-9)

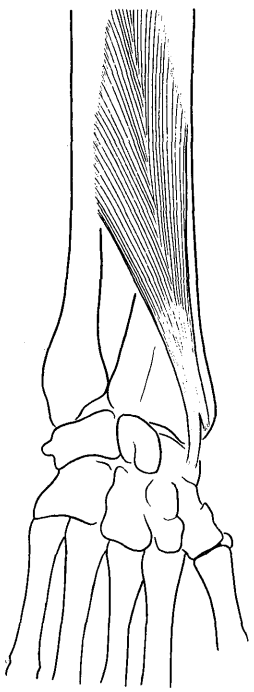
This robust muscle, located in the deepest layer among the extensor muscles of the forearm, arises muscularly from the radius, ulna and interosseous membrane. The radial origin is from the dorsal surface between the upper third to lower fourth of this bone. The upper level of the origin is at a line connecting the supinator crest of the ulna and the middle of the radius, and is adjacent to the insertion of the M. supinator, but there is no adhesion with this muscle. The ulnar origin of this muscle extends from directly below the supinator crest of the ulna to the lower fourth of the forearm on the radial side of the origin of the M. extensor pollicis longus and Mm. extensores digitorum secundi and tertii proprii, but there is no adhesion with any of these muscles. Moreover, the ulnar side of this muscle is initially covered by the M. extensor pollicis longus and the Mm. extensores digitorum secundi and tertii proprii, while its radial part lies covered by the M. extensor digitorum communis, but it runs obliquely to converge radiolateralward toward the distal third of the forearm where it emerges to the subcutaneous region from between the M. brachioradialis and the M. extensor digitorum communis. It then crosses over the tendons of the Mm. extensores carpi radialis longus and brevis to the lateral margin of the lower tip of the radius where it passes through the first compartment of the dorsal carpal ligament.

The belly of this muscle is already divisible into the radial and ulnar portions at the lower forearm, and they both undergo change to tendon immediately before they reach the dorsal carpal ligament. Just before they insert, the radial portion enters to beneath the ulnar portion, and tendon fibers are frequently exchanged between these two portions (20/30). That is, the insertion of the tendon from the radial portion can be classified into two patterns, one in which the insertion takes place only into the radial sesamoid

(22/30), and the other in which the insertion is largely upon the radial sesamoid, but also partly upon the base of the first metacarpal bone by tendon fibers sent off to the superficially located ulnar portion (6/30). The insertion of the other tendon from the ulnar portion showed two patterns that are seen at equal frequency. That is, the insertion takes place either into only the radial side of the dorsal surface of the base of the first metacarpal bone (14/30) or mostly into the metacarpal bone, but also partly upon the radial sesamoid by tendon fibers sent off to the deeper radial portion (14/30). In addition, there was a rare case in which these tendons from this muscle were completely fused so that they were indivisible to as far as the insertion (1/30). An abnormal case was noted in which the distal part of the muscle belly that was smaller than usual did not separate until nearly reaching the insertion, which was partly the tip of the radius, but was mostly upon the navicular bone (case number 31, right side, Figure 11).

Incidentally, the M. extensor pollicis brevis was not present in Formosan monkey.

Fig. 11. A variation of M. abductor pollicis longus



(No.31, ♀, R)

The origin of the M. abductor pollicis longus is stable in Primates and in man. It generally arises from the ulna, interosseous membrane and radius, although there are minute differences among species on the range of their original portions. In Prosimia and Platyrrhina, however, the ulnar origin is comparatively frequently absent (Lemuroidea - MURIE and MIVART; *Hapalemur* - BEDDARD; *Lemur* - STRAUS; *Tarsius* - WOOLLARD), and the radial origin may be absent in rare instances (*Callimico* - HILL). In contrast to this, in Catarrhina and higher Primates and in man, there simply is mention that the radial origin may be absent in very rare cases (Gibbon - STRAUS).

The insertion of this muscle has been classified into five types by STRAUS according to the combination of the relationship to the first metacarpal bone, radial sesamoid bone, greater multangular bone, etc. The insertion of this muscle in Primates is very variable, and most reports differ in their description of the insertion for the same genus and even for the same species. In general, there is no separation of the tendon in Prosimia and Platyrrhina with most cases having insertion into only the base of the first metacarpal bone, while this muscle in Catarrhina is usually divisible into the ulnar and radial portions that attach to the base of the first metacarpal bone and the radial sesamoid bone, but there also are reports

of insertion into the first metacarpal bone and the trapezium (*Cynopithecus* - PATTERSON). In many Anthropoid apes, there is insertion onto the first metacarpal bone and the greater multangular bone, but additional attachment to other nearby structures is frequently seen as in man. According to STRAUS, the insertion is particularly variable in Gibbon in comparison with the other three great apes. The condition in man has been classified into three types by BABA and into five types by KIMURA based upon the relation to the first metacarpal bone, trapezium, M. abductor pollicis brevis, articular capsule, etc., but this muscle usually separates into two or three tendons, and while the main tendon runs to the base of the first metacarpal bone, accessory tendons are sent off to either or to both the M. abductor pollicis brevis and trapezium.

In the Macaca group, there is separation of the tendon of insertion into two parts that insert, respectively, onto the first metacarpal bone and the radial sesamoid bone, but in my cases of Formosan monkey the tendons ran directly to their insertion in only a few cases, and there was exchange of tendon fibers between these tendons just before they inserted in most cases. Mention of such a condition, however, is not seen in the descriptions by earlier investigators. Furthermore, this separation into these two portions has been reported by some investigators to occur in the lower forearm at the level of the muscle belly(*Macaca mulatta* - HOWELL and STRAUS), while others report that the common tendon becomes separated at the radiocarpal joint (*Macaca irus* - KIMURA). The findings in Formosan monkey are consistent with that in *Macaca mulatta*. A rare abnormality was noted in Formosan monkey in which the insertion was the navicular bone and the tip of the radius, but such a condition has not yet been reported in other Primates or man.

Finally, a muscle which corresponds to the M. extensor pollicis brevis of man and which appears to have differentiated from the M. abductor pollicis longus has been found in Anthropoid apes, particularly in Gorilla and Chimpanzee (PIRA, PREUSCHOFT, RAVEN, SONNTAG, HEPBURN, etc.), but such a muscle is not found as a rule in such lower monkey as Prosimia, Platyrrhina or Catarrhina, and the condition in Formosan monkey is no exception.

12. Nerve supply (figure 12)

The muscular branches to the extensor muscle group of the forearm are all from the radial nerve.

The radial nerve, which arises from the brachial plexus, runs to the posterolateral side of the humerus, and passes between the medial and lateral heads of the M. triceps brachii to about the proximal third of the upper arm where the dorsal antebrachial cutaneous branch is soon given off. This latter branch passes down between the M. triceps brachii and M. brachioradialis to emerge into the subcutaneous region on the radial surface of the distal part of the upper arm and supplies the dorsal surface of the

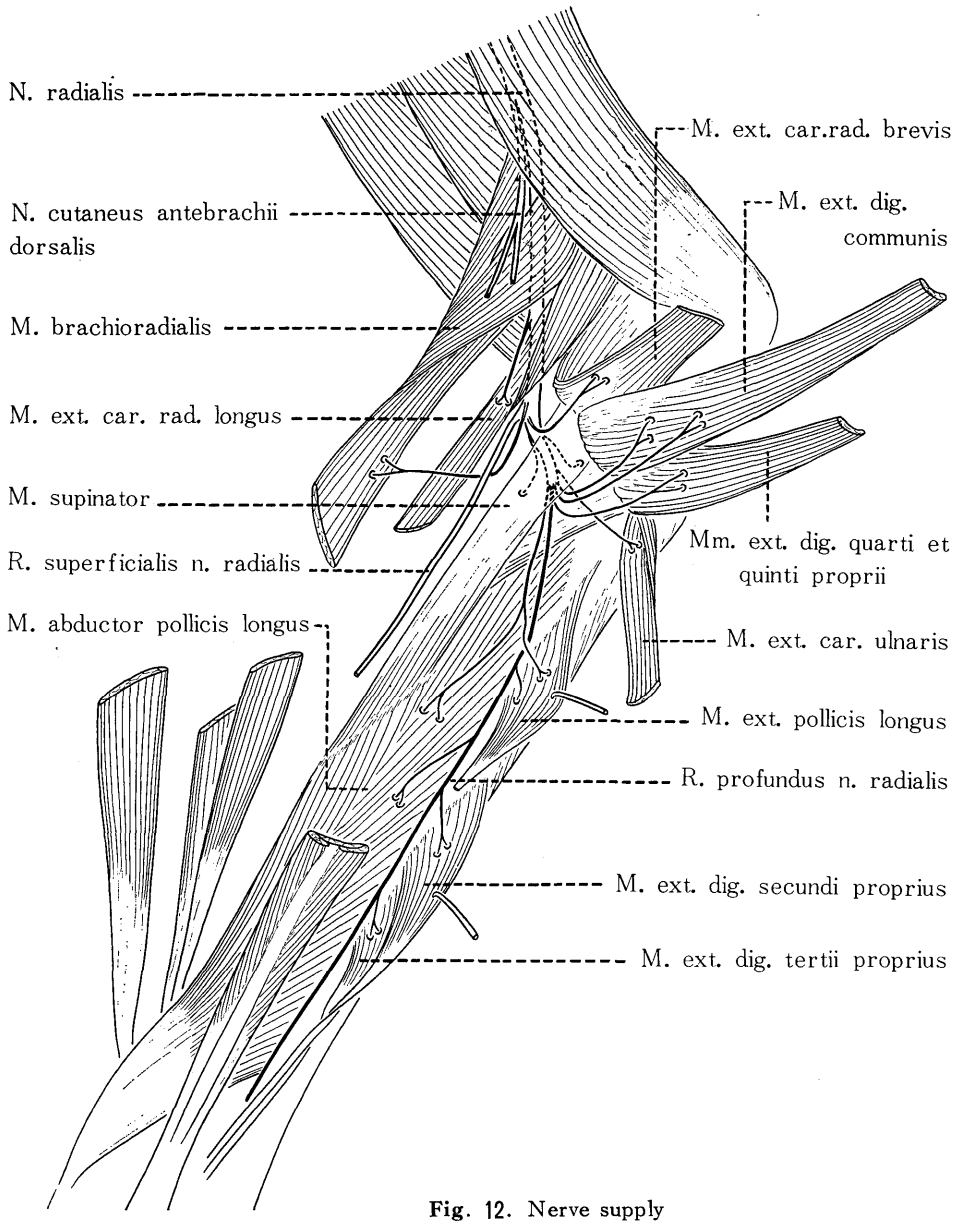


Fig. 12. Nerve supply

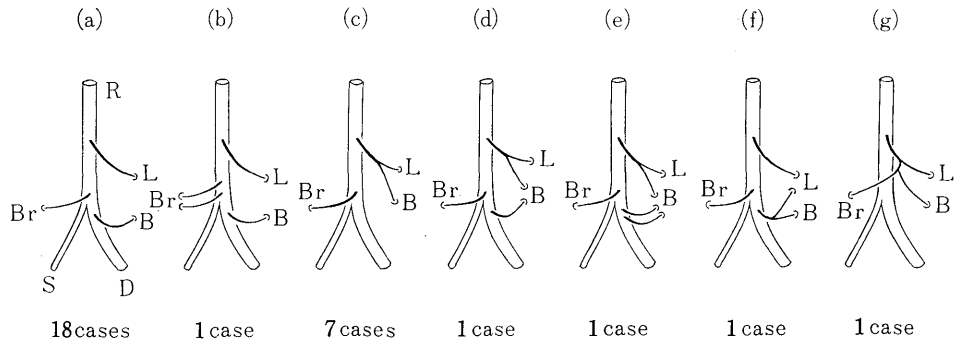
forearm.

The main trunk of the radial nerve continues downward between the M. brachioradialis and the humerus to the radial side of the elbow joint where it divides into the deep branch which gives off many muscular branches and the superficial branch that has no muscular distribution. Just before this separation occurs, the muscular branch to the M. extensor carpi radialis longus is given off. The muscular branch to this muscle usually is

given off as an independent branch (19/30, Figure 13-a and b), but it occasionally arises from a common branch that also innervates the M. extensor carpi radialis brevis (9/30, c, d and e), and in one case this muscle received both an independent branch from the main trunk of the radial nerve and a nerve branch from the branch that also innervates the M. extensor carpi radialis brevis (1/30, f). In a rare case, this muscle was supplied by a nerve which arose from a common branch that also sent off nerves to the M. brachioradialis and the M. extensor carpi radialis brevis (1/30, g).

The muscular branch that supplies the M. brachioradialis is usually given off near the bifurcation into the superficial and deep branches, and it arises as a single branch in most cases (28/30), but in rare cases this muscle may receive two branches (1/30, b) or the branch may arise from a common branch that also sends off the nerves to the Mm. extensores carpi radialis longus and brevis (1/30, g).

Fig. 13. Types of the nerve supply to the M. ext. car. rad. longus (L), M. ext. car. rad. brevis (B) and M. brachioradialis (Br).
R: main trunk of radial nerve, D; deep branch, S: superficial branch



The musclular branch to the M. extensor carpi radialis brevis generally is given off as an independent branch from the deep branch of the radial nerve in the vicinity of the bifurcation into the deep and superficial branches (19/30, a and b), but the type in which a branch arose from the common branch that also supplied the M. extensor carpi radialis longus at the level of the main trunk of the radial nerve was seen comparatively frequently too (7/30, c). What is more, in addition to a branch from the common trunk this muscle may receive one or two branches from the deep branch (2/30, d and e), and some rare cases may show the condition described above (f and g).

As mentioned earlier, the radial nerve separates into the deep branch and the slightly smaller superficial branch. The superficial branch descends beneath the M. brachioradialis to slightly above the wrist where it emerges subcutaneously at the radial side of the forearm and supplies the dorsal aspects of the hand and the first to fourth fingers.

On the other hand, the deep branch, after giving off the branch to the M. extensor carpi radialis brevis as described above, enters into the M. supinator from its radial side and passes between the superficial and deep layers of this muscle to emerge to the dorsal side of the forearm. This nerve gives off two muscular branches to the M. supinator just before it enters into this muscle, and during its course between the two layers of the M. supinator, many muscular branches are given off almost simultaneously that supply the M. extensor carpi ulnaris, Mm. extensores digitorum quarti and quinti proprii, M. extensor digitorum communis, M. extensor pollicis longus and the M. abductor pollicis longus. The muscular branches to latter two muscles frequently arose by a common stem (16/30, Figure 12).

The small remaining main trunk of the deep branch (the posterior interosseous nerve) gives off additional branches from farther distaly to the M. extensor pollicis longus and the M. abductor pollicis longus as it descends, and then it also sends off muscular branches to the M. extensor digiti secundi proprius and the M. extensor digiti tertii proprius. Furthermore, it continuous down to terminate in branches to the dorsum of the wrist joint.

SUMMARY

Inspection was made of 30 limbs of 15 Formosan monkey (male 7, female 8) to determine the origin and insertion of the extensor muscles of the forearm as well as their nerve supply and relationship with surrounding muscles. The extensor muscle group of the forearm consists of 11 muscles, and an attempt was made to ascertain the normal condition of these muscles. In addition, a comparison was also made with the findings reported for other Primates and man.

1. M. brachioradialis

This muscle, which is the largest of the extensor muscle group of the forearm, arises from the lateral brachial intermuscular septum and the lateral margin of the distal part of the humerus. It descends along the radial side of the forearm to its insertion by tendon into the area near the styloid process of the radius. Although the dorsal antebrachial cutaneous branch of the radial nerve passes through the narrow space that is formed between the two parts of origin of this muscle, the superficial branch of the radial nerve never penetrates this muscle.

2. M. extensor carpi radialis longus

The origin of this muscle is distal to that of the foregoing muscle and occurs by muscle from the lateral margin of the lower part of the humerus to the lateral epicondyle. It undergoes transition to tendon at about the middle of the forearm. This tendon runs to the lower forearm where it passes beneath the M. abductor pollicis longus. After passing through the second compartment of the dorsal carpal ligament, it runs beneath

the tendon from the M. extensor pollicis longus to the other side and inserts onto the radial side of the dorsal surface of the base of the second metacarpal bone.

3. M. extensor carpi radialis brevis

This muscle arises from the lateral epicondyle of the humerus, adjacent to the M. extensor carpi radialis longus and partially adhered to the M. extensor digitorum communis, which is located on its ulnar side. This muscle undergoes transition to tendon at a slightly lower level than the M. extensor carpi radialis longus, along the ulnar side of which this tendon descends until it reaches the back of the hand where insertion takes place onto the radial side of the dorsal surface of the base of the third metacarpal bone.

4. M. extensor digitorum communis

This muscle arises mainly tendinously from the lateral epicondyle of the humerus. At the middle of the forearm, the muscle belly is already divisible into three parts, the radial, the central and the ulnar portions. The radial and ulnar portions form the superficial layer, and they both change to tendon about three quarters down the forearm. The tendon of the former runs to the second finger, while that of the latter runs to the fifth finger. The central muscular portion forms the deep layer, which changes to tendon at about the middle of the forearm. This tendon subdivides into two parts that run to the third and fourth fingers, respectively. These tendons pass through the third compartment of the dorsal carpal ligament to the back of the hand where they contribute to the formation of the main part of the dorsal digital expansions of the four ulnar digits. These intrinsic tendons from the M. extensor digitorum communis continue down to the base of the middle and distal phalanges.

The structural pattern of the terminal tendons from this muscle in the metacarpal resgion can be classified into three types, and the most common is the type in which the first and second tendons become the intrinsic tendons to the second and third fingers, respectively, without giving off any branches. Moreover, in area where the branches are not found, the main tendons are connected to each other by a thin fibrose membrane.

5. Mm. extensores digitorum quarti and quinti proprii

These two muscles arise as a single muscle from the radial epicondyle of the humerus, and they are firmly fused to the M. extensor digitorum communis, which is located on their radial side. The tendons from these muscles in Formosan monkey run to the fourth and fifth fingers which is the same condition as that which is seen as a rule in lower monkey. On the ulnar side of the proximal phalanx, they participate in the formation of the dorsal digital expansions of the respective fingers by joining with the corresponding tendons from the M. extensor digitorum communis. These tendon fibers continue down to the base of the distal phalanx. The findings for these muscles in Formosan monkey seem to indicate that they are derived from the M. extensor digitorum communis.

6. M. extensor carpi ulnaris

This muscle, located on the most ulnar side among the extensors of the forearm, arises from the lateral epicondyle of the humerus, and changes to tendon in the lower forearm. The tendon passes through the fifth compartment of the dorsal carpal ligament to its insertion upon the ulnar margin of the base of the fifth metacarpal bone. This is a stable muscle.

7. M. supinator

This muscle consists of two layers, the superficial and the deep, that extend over the extensor and flexor surfaces of the forearm. The deep layer arises from the supinator crest of the ulna, and inserts into the dorsal and radial surface of the upper part of the radius. The superficial layer arises from the lateral epicondyle of the humerus and the articular capsule of the elbow, and inserts into the dorsal, radial and volar surfaces of the middle part of the radius. The ratio between the length of the radius and the length of the area of insertion upon the radius was 46.3.

The deep branch of the radial nerve, which enters into this muscle from the radial side, passes through between the superficial and deep layers to emerge to the dorsal side of the forearm.

8. M. extensor pollicis longus

This muscle arises muscularly from the dorsal surface of the upper part of the ulna, and changes to tendon at about the middle of the forearm. This tendon passes through the third compartment of the dorsal carpal ligament to its insertion upon the dorsal surface of the base of the distal phalanx of the first finger.

9. M. extensor digiti secundi proprius

This muscle arises muscularly from the dorsal surface of the lower part of the ulna, and is usually firmly adhered to the M. extensor digiti tertii proprius. It changes to tendon just before reaching the wrist. This tendon passes through the third compartment of the dorsal carpal ligament to above the proximal phalanx of the second finger where it participates in the formation of the dorsal digital expansions by joining with the corresponding tendon from the M. extensor digitorum communis. The tendon fibers continue down to the distal phalanx. In one case, the tendon was noted to be subdivided into two parts and attached to the aponeurosis of the fifth finger as well as to the second finger.

10. M. extensor digiti tertii proprius

The origin of this muscle by muscle from the dorsal surface of the lower part of the ulna is continuous with that of the foregoing muscle. After undergoing transition to tendon immediately above the wrist, it passes through the third compartment of the dorsal carpal

ligament, and participates in the formation of the dorsal digital expansions by joining with the tendon that runs to the third finger from the M. extensor digitorum communis. The tendon fibers continue down to the distal phalanx.

11. M. abductor pollicis longus

This muscle is located in the deepest layer among the extensors of the forearm, and arises muscularly from the radius, ulna and the interosseous membrane. The muscle belly converges radiolateralward and emerges into the superficial layer in the lower forearm. After crossing over the tendons of the Mm. extensores carpi radialis longus and brevis, it immediately undergoes transition to tendon, which passes through the first compartment of the dorsal carpal ligament. At the site of this transition to tendon, there is separation into the radial and ulnar portions. The tendon of the radial portion inserts mostly into only the radial sesamoid bone, but the tendon of the ulnar portion may insert either into only the metacarpal bone or into the metacarpal bone and the radial sesamoid bone. There was a case in which the terminal tendons were found to insert into the tip of the radius and the navicular bone.

12. Nerve supply

The extensor muscle group of the forearm is innervated by branches from the radial nerve. The radial nerve runs to the posterolateral side of the humerus where the dorsal antebrachial cutaneous branch is given off to the dorsal surface of the forearm. As the main trunk of the radial nerve continues down, further muscular branches are sent off to the M. extensor carpi radialis longus and the M. brachioradialis. Then, at about the elbow joint, it separates into the superficial branch that supplies the dorsal aspects of the hand and fingers, and the deep branch that gives off many muscular branches to the M. extensor carpi radialis brevis, M. supinator, M. extensor carpi ulnaris, etc.

REFERENCES

1) ADACHI, B.; Beiträge zur Anatomie der Japaner. *Zeit. Morph. Anthrop.*, 12 : 261-312, 1910.

2) BABA, M. A.; The accessory tendon of the abductor pollicis longus muscle. *Anat. Rec.*, 119: 541-547, 1954.

3) BARNARD, W. S.; Observations on the membral musculation of *Simia satyrus* (Orang) and the comparative myology of man and the apes. *Proc. Amer. Assoc. Adv. Sci.*, 24: 112-144, 1875.

4) BEATTIE, J.; The anatomy of the common marmoset (*Hapale jacchus* Kuhl). *Proc. Zool. Soc. Lond.*, 593-718, 1927.

5) BEDDARD, F.E.; Additional notes upon *Hapalemur griseus*. *Proc. Zool. Soc. Lond.*, 449-461, 1891.

6) BEDDARD, F. E.; Contributions to the anatomy of the anthropoid apes.

Trans. Zool. Soc. Lond., 13: 177-218, 1893.

7) BISCHOFF, T. L. W.; Beiträge zur Anatomie des *Hylobates leuciscus* und zu einer vergleichenden Anatomie der Muskeln der Affen und des Menschen. *Abh. bayer Akad. Wiss., math.-phys.*, 10: 198-297, 1870.

8) BISCHOFF, T. L. W.; Beiträge zur Anatomie des Gorilla. *Abh. bayer. Akad. Wiss., math.-phys.*, 13: 1-48, 1880.

9) CARLSSON, A.; Über die Tupaiidae und ihre Beziehungen zu den Insectivora und den Prosimiae. *Acta. Zool.*, 3: 227-270, 1922.

10) CHAMPNEYS, F.; On the muscles and nerves of a Chimpanzee (*Troglodytes niger*) and a *Cynocephalus anubis*. *J. Anat. Physiol.*, 6: 176-211, 1872.

11) CHAPMAN, H. C.; On the structure of the Gorilla. *Proc. Acad. Nat. Sci. Philad.*, 385 - 394, 1878.

12) CHAPMAN, H. C.; On the structure of the Chimpanzee. *Proc. Acad. Nat. Sci. Philad.*, 52-63, 1879.

13) CHAPMAN, H. C.; On the structure of the Orang outang. *Proc. Acad. Nat. Sci. Philad.*, 160-175, 1880.

14) CLARK, W. E. Le Gros; The myology of the tree-shrew (*Tupaia minor*). *Proc. Zool. Soc. Lond.*, 461-497, 1924.

15) CLARK, W. E. Le Gros; On the anatomy of the pen-tailed tree-shrew (*Ptilocercus lowii*). *Proc. Zool. Soc. Lond.*, 1179-1309, 1926.

16) FICK, R.; Vergleichend anatomische Studien an einem erwachsenen Orang-Utang. *Arch. Anat. Entw.*, 1-100, 1895.

17) FICK, R.; Beobachtungen an einem zweiten erwachsenen Orang-Utang und einem Schimpansen. *Arch. Anat. Entw.*, 289-318, 1895.

18) FROHSE, F. & FRÄNKEL, M.; Die Muskeln des Menschlichen Armes. III: Vorderarmmuskeln. pp. 101-198, *Gustav Fischer, Jena*, 1908.

19) GRAY' S ANATOMY; 33 rd edition. edited by Davies, D. V. & Davies, F., pp. 659-667, Longmans, London, 1962.

20) GRUBER, W.; Ueber die drei Hauptvarianten des M. extensor digiti quinti proprius manus des Menschen. *Beobuch. Mensch. Vergl. Anat.*, 3: 1-61,

21) GRUBER, W.; Monographie über den M. extensor digiti indicis proprius und seiner Variatäten bei dem Menschen und bei den Säugethieren. *Beobach. Mensch. Vergl. Anat.*, 5: 1-77, 1879.

22) HAYASHI, M.; On the musculature of the upper extremity of the Japanese twin fetus. *Zwillingsanatomie*, Keio Univ., Tokyo, 20: 1-104, 1952. (in Japanese)

23) HEPBURN, D.; The comparative anatomy of the muscles and nerves of the superior and inferior extremities of the anthropoid apes. Part I. *J. Anat. Physiol.*, 26: 149-186, 1892.

24) HILL, W. C. O.; The anatomy of *Callimico goeldii* (Thomas). *Trans. Amer. Philos. Soc.*, 49: 1-116, 1959.

25) HOLLINSHEAD, W. H.; Anatomy for surgeons. Volume 3: The back and limbs. pp. 423-436, Harper, New York, 1969.

26) HOWELL, A. B. & STRAUS W. L. Jr.; The muscular system. In: *The Anatomy of the Rhesus Monkey* (*Macaca mulatta*). edited by Hartman, C. G. & Straus,

W. L., Hafner, New York, 1971.

27) HUMPHRY, G.; On some points in the anatomy of the Chimpanzee. *J.Anat. Physiol.*, 1 : 254-268, 1867.

28) INOUE,R.; On the muscles, blood vessels and nerves of the forearm of Japanese. *Acta Anat. Nippon.*, 7: 1155-1207, 1934. (in Japanese)

29) IWAMI,S.; On the musculature of the forearm and the hand of the Japanese fetuses. *Igaku kenkyu*, 21: 23-35, 1951. (in Japanese)

30) JACOBI, U.; Die Muskulatur des Unterarmes und der Hand bei *Macaca mulatta*. *Zeit. Morph. Anthrop.*, 58: 48-73, 1966.

31) KANEFF, A. Vergleichende Untersuchung des tiefen Fingerstreckers, M. extensor digitorum profundus, beim Menschen und bei einigen Säugern. *Morph.Jb.*, 114: 542-571, 1970.

32) KANEFF, A.; Umbildung der dorsalen Daumenmuskeln beim Menschen. *Verh. Anat. Ges.*, 63: 625-636, 1969.

33) KIMURA, K.; Variation of the tendons of insertion of the abductor pollicis longus muscle in the Japanese. *Acta Anat. Nippon.*, 33: 523-527, 1958.(in Japanese)

34) KIMURA, K. & TAKAI, S.; On the musculature of the forelimb of the Crab-eating monkey. *Primates*, 11: 145-170, 1970.

35) KŌ, B.; Anatomical studies on the upper limb of the Japanese fetus. *Iwate Ika Daigaku Kaibogaku Gyosekishu*, 5: 107-138, 1958. (in Japanese)

36) KOGANEI, R. & ARAI, S.; Statistics on the variation of the muscles. *Tokyo Igakkai Z.*, 17: 127-131, 1903. (in Japanese)

37) LANGER, C.; Die Musculatur der Extremitäten des Orang als Grundlage einer vergleichend- myologischen Untersuchung. *Sitzugsber. Math-Nat. Cl. Kais. Akad. Wiss., Wien*, 79: 177-222, 1879.

38) LOTH, E.; Bëitrage zur Anthropologie der Negerweichteile. *Stud. Forsch. Mensch. Völkerkunde*, 9; Stuttgart, 1912.

39) LOTH, E.; Anthropologie des Parties Molles. Paris, 1931.

40) MACALISTER, A.; On some points in the myology of the Chimpanzee and others of the Primates. *Ann. Mag. Nat. Hist.*, 7: 341-351, 1871.

41) MACDOWELL, E. C.; Notes on the myology of *Anthropopithecus niger* and *Papiothoth ibeanus*. *Amer. J. Anat.*, 10: 431-460, 1910.

42) MICHAËLIS, P.; Beiträge zur vergleichenden Myologie des *Cynocephalus babuin*, *Simia satyrus*, *Troglodytes niger*. *Arch. Anat. Physiol., Anat. Abth.*, 205-256, 1903.

43) MILLER, R. A.; Evolution of the pectral girdle and forelimb in the primates. *Amer. J. Phys. Anthrop.*, 17: 1-56, 1932.

44) MILLER, R. A.; The musculature of *Pan paniscus*. *Amer. J. Anat.*, 91: 183-232, 1952.

45) MIVART, S. G. & MURIE, J.; Observations on the anatomy of *Nycticebus tardigradus*. *Proc. Zool. Soc. Lond.*, 240-256, 1865.

46) MORI, M.; Statistics on the musculature of the Japanese. *Okajimas Fol. Anat. Jap.*, 40: 195-300, 1964.

47) MURIE, J. & MIVART, S. G.; On the anatomy of the Lemuroidea. *Trans. Zool. Soc. Lond.*, 7: 1-113, 1872.

48) NISHI, S.; Miologie de la Japano. Statistika raporto pri muskolanomalioj ce japanoj. *Gunma J. Med. Sci.*, 2: 173-182, 1953.

49) OWEN, R.; On the Aye-aye. *Trans. Zool. Soc. Lond.*, 5: 33-101, 1866.

50) PARSONS, F. G.; The muscles of the mammals, with special relation to the human myology. Lecture II:The muscles of the shoulder and fore-limb. *J. Anat. Physiol.*, 32: 721-752, 1898.

51) PATTERSON, E. L.; The myology of *Rhinopithecus roxellanae* and *Cynopithecus niger*. *Proc. Zool. Soc. Lond.*, 112: 31-104, 1942.

52) PIRA, A.; Beiträge zur Anatomie des Gorilla. I: Das Extremitätenmuskelsystem. *Morph. Jb.*, 47: 309-354, 1913.

53) PREUSCHOFT, H.; Muskeln und Gelenk der Vorderextremität des Gorillas. *Morph. Jb.* 107: 99-183, 1965.

54) RAVEN, H. C.; The anatomy of the Gorilla. Raven memorial volume. Columbia Univ. Press, New York, 1950.

55) RIBBING, L.; Die distale Armmuskulatur der Amphibien, Reptilien und Säugetiere. *Zool. Jb.*, 23: 587-682, 1907.

56) SANO, K.; Anatomical studies on the Ainu. III: On the musculature of the forearm. *Fukuoka Igakkai Z.*, 24:pp. 52-92, 1931. (in Japanese)

57) SOMMER, A.; Das Muskelsystem des Gorilla. *Jena. Zeit. Natur.* 42: 181-308, 1907.

58) SONNTAG, C. F.; On the anatomy, physiology, and pathology of the Chimpanzee. *Proc. Zool. Soc. Lond.*, 323-429, 1923.

59) SONNTAG, C. F.; On the anatomy, physiology, and pathology of the Orang-outan. *Proc. Zool. Soc. Lond.*, 349-450, 1924.

60) STRAUS, W. L.; The phylogeny of the human forearm extensors. *Hum. Biol.*, 13: 23-50, 203-238 (concluded), 1941.

61) SULLIVAN,W. E. & OSGOOD, C. W.; The musculature of the superior extremity of the Orang-utan, *Simia satyrus*. *Anat. Rec.*, 35: 193-239, 1927.

62) SUTTON, J. B.; On some points in the anatomy of the Chimpanzee (*Anthropopithecus troglodytes*). *J. Anat. Physiol.*, 18: 66-85, 1884.

63) WAGENSEIL, F.; Untersuchung über die Muskulatur der Chinesen. *Zeit. Morph. Anthrop.*, 36: 39-150, 1936.

64) WILDER, B. G.; Contributions to the comparative myology of the Chimpanzee. *Boston J. Nat. Hist.*, 7: 352-384, 1863.

65) WOOD, J.; Variations in human myology observed during the winter session of 1867-68 at King's College, London. *Proc. Roy. Soc. Lond.*, 16: 483-525, 1868.

66) WOOLLARD, H. H.; The anatomy of *Tarsius spectrum*. *Proc. Zool. Soc. Lond.*, 1071-1184, 1925.

67) ZUCKERKANDL, E.; Zur Anatomie von *Chiromys madagascarensis*. *Denkschr. Akad. Wiss. Wien, Math-Nat.*, 68: 89-200, 1900.