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STUDY OF MONKEY, APE, AND HUMAN MORPHOLOGY AND PHYSIOLOGY RELATING TO STRENGTH AND ENDURANCE

PHASE VII

THE MUSCULOSKELETAL ANATOMY OF THE ANTEBRACHIUM OF A SQUIRREL MONKEY (SAIMIRI)

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Erika Fogg-Amed

July 1965

6571st Aeromedical Research Laboratory
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Air Force Systems Command
Holloman Air Force Base, New Mexico

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FOREWORD

This study was conducted by William E. Edwards under Contract AF 29(600)-3466, Project 6892, Task 689201 from 1961 - 1963. The program was monitored by Major James E. Cook, Veterinary Services Division, ARV.

This is the seventh in a series of nine papers being prepared under contract AF 29(600)-3466 on the Study of the Monkey, Ape and Human Morphology and Physiology Relating to Strength and Endurance and the last of four papers concerned with the musculoskeletal system of the thorax and upper extremities of the chimpanzee and the squirrel monkey.

The very helpful cooperation of Lt Col Hamilton H. Blackshear, Major James E. Cook and Major Clyde H. Kratochvil, all of the 6571st Aeromedical Research Laboratory, is gratefully acknowledged.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

C.H. KRATOCHVIL
Major, USAF, MC
Commander

ABSTRACT

The antebrachial musculature of a female squirrel monkey (Saimiri) is quantitatively described in detail and illustrated by the photo-etching process. Comparisons with data from the literature on other platyrrhines and non-platyrrhine primates indicate marked taxonomic distinctiveness and primitivity in many features.

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1. INTRODUCTION

The history of primate anatomy has been summarized in an earlier paper on the musculoskeletal anatomy of the thorax and brachium of an adult female chimpanzee (Edwards, 1965a).

The reasons for the special significance of the squirrel monkey (Saimiri) -- its great abundance, tractability, and generalized nature -- have been discussed in the companion paper on its thoracic and brachial anatomy (Edwards, 1965b). Yet, like almost all of the other platyrrhines, Saimiri has been subjected to relatively little anatomical study (Hill, 1957, p. 91; Hill, 1960, pp. 253-293), and apparently the musculoskeletal system of the thorax and upper extremities has received no previous study whatever.

2. HISTORY OF THE RESEARCH

A moderately detailed history of the multiple project of which the current study constitutes a part was reported in the first of this series of papers (Edwards, 1965a).

The subject died at the Aeromedical Research Laboratory on 17 July 1961. Death was caused by dehydration; avoidance of which is especially difficult with these monkeys (Hill, 1960, p. 295), in part because of their small volume-to-surface-area ratios and the requirements resulting from geometrical similitude (Edwards, 1963c). Measurements of the subject before dissection have been provided in the companion paper (Edwards, 1965b).

Dissection was initiated immediately upon autopsy the day after death. After intermittent study during the following two months, work was discontinued until the spring of 1963, when it was resumed under Aeromedical Research Laboratory contract AF 29(600)-3466.

3. PROCEDURE OF STUDY

Dissection was performed primarily on this subject's right side, to which all drawings refer. For consistency and ease of comparisons with drawings, all descriptions and all measurements in the text also refer to the right side.

The photo-etching process -- described in Edwards, 1965a, and modified as described in Edwards, 1965d -- was employed for the high accuracy obtainable, with pencil and India ink drawings made directly on photographs which were subsequently bleached out.

Two of the photographs were taken by Mr. Henry Phillips; the remainder were prepared by the senior author and taken by Mr. Robert Halverty of Land Air, Inc. Mrs. Erika Fogg-Amed, the assistant author, prepared all of the drawings except Figures 1 and 4. The text of this report was prepared by the senior author.

4. DESCRIPTION OF MUSCULATURE

A. Superficial Flexors

Pronator teres. This parallel, spindle-shaped muscle arises from the mid-radial aspect of the medial epicondyle with the broadest (3.0 mm.) area of origin there except for flexor carpi ulnaris and also with the exception of flexor carpi ulnaris is the thickest (2.3 mm.) of all the condylar flexors (Figs. 1-7). The common tendon for these flexor muscles is here not as strongly developed relatively as in the chimpanzee and man, but it extends superficially on this muscle some 12.5 mm. beyond the origin, farther on the ulnar than on the radial border. Insertion is tendinous along a thin line down most of the middle third of the mid-lateral aspect of the radius (25 to 42 mm. from the proximal end of the 66.5-mm.-long radius) and more proximally contiguously into a portion of the oblique line between supinator and the deep common flexor. The largest cross-sectional area of this muscle occurs at 12 mm. from the proximal end, where it is 5.0 mm. wide and 4.2 mm. thick.

There was no trace of a deep (ulnar) head for this muscle.

In another primitive platyrrhine, Callimico goeldii, pronator teres also has a single head of origin, although a fibrous tract which is part of the origin of flexor digitorum sublimis suggests the possibility of a vestigial deep head as well (Hill, 1959, p. 51).

In the capuchin (Cebus), another platyrrhine genus apparently much more closely related to Saimiri than Callimico is, pronator teres is proximally inseparable from adjacent muscles and inserts "on the summit of the radial curvature," in both respects apparently rather different from Saimiri (Hill, 1960, p. 350). In the less conservative platyrrhine howler monkey (Alouatta), the largest New World primate, pronator teres is "as in Man" (Hill, 1962, p. 41). Unlike its platyrrhine very near relatives Brachyteles and Ateles, which have virtually or entirely lost one digit through brachiation (Midlo, 1934, pp. 356-357), the woolly monkey (Lagothrix) retains the pollex. The woolly monkey manifests "a deep wholly tendinous origin from the epicondyle" as well as a more superficial origin for pronator teres; this tendon passes through the mid-portion of the muscle to insert on the radius (Hill, 1962, p. 195) -- an arrangement the efficacy of which is difficult for the present writer to understand.

In the family Hapalidae (marmosets) -- the division of neotropical primates apparently the most primitive in most respects -- pronator teres is similar to that of Saimiri (Hill, 1957, p. 150).

Pronator teres in Tarsius is also similar to that of Saimiri (Hill, 1955, p. 170).

Flexor carpi radialis. This long, slim, spindle-shaped muscle arises from the radial-distal aspect of the medial epicondyle, only 1.5 mm. wide and 1.0 mm. thick, adjacent to pronator teres, as well as from the tendinous intermuscular septa in the proximal portion on either (especially the ulnar) side (Figs. 1-5). The common flexor tendon covers approximately the proximal 16 mm. of flexor carpi radialis, which extends obliquely across the forearm immediately distal to pronator teres, with maximum dimensions of 3.8 by 2.9 mm. at 16 mm. Upon examination from the proximal to the distal end, tendon appears as a thin band on the superficial surface (but extending deep into the muscle) at 30 mm. and expands to extend across most of the muscle at 35 mm. But the fleshy portion extends as a slim strip most of the way from this latter point to the insertion upon the proximal aspect of the navicular bone, 71 mm. from the origin. At its narrowest point, 3 mm. above the navicular, the tendon is 0.9 mm. wide and 0.8 mm. thick.

In Callimico, flexor carpi radialis is quite similar to that of Saimiri, but insertion is upon the base of the indicial metacarpal (Hill, 1959, p. 51), as is that of Cebus (Hill, 1960, p. 350). In Alouatta, this muscle at least shows some variation from the condition in man and almost all other primates in its insertions, "a slender one to metacarpal II and a stouter one to metacarpal III" (Hill, 1962, p. 41). The thin, rounded muscle of Lagothrix arises from the epicondyle and intermuscular septa (Hill, 1962, p. 195).

Flexor carpi radialis is fairly similar in marmosets to that of Saimiri, but its flattened tendon pierces the carpal tunnel and makes the customary insertion on the second metacarpal (Hill, 1957, p. 150).

This muscle is similar to that of Saimiri in the catarrhine rhesus monkey (Macaca mulatta), except for insertion upon the second metacarpal bone, "and sometimes upon the third as well" (Howell and Straus, 1933, p. 135).

Straus (1942) has provided intensive studies of the phylogenetic history of the antebrachial flexors in quadrupedal vertebrates. In the amphibians, there is but one muscle in the radial sector of the superficial flexors; it arises on the ulnar epicondyle, as in the primates, and inserts upon the radius and radiale in a pattern suprisingly similar to the insertions of the two muscles in Saimiri. Even more closely comparable are the separate muscles to the radius and to the distal radius and the radiale in the reptile Ctenosaura, while in another reptilian, Sceloporus, flexor carpi radialis inserts upon the radiale and upon the base of the first metacarpal.

An antebrachial (pronator teres) and a manual (flexor carpi radialis) muscle, both originating from the ulnar epicondyle, are characteristic of "practically all mammals." "The mammalian flexor carpi radialis is a rather uniform muscle. . . . Insertion in most forms is on the metacarpus, commonly on metacarpale II, but often on I or II; occasionally it is partly or even wholly carpal (many marsupials) as in more primitive tetrapods." In summary, then, insertion of flexor carpi radialis distal to the carpus is "present in some reptiles and has come to be virtually fixed in mammals, in which metacarpal attachment is almost universal" (Straus, 1942, pp. 282-286). Whether the unique condition in Saimiri represents an individual anomaly, a "chance" evolutionary retrogression, or an unaltered survival of the more primitive condition will be considered in the concluding section of this paper.

Palmaris longus. This specimen manifests no trace of palmaris longus.

In Callimico, palmaris longus is very well developed (Hill, 1959, p. 51). In Cebus, this muscle is "well developed but slender" (Hill, 1960, p. 350). "A thin palmaris longus is sometimes present [in Lagothrix], but may be fused with [flexor carpi ulnaris]" (Hill, 1962, p. 195). In marmosets, this muscle, absent from the present specimen of squirrel monkey, is "substantial" (Hill, 1957, p. 150).

In the primates "higher" than Tarsius, "palmaris longus is very variable and may be lacking" (Hill, 1957, p. 32). In Tarsius, it also occurs, "blended" with flexor carpi ulnaris at its origin (Hill, 1955, p. 170).

Broader comparisons reveal that "some type of palmaris longus is found regularly in mammals, excepting only monotremes and a few placentals" (Straus, 1942, p. 289). On the other hand, Parsons (1898, p. 729) has concluded that "this muscle is almost as inconstant [in form] in the lower mammals as it is in man." The present writer would accept the conclusion of Straus (1942, p. 304) that "from an evolutionary aspect, it is a new structure, and not a vestige as so often believed," but only if referring to pan-mammalian evolution. The wide intraspecific variability and frequent reduction and absence of this muscle in primates reflects a general trend in primates to its decline and disappearance, except in vestigial form.

Flexor digitorum sublimis. Taking its origin from the mid-distal aspect of the medial epicondyle between flexor carpi radialis and flexor carpi ulnaris, as well as from the bordering septa along both sides of the proximal portion (especially the radial side), this long, fusiform, parallel muscle gradually expands from 1.4 mm. wide by 1.9 mm. thick to 5.9 mm. wide by 2.9 mm. thick at 30 mm., the approximate mid-point of the belly (12 mm. beyond the superficial tendon), beyond which gradual constriction occurs to the end of the fleshy portion at 61 mm., approximately the proximal border of the wrist and 15 mm. beyond the appearance superficially of a perpendicular band of tendon near the mid-line (Figs. 1-5 and 7). At approximately 45 mm. begins a shallow, tendon-lined trough in the surface of flexor digitorum profundus into which the superficial flexor extends. Distally, this trough deepens but becomes narrower as the belly of the superficial flexor constricts and fuses into tendon. Across the mid-line of the wrist the channel is so deep that the superficial surface of the four fused tendons separate and maintain extremely uniform dimensions -- a uniformity which might have been anticipated, for the heavier links of a non-uniform chain represent wasted material, since they cannot increase the strength of the chain. These tendons are approximately 0.45, 0.5, 0.65, and 0.3 mm. wide and roughly one-third as thick as they extend to insert upon either side of the proximal volar surfaces of the middle phalanges of the second to fifth digits, respectively, as in man (Fig. 4).

In Callimico, flexor digitorum sublimis arises deep to flexor carpi radialis and palmaris longus, it manifests "a very distinct postaxial belly of fusiform shape arising from the back part of the condyle" (a postaxial belly which is intimately associated with the deep flexor and gives rise to a tendon a portion of which extends to the fifth digit), and its preaxial belly portion gives rise to tendons to the second, third, and fourth digits (Hill, 1959, pp. 51-52); in all of the foregoing traits, Callimico contrasts sharply with Saimiri.

In Cebus, this muscle is "well developed, but not entirely independent of the deeper flexors" (Hill, 1960, p. 350). In Alouatta, a superficial lamina supplies the third to fifth digits, while a distinct deeper lamina, also from the condyle, inserts upon the second (Hill, 1962, p. 41). There are two heads of origin in Lagothrix -- a narrow, fleshy one from the medial epicondyle and an aponeurotic one "from the ulna from about 1 cm. distal to olecranon to within about 1 cm. above the radio-ulnar joint" (Hill, 1962, p. 195).

This muscle is only "feebly developed" and arises on "a deeper plane" than the other superficial flexors in marmosets; with only a few condylar fibers, it arises mainly from the septum between it and flexor carpi radialis, but, as in Saimiri, the fused tendon of insertion splits to proceed to the four ulnar digits (Hill, 1957, p. 150).

In the rhesus monkey, flexor digitorum sublimis is surprisingly similar to that of the squirrel monkey, although it does manifest such minor differences as being mostly overlain by other superficial flexors, as arising also from the capsule of the elbow-joint, and as having the central two of its four tendons of insertion at a more superficial level. It even has fused to it at its condylar origin a second head -- the present writer would instead have considered this an accessory head of the deeper flexor -- which extends deeply to fuse by tendon to flexor digitorum profundus, although into the medial margin of its radial portion (Howell and Straus, 1933, pp. 135-136), instead of slightly to the radial side of its radial and ulnar portion, as in the present Saimiri specimen.

Hill (1957, p. 32) has summarized that among platyrrhines and catarrhines this muscle usually lacks the coronoid origin, present in chimpanzees and humans, while the radial origin occurs only in the great apes and humans. In *Tarsius* also its origin is limited to the medial epicondyle, and there is a connection with the deep flexors in the lower third of the antebrachium, before the divergence of four tendons (Hill, 1955, p. 170).

Even the primitive opossum (*Didelphis*) exhibits "an incompletely differentiated flexor digitorum sublimis, and a complete palmaris longus." In most placentals, "sublimis is an independent muscle with separate epicondylar origin, although in many instances it is also united with the deep flexor, as in Tupaia. . . . There are usually three tendons -- for digits II, III, and IV. . . . The last tendon to make an evolutionary appearance is that for V, which occurs only sporadically save in primates" (Straus, 1942, pp. 287-289).

Flexor carpi ulnaris. This most ulnar (medial) muscle of the superficial flexor group arises proximally from the ulnar aspect of the medial epicondyle, the volar aspect of the olecranon process, and the tendinous superficial fascia between these areas (Figs. 2-4). The superficial tendon covers the proximal portion of the muscle for a distance of 30 mm. Distal to 12 mm. from the proximal tip of the ulna, this muscle is separated from the ulna by the ulnar head of flexor digitorum profundus, unlike the situation in such other primates as the chimpanzee and man. Down almost the entire length of the forearm extends the antebrachial fascia, which appears to attach especially strongly to the ulnar border of flexor carpi ulnaris and to the superficial-anterior border of the ulna, extending much more loosely over the intervening ulnar extension of flexor digitorum profundus; the breadth of this ulnar strip of flexor digitorum profundus where it attains the dermal surface (except for the intervening, loosely attached antebrachial fascia) is approximately 1, 2, 3, 2.7, and 2.5 mm. at 15, 25, 35, 45, and 55 mm. below the proximal tip of the ulna, respectively. The origin of flexor carpi ulnaris thus includes this narrow strip along the ulna from the olecranon process to 7 mm. above the tip of the styloid process. The tendon of insertion appears near the mid-line of the superficial surface 22 mm. above the insertion; it gradually widens for 11 mm. and then broadens abruptly to extend across most of the muscle at 6 mm. above the insertion, although on the ulnar border muscle fibers continue to the insertion. Insertion is upon the entire proximal aspect of the dorsally oriented pisiform bone, which is relatively large compared with the human condition.

Unlike the muscles previously described, all of which are fusiform, flexor carpi ulnaris is almost uniform in width along its proximal 80 per cent, tapering very slightly from 5.0 to 4.5 to 4.1 to 3.7 mm. at 0, 25, 50, and 75 per cent of the distance down the muscle. Maximum thickness at the same points are, respectively, 1.5, 2.5, 2.4, and 2.0 mm. At 2 mm. above the insertion, the tendon is 1.3 by 1.3 mm., with the fleshy portion of the muscle adding an additional 0.7 mm. to the breadth.

In Callimico, flexor carpi ulnaris has two heads of origin and is fleshily attached to most of the length of the ulna (Hill, 1959, p. 52), in contrast with Saimiri. In Cebus (Hill, 1960, p. 350), this muscle takes fleshy origin from the condyle (as in Saimiri), the olecranon (as is true only to a slight degree in Saimiri), and from the ulnar shaft to the wrist (as in Callimico but not Saimiri). This muscle in Alouatta has two heads -- from the condyle and from the border of the olecranon (Hill, 1962, p. 41). Except for its origin's not extending to the olecranon, this muscle in Lagothrix is very similar to that in Saimiri (Hill, 1962, p. 195).

In the marmoset, this muscle closely resembles that of the squirrel monkey except for a secondary insertion upon the base of metacarpal V (Hill, 1957, pp. 150-151).

The squirrel monkey's superficial ulnar flexor is very similar to that of the rhesus monkey (Howell and Straus, 1933, p. 135).

Flexor carpi ulnaris is rather similar to that of Saimiri in Tarsius, although the latter lacks any olecranon origin and has a secondary insertion upon the base of metacarpal V (Hill, 1955, p. 170).

"This is a very constant muscle in mammals" (Parsons, 1898, p. 734), but it "commonly arises by both humeral and ulnar heads," or only one or the other, with insertion on the pisiform alone or upon metacarpal V as well (Straus, 1942, p. 294). For example, in the very primitive Tupaia glis, a small epicondylar and a large ulnar head make both insertions, as is essentially the case with the opossum. In the reptile Ctenosaura there is, interestingly, even greater resemblance to Saimiri, with origin from both the epicondyle and the olecranon and insertion only upon the pisiform (Straus, 1942, pp. 292-294).

B. Deep Flexors

Flexor digitorum profundus. This complex muscle, underlying all of the superficial flexors and extending beyond them on both sides, is composed of five heads, which do not, however, at all precisely correspond to the five digits (Figs. 2-7).

The most radial head is apparently homologous with flexor pollicis longus in man, and is thus named on the drawings to distinguish it from the other segments of this muscle. Its fascicles extend proximally to the oblique line, with origin from most of the volar surface of the radius from that line to 15 mm. distal from the most proximal point on that line; this distal limit of origin is 23 mm. from the distal tip of the radius. The muscle above the distal limit of its area of origin is completely coalesced with the radial head, and beyond the area of origin is separated from the radial head by a plane of cleavage which proximally is slightly radial from the common superficial tendon of insertion but in its more distal portion extends down the common tendon's radial border; this plane of cleavage extends only part of the way through the muscle from the superficial surface, with fusion of the two heads in their deepest portions.

The radial (second) head also extends proximally to the oblique line; its area of origin from the ulnar portion of the volar surface of the radius and from the ulnar surface of the radius extends distally approximately as far as the area of origin of the first head -- as well as from the adjacent portions of the interosseus membrane. Thoroughly fused to the first head ("flexor pollicis longus") proximally, just described, it is entirely separated proximally from the adjacent ulnar head to the point of thorough fleshy fusion at 27 mm. (deeply) to 23 mm. (superficially) from the distal tip of the radius, thereby virtually reversing the fusion-separation pattern on the other side of the second head. The most distal point of separation is slightly below the proximal end of the common superficial tendon.

The humeral head arises on the distal aspect of the medial epicondyle deep to flexor digitorum sublimis and is partially fused to that superficial flexor for the most proximal 6 mm. Fusiform in shape, it fuses to the supraradial proximal end of the common tendon 38 mm. from its origin and 28 mm. above the distal tip of the radius. Where its partial fusion with flexor digitorum sublimis terminates, it is 1.6 mm. wide and 2.0 mm. thick; it gradually expands to maximum dimensions of 3.0 mm. wide by 3.5 mm. thick at the middle of its extent as a separate head. By means of a broad tendon sheet, this humeral head fuses to the radial and ulnar heads at 23.5 mm. above the ulnar tip, with oblique descent to these two deeper heads, which proximal to the area of fusion of all three are separated but closely contiguous to one another; the more superficial humeral head bridges the separation plane between the radial and ulnar heads almost symmetrically but slightly more on the radial side (Fig. 7). The tendon sheet appears 15 mm. above the juncture on the ulnar side of the deep surface and 5 mm. above the juncture on the ulnar side of the superficial surface, at which latter point the maximum thickness of the muscle is only some 0.8 mm. and the tendon is perhaps slightly over 0.1 mm. thick. This tendinous sheet, contained within the distal portion of the belly of the humeral head, with some fleshy portion of the belly deep to it and more of the belly superficial to it, is aligned in the frontal plane; it represents essentially the tendon of insertion of the humeral head, inserting (by fusion) into the broader common superficial tendon. The most distal extension of the fleshy portion occurs on the radial side, both superficially and deeply just above the transformation of the tendon into the common tendon over the superficial surface of the radial head and the radial half of the ulnar head. Slightly distal to the area of fusion, the tendon extends entirely across the radial head, reaching the radial border 10 mm. distal to the juncture with the humeral head. For some distance, the tendon over the ulnar head is only about half as broad as that over the radial portion; but a little over half-way from the juncture to the wrist, the tendon reaches the ulnar border of the two heads, and shortly above the wrist fuses to the narrow tendon of the fifth head. With a breadth of 4.5 mm. at its widest point, the common tendon maintains constant dimensions before gaining additional breadth (to 6.0 mm.) 5 mm. above the tip of the ulna by the fusing to it of the comparable tendon of the fifth head, 1.5 mm. wide.

The ulnar head, almost as broad as the radial head, arises fleshily from the entire volar surface of the ulna, as well as from part of the radial and from most of the medial surfaces, extending from the area of insertion of brachialis at its proximal end to 2 mm. above the distal end of the origins of the first two heads distally. Another even more distal area of origin extends along the dorsal border where it is fused to the fifth head, and fascicles arise in common with the fifth head from the medial (ulnar) border of the superficial surface of the ulna and extend distally to within 18 mm. of the distal tip of the ulna. Origin also occurs from adjacent portions of the proximal 60 per cent of the interosseus membrane.

The most separate head of flexor digitorum profundus except for the humeral one, the fifth head is also the slimmest, by a slight margin over the humeral head. The proximal origin of the fifth head is from the ulna a short distance below the olecranon process and immediately beneath the broad tendon of origin of flexor carpi ulnaris. Below the most proximal end, the entire origin is a thin strip extending down the dorsomedial aspect of the bone to within 18 mm. of its distal end. Along this entire origin it is fused to the ulnar head; but fusion occurs only along this very thin strip, and anterior to this area of origin it is entirely separated. It is of course impossible to separate sharply a fused portion into its separate components. But if such allocation were made by extending the plane of separation, in its proximal half the muscle is attached to the bone, while in its distal half it fuses to the ulnar head, which in turn is attached to the bone. Superficially, the tendon of insertion extends 37 mm. above the tip of the ulnar styloid process, and is thus the highest such tendon among the five heads, almost two-thirds the distance up the length of the fleshy portion.

In the middle of their relatively separated portions, on their volar surfaces the four deeper heads are 4, 4, 3, and 1.2 mm. wide respectively, but the first head narrows sharply beneath this surface and the ulnar head broadens to 4 mm. beneath this surface. The thickness (depth) of all four deeper heads is fairly uniformly some 4 to 5 mm. throughout most of their fleshy portions.

Forming a progressively deepening and narrowing trough as it proceeds distally, the superficial common tendon-plate, 6.0 mm. wide just above the wrist, is only 3.6 mm. in width as it traverses the wrist. Beyond this point the tendon sheet broadens again to 5.8 mm. at 12 mm. below the end of the radius, at which point the tendon divides into four branches, the most radial of which is twice as wide as the others. At 2 mm. farther, the first branch forks again, with 40 per cent of the total extending into the first and the remainder into the second digit. In each of the digits but the thumb, after extending deep to the superficial flexor tendons until they bifurcate and insert in the distal portion of the first phalanx, the tendon (which down most of the length of the third digit is 1.5 mm. wide and 0.4 mm. thick) gives off a branch on both sides in the middle of the second phalanx; these insert into the volar halves of the radial and lateral aspects of the joint capsule, while the larger central tendon proceeds onward to insert into the entire proximal half of the volar surface of the third phalanx (Fig. 4).

Comparisons with Callimico again reveal marked contrasts. The radial head in this other primitive South American monkey arises from two distinct heads from the distal part of the medial epicondyle as well as from a fleshy origin from the shaft of the radius and the interosseus membrane (Hill, 1959, p. 52). As a further distinction, the radial fleshy mass remains entirely distinct from the ulnar mass -- as is not quite the case in Saimiri -- but at least both forms manifest fusion of their tendons distally. The "ulnar moiety of the deep flexor mass" consists of superficial and deep parts, quite unlike this area in Saimiri. "The main tendon. . .also receives a contribution from the flexor sublimis"; the present writer would suggest that this contributing, fusiform head, which is "an intermediary between flexor sublimis and flexor profundus" taking origin from the medial epicondyle, is very likely homologous with the humeral head of the deep flexor complex in Saimiri.

In the capuchin (Cebus), the deep flexors are composed of the "usual parts," "condylo-radialis, condylo-ulnaris, radialis proprius and ulnaris proprius" segments (Hill, 1960, p. 350), quite unlike the situation in Saimiri; but apparently rather like the present form, Cebus manifests a "fairly distinct" radial portion with a tendon fusing to the tendon from the ulnar portion. In the less primitive howler monkey (Alouatta), the deep flexors are similar to man's, including a fairly well-differentiated flexor pollicis longus (Hill, 1962, p. 41).

Lagothrix exhibits a humeral head which "shares a common tendon with flexor sublimis" but seems otherwise rather similar to the humeral head of the present specimen. In the wrist, the tendon is partly radial to that of sublimis. A fifth head is also rather similar, but sends a slip to the fourth digit as well. There is no separate flexor pollicis longus in Lagothrix (Hill, 1962, p. 196). Straus (1942, p. 299) reports that instead of the usual segmentation on the sagittal plane, in his specimen it tended to be more on the frontal plane, suggesting laminae of both muscle and tendon.

The deep flexors of marmosets manifest some general but rather limited similarity to those of squirrel monkeys. The separation of the radial and ulnar portions is similar but, at least in one genus, there is no possible homolog with the humeral head. Additional differences include division into six tendons a short distance distal to the origin and recombination to produce only four tendons to the four ulnar digits in Hapale. One of two flexor pollicis longus heads in Tamarin arises deeply from the condyle; both operate the pollex, with a slip to the index as well (Hill, 1957, p. 151). Comparisons of Saimiri with Macaca mulatta, a fairly representative Old World monkey, again reveal unexpectedly close similarities for this muscle-complex. Its radial and ulnar portions are separate except shortly above the wrist, where they fuse to a common tendon, as in Saimiri. Similar to Saimiri, "there is usually a definite cleavage plane between the portions of the muscle supplying the fourth and fifth fingers." The humeral head (termed by Howell and Straus a head of sublimis) is also quite like that in Saimiri, as previously noted. The tendons to the digits show certain differences, however (Howell and Straus, 1933, p. 136).

In generalizing about the "Pithecoidea" (all primates "above" the tarsier), Hill (1957, p. 32) states that, "except in Man, there is always more or less fusion between flexor digitorum profundus and flexor pollicis longus," to which Straus (1942, p. 299) would except only "some gibbons."

As in some of the other muscles previously considered, for the deep flexors there seems to be less contrast between Saimiri and Tarsius than between the former and most other platyrrhines, although the differences occurring are marked. The radial and ulnar moieties are entirely separate except for partial fusion of the tendons of insertion in the tarsier. The origin of the radial portion (flexor pollicis longus) is from the humerus as well as the radius, and insertion is upon the first two digits. The ulnar portion has three heads rather similar to those in Saimiri, but instead of the latter's fifth head, one arises from the interosseus membrane (Hill, 1955, p. 170).

For the deeper flexors, the primitive mammalian condition, derived from reptilian ancestry, is that of five separate portions: radio-condylar, ulno-condylar, centro-condylar, radial, and ulnar (Windle, 1889). Of these, Saimiri manifests the last two and one of the condylar ones, likely the third. In Tupaia, the fourth and fifth heads form a "practically indivisible sheet" and are joined at the wrist by much of the first three (separate) heads, forming a common tendon-plate which produces a tendon for each of the five digits (Straus, 1942, p. 298). A very similar arrangement exists in the oppossum, Didelphis (Straus, 1942, p. 298).

Pronator quadratus. This very thin, flat, short, quadrilateral muscle lies deep to all the flexor tendons. It arises tendinously from a narrow strip along the radial portion of the volar surface of the distal end of the ulna (almost as deep as the mid-line of the ulna's radial aspect), 15 to 3.5 mm. above the ulna tip, and it crosses the lower forearm at an angle roughly 55 to 60 degrees to the forearm's main axis to insert fleshily and as deep as the origin upon the lateral border of the volar aspect of the radius, 12.5 to 3 mm. from the radius tip at the lateral border of the insertion. The muscle is thus confined to the distal fifth of the antebrachium. The hiatus between the radius and the ulna -- attaining a maximum width of 5.6 mm. just below the middle of the forearm -- crossed by pronator quadratus is 4.9 mm. wide at the proximal end and 1.7 mm. wide at the distal end of the muscle.

In Callimico, this muscle arises from the distal 8 mm. of the 61-mm. ulna and inserts slightly more narrowly on the 53-mm. radius (Hill, 1959, pp. 28 and 52), proportionately rather similar to the present specimen.

This muscle is apparently also very similar to that of the present specimen in Lagothrix (Hill, 1962, p. 196), and not markedly different in the Hapalidae (Hill, 1957, p. 150) or in Tarsius (Hill, 1955, p. 170).

C. Superficial Extensors and Supinators

With the exception of the first two muscles to be discussed, suspensor radialis and brachioradialis, the dorsal musculature of the squirrel monkey antebrachium is much less atypical of platyrrhines and is therefore less phylogenetically significant than the forearm flexors. So comparative data for these dorsal muscles will be slightly more limited than that for the preceding volar muscles in this paper.

Suspensor radialis. This muscle, apparently unique to Saimiri, arises tendinously (but at first view apparently fleshily, for the tendons are short) from either side of the insertion of deltoid, from 7 to 3 mm. on the dorsal (lateral) side and 9 to 2 mm. on the ventral (medial) side above the distal tip of deltoid, while there appears to be some proximal extension of these tendons, fused to those of deltoid along its border of insertion (Figs. 1-5, 8, and 10). Closely embracing both sides of the tip of deltoid, the two heads of the muscle become closely adherent by thin fascia immediately below this tip and extend distally immediately dorsal to biceps across a flattened depression on the surface of the proximal portion of brachialis; this slight depression of the superficial surface of brachialis terminates in the middle of the brachium. Deeply, the fascicles of the two heads fuse 4.0 mm. below the tip, but a slight superficial fissure marks a partial separation of the two heads to a point 18 mm. distal to the tip of deltoid, which tip is 38 mm. above the distal tip of the lateral epicondyle of the humerus.

Consistent with its more extensive origin, the anterior head is 2.7 mm. wide and 1.5 mm. thick at the tip of deltoid, compared with 1.9 by 0.7 mm. for the posterior head, measured in 1963 after some dehydration. Below their point of fusion, the partially differentiated posterior head forms a thin cross-sectionally triangular flange which is only accessory to the cross-sectionally oval anterior portion; at 13 mm. distal to deltoid, the breadths of the two heads are 1.8 and 1.3 mm., while the thicknesses are 1.3 and 0.7 mm. In breadth 2.6 mm. by 1.6 mm. in thickness as it traverses the elbow-joint as the most lateral (radial) muscle in that area, it continues to maintain fairly constant oval cross-sectional area, as is essential for optimal efficiency if fibers extend the entire length of a muscle.

The greatest breadth of suspensor radialis, 3.5 mm., is attained 25 mm. below the lateral epicondyle, where its thickness is 1.1 mm. Continuing down the radial border of the forearm, it begins to narrow appreciably just before joining brachioradialis, with dimensions of 2.3 by 1.2 mm. at that juncture. It fuses fleshily to brachioradialis (which at this point is solely tendinous) 9 mm. above the proximal end or the

2-mm.-long combined insertion upon the proximal-radial aspect of the radial styloid process, with the more lateral muscle remaining fleshy to the proximal border of the insertion.

The closest analogies to suspensor radialis are to be found in the brachioradialis of the potto, the indri lemur, and the rhesus monkey, with origins in the first as high as the surgical neck of the humerus and in the other two forms almost as high as in the squirrel monkey, as will be discussed in the subsequent section on brachioradialis. But in no other mammal known to the writer is there a muscle at all comparable to suspensor radialis which is separate from brachioradialis, with the exception of the interesting condition of biceps in the gibbon (Hylobates lar), which reveals some structural and perhaps functional similarities to suspensor radialis. "The humeral head . . . was inserted . . . powerfully and fleshily into the substance of the flexor digitorum sublimis going to the fourth and fifth fingers, the fibers of the two muscles being uninterruptedly continuous. Thus the humeral biceps and the superficial digital flexor may act as one continuous, long muscle," which is also connected directly to pectoralis major, latissimus dorsi, and dorsoepitrochlearis, all of which may aid in "tremendous leaps from branch to branch" (Howell and Straus, 1931, pp. 4 and 15-16), although "the leaping forms, Tarsius and Galago, have relatively slight development of [brachioradialis]" (Miller, 1932, p. 21).

Comparative data indicate fairly clearly the probable evolutionary history of suspensor radialis. Unlike the other forms which manifest the tendency toward proximal migration of the origin for brachioradialis, in the ancestor of Saimiri the muscle appears first to have undergone a longitudinal separation into proximal and distal heads. Only the proximal segment migrated -- up the brachium between brachialis and the medial head of triceps until firmer anchorage (less competition for suitable humeral attachment, that is) was secured upon attainment of the distal tip of deltoid. In the final phase, the muscle split again to take better advantage of potential fusion to the tendinous insertions on either side of deltoid.

A rather different consideration is that of the factors promoting such migration and the functional advantages of the present form. As in all primates, brachioradialis is a major flexor of the antebrachium at the elbow-joint (Straus, 1941, p. 41); it is thus especially useful for arboreal climbing -- the primarily non-arboreal baboon manifests a relatively slight development of this muscle, as does man (Miller, 1932, p. 21). The reasons for the high origin of this muscle in the potto, in which a very heavy brachioradialis is combined with a mid-radial insertion and permanent flexure at the elbow, have been discussed by the writer in another recent paper (1965e). Because the squirrel monkey is smaller and relatively slimmer than the potto and indri, geometrical similitude demands less strength, so suspensor radialis has remained slim and has not shifted its insertion. But by its higher origin and somewhat more lateral position than accompanying brachioradialis, the squirrel monkey's suspensor radialis provides not only additional muscular contractile tissue but also a disproportionately large increase in effective muscular force because of its more nearly perpendicular alignment. This improved angularity manifests itself at the most critical point when flexure of the forearm is weakest -- when the forearm is extended and the other flexors in the forearm are more nearly parallel to the antebrachial axis. Furthermore, like brachioradialis, suspensor radialis can continue to operate over the entire range of forearm flexure; but it has some advantage over the more distally arising muscle for, since it is longer, somewhat less relative contraction is required for the same angular flexion, and suspensor radialis remains nearer its optimum length for maximum strength. Interestingly, in this case the dermis at the elbow functions as a superficial "pulley" in place of the more general form of superficial ligamentous (digital flexors) or deep bony (digital extensors) pulleys.

In conclusion, it thus appears that suspensor radialis is quite useful for arboreal locomotion, especially for lifting the body toward an overhead branch when the upper extremity is almost fully extended -- thus the writer's appellation of it, based on function and the location of its insertion. For arboreal climbers, both more proximal and more distal origins for brachioradialis have their respective advantages; seemingly only the squirrel monkey has its cake and eats it too by having developed separate muscles.

The writer would conclude, in agreement with the comparable evaluation of Howell and Straus regarding the "curious and apparently unique specialization of the brachial flexors in the gibbon /which appeared to them/ as a secondary adaptation of purely functional significance . . ." (1931, p. 16), that the phylogenetic significance of suspensor radialis is little or non-existent -- unless it can be discovered in other primates (such as, perhaps, Aotus).

Brachioradialis. This muscle arises as a flattened, fleshy band from the lateral border of the humerus between brachialis and the lateral head of triceps, from 24 to 16 mm. above the distal tip of the lateral epicondyle (Figs. 1-5 and 8-10). With a transverse width of 5.2 mm., it has a maximum thickness of 1.3 mm. at 5 mm. from the origin of the center-line. Fitting into a broad, shallow trough formed by depression of the underlying superficial surfaces of the proximal head of brachialis (the proximal half of which underlies all of the portion of brachioradialis nearest its origin) and, more distally, by depression of the distal head of brachialis, brachioradialis extends down the arm between suspensor radialis and extensor carpi radialis longus; it gradually narrows and thickens to ovoid cross-section 3.2 by 2.2 mm. at the lower end of the elbow, 20 mm. from the origin. In the middle of the antebrachium, it again broadens (to 4.2 mm.), but it thins to maintain expectably almost uniform cross-sectional area. It begins rapidly to narrow below the point at which the tendon of insertion begins to appear on its deep aspect, 18 mm. from the insertion. The fleshy portion of brachioradialis terminates entirely at the point where suspensor radialis fleshily conjoins it -- where the tendon measures 1.0 by 0.3 mm. and maintains approximately constant dimensions to the insertion -- 9 mm. above the 2-mm.-long area of insertion on the radial styloid process.

Brachioradialis in Callimico is very similar to that in Saimiri (Hill, 1959, p. 54), but there is of course nothing in this other South American monkey comparable to suspensor radialis. In Cebus the muscle "extends its origin high up the humerus, but not to the extent met with in Perodicticus" and shows a similar insertion (Hill, 1960, p. 349). In the more primitive Hapalidae, it is "highly developed," from the "highest part of the epicondylar ridge" (Hill, 1957, p. 149).

Miller (1932, p. 21) generalizes that the form of this muscle is in catarrhine monkeys similar to that in platyrrhines, but with relatively greater massiveness. Straus (1941, p. 41) observes that insertion in catarrhines may be carpal or even metacarpal, but may also be as high as the middle of the radius in the gibbon. In the rhesus monkey, it "originates from the lateral epicondylar ridge of the humerus and the adjoining intermuscular septum, extending almost as high as the m. deltoideus [with] insertion . . . to the distal part of the shaft of the radius" (Howell and Straus, 1933, p. 138 and Fig. 43).

Insertion is well above the styloid process in the tarsier, and in the potto and indri the origin is, respectively, as high and almost as high as the surgical neck, and insertion is far above the styloid process in the permanently flexed forelimb (Straus, 1941, pp. 40-41; Hill, 1953, pp. 183 and 535), for reasons discussed by the writer elsewhere (1965e). Although universal to all other primates, brachioradialis is absent in some Tupaioidea (Straus, 1941, p. 40).

More broadly considered still, this muscle is in mammals "an inconstant muscle, being absent in a variety of forms, including insectivores, many rodents, armadillos, come carnivores, hyrax, and most ungulates. Insertion usually is upon the more distal portion of the radius but may extend over onto the carpus, as in the dipodid rodents, some Xenarthra, marsupials, and monotremes, in which two latter groups a radial insertion commonly is absent . . . . These tendencies [indicated in the foregoing data] toward proximal migration of origin and insertion are exactly the reverse of those exhibited by the other superficial antebrachial muscles of dorsal innervation" (Straus, 1941, pp. 40-41).

Extensor carpi radialis longus. Immediately distal to the origin of brachioradialis and on the same intermuscular line, this muscle arises fleshily from 15.5 to 6 mm. above the distal tip of the humerus; the distal end of the origin is also 1 mm. above the proximal border of the lateral epicondyle. Arising both more broadly and more thickly than brachioradialis, the fascicles rapidly converge to narrow to 3.2 mm. and thicken to 3.9 mm. at 7 mm. from the distal end of the origin (Figs. 1-10). It covers near its origin approximately the distal half of the distal head of brachialis; since the extensor constricts away from the origin less rapidly than brachialis underlying it, and also extends somewhat obliquely to the fascicles of brachialis, it covers all of the distal head and a portion of the proximal head of brachialis from the extensor's origin to an area 12 mm. distal to the most proximal portion of the extensor's origin. Since this extensor is proximally thicker than the proximal portion of brachioradialis, the depression in the distal head of brachialis is deeper under longus than under brachioradialis. Closely paralleling and loosely adhering to brachioradialis and extensor carpi radialis brevis on either side, this extensor rapidly alters distally to a form somewhat approaching a quarter-moon cross-sectionally, with the slight concavity on the ulnar (brevis) side. Rather reminiscent of the situation in the chimpanzee, it gradually begins to attenuate immediately upon the fusion of some of the fibers to the moderately heavy tendon of insertion, which extends proximally almost as high as mid-belly, to within 24 mm. of the distal end of the origin near the mid-line of the broad ulnar surface, and across the volar two-thirds of the ulnar surface (in apposition with brevis), 24 mm. from the condylar (distal) end of the origin; here the muscle attains its maximum thickness (breadth if viewed laterally -- that is, from the radial side -- instead of dorsally) of 5.2 mm. and width of 1.8 mm. At 37 mm. from the condylar end of the origin, tendon appears on both sides when viewed laterally, with a breadth from that view of 2.1 mm. and a thickness (belly plus tendon) of only 0.2 mm. At 1.5 mm. more distally, just below mid-forearm, the organ is tendinous throughout, and at 43 mm. distally this tendon of insertion is 1.2 mm. wide (viewed laterally) and roughly 0.15 mm. thick. Beyond this last point, the tendon undergoes only slight further constriction as it runs deep to the single tendon of abductor pollicis longus. At 78 to 80 mm. from the condylar end of the origin, the tendon inserts upon the dorsoradial aspect of the second metacarpal near its base.

A small quantity of comparative data will be considered after the description of the companion muscle.

Extensor carpi radialis brevis. This muscle arises fleshily immediately distal to the origin of longus, from the proximal portion of the radial aspect of the lateral epicondyle of the humerus; this surface of origin is thus perpendicular to the dorsal surface of the antebrachium (Figs. 1, 3, 4, and 8-10). This origin occurs only in a small, thin area, less than 1 mm. wide and some 3.5 mm. long. More weakly developed tendon of origin also extends across most of the surface of the muscle opposite to the surface contacting longus as far as 27 mm. from the origin, thereby explaining the mechanical feasibility of the muscle's rather fusiform shape, which combines the advantages of extreme mobility with relatively great maximal strength when fully extended. The belly of extensor carpi radialis longus is in close contact throughout with the fleshy portion of this muscle, seeming to form a somewhat rectanguloid cross-section "double-muscle" -- but the only very thin fascial attachment of the two to each other is very tenuous, and the two function of course quite differently and separately. The glossy and closely contiguous tendons of insertion largely separating the fleshy portions of the two muscles have aided the fascia as friction-reducing surfaces during independent performance of the muscles. Extensor carpi radialis brevis gradually expands to a maximum thickness of 2.2 mm. (x 5.3 mm.) at 17 mm. from the origin and to a maximum breadth of 5.6 mm. (x 2.0 mm.) at 20 mm. (both viewed from the radial side). This muscle begins gradually to constrict shortly distalward of the proximal end of the fairly thick tendon of insertion, which extends proximally near the mid-line of the broad radial surface to within 16 mm. of the lower end of the muscle's origin and spreads over most of this surface shortly distal to that point. The muscle decreases in transverse dimensions to 1.2 by 3.9 mm. at 37 mm. from the area of origin, the point at which the muscle begins to contact the surface of the radius. The fleshy portion of the muscle terminates at 45 mm. from the origin, slightly less than two-thirds the length of the antebrachium. The tendon very gradually constricts to 1.3 by approximately 0.2 mm. as it passes beneath the tendon of abductor pollicis longus at 55 mm. distal to the area of origin, separated 1 mm. from the tendon of longus, which lies radial to that of brevis. Constricting very slightly further as it traverses the wrist just radial of the mid-line, it inserts upon the dorsoradial aspect of the third metacarpal bone near its base.

There is little that is noteworthy comparatively viewed about the radial extensors of the carpus, consistent with the fact that they are "essentially conservative in Tupaioidea and [other] primates" (Straus, 1941, p. 41). But varying degrees of fusion can occur between longus and brevis in the middle and higher primates. Also, although the pattern reported here is the general one, in many gibbons and a fairly large proportion of humans, longus sends an accessory tendon to the metacarpal of the thumb, or inserts in many humans upon both the second and third metacarpals, as brevis occasionally does too (Straus, 1941, pp. 41-42).

The general division of the radial carpal extensor mass into longus and brevis is most marked in primates, rodents, carnivores, and marsupials. Origin and insertion in other mammals are generally fairly similar to those in primates, and in all the tendons pass deep to that of abductor pollicis longus (Straus, 1941, p. 41).

Extensor digitorum communis. This fusiform superficial flexor of the three central digits is the sole thoroughly bipennate muscle of this antebrachium (Figs. 8-10). It arises tendinously in common with extensor digiti quinti proprius adjacent to extensor carpi radialis brevis from the radial and distal aspects of the lateral (radial) epicondyle of the humerus. With a maximum width of 1.6 mm., the tendinous origin of the muscle extends some 2.5 mm. along the radial surface of the epicondyle, primarily on the radial and partially on the dorsal aspects of the epicondyle's middle and distal portions, immediately dorsoulnar to and mostly immediately distal to the origin of brevis. Fairly thin tendinous fascia extends superficially from the epicondyle to the dorsal surface of the proximal portion of the ulna, extending distally some 8 mm. below the humerus over this extensor and slightly less over the ulnar extensor; this fascia is intimately attached to the common tendon of origin here considered and is continuous with a thin but tendinous sheath quite completely encasing the two fused digital extensors (communis and quinti proprius) for approximately 12 mm. below the epicondyle.

The fleshy portion of the muscle begins immediately below the origin, where it is 1.6 mm. wide by 1.0 mm. thick, with gradual enlargement of the cross-sectionally almost round proximal portion of the muscle to 1.7 by 1.6 mm. at 6 mm. below the epicondyle, where the extensor of digit V branches off. The muscle becomes progressively more flattened distal to this last point, attaining maximum cross-sectional area at 20 mm. below the area of origin on the humerus, with dimensions of 4.8 by 1.8 mm., thicker near the radial border. Tendon clearly extends beneath the surface proximal to the cross-sectional maximum point, but it does not appear superficially above 2 mm. distal to this point (where it is very slightly radial of the mid-line), or on the deep surface until just above the distal end of the belly. The tendon broadens as it extends distally, with gradual attenuation of the belly to 43 mm. ulnarly and 46 mm. radially below the humerus; the latter point of fleshy termination is 20 mm. above the distal tip of the radius.

At 47 mm. below the humerus, the tendon is oval in cross-section, some 0.8 mm. wide by 0.6 mm. thick. This tendon of insertion remains cross-sectionally equivalent, broadening but thinning as it extends distally across the wrist very slightly ulnar to the mid-line. At the base of the metacarpals, it gives off a round branch which broadens and thins to 1.2 by perhaps 0.2 mm. just before inserting upon the ulnar half of the dorsal surface of the distal end of metacarpal II and the adjacent joint capsule. The remainder of the tendon of insertion undergoes comparable broadening, but it does not split until the distal third of the metacarpal zone, where the two tendons attain maximum widths of 1.3 and 1.6 mm. just before inserting upon the joint capsules of III (slightly to the ulnar side of the joint's mid-line) and IV (on the radial three-fifths of the dorsal surface), very slightly distal to the insertion of II.

In Callimico, extensor digitorum communis is fairly similar but is apparently not so markedly bipennate and gives rise to tendons to all four ulnar digits (Hill, 1959, p. 54). This muscle in Saimiri is more similar to its condition in man (bipennate and frequently inserting only upon the three middle digits) than in Callicebus or the most primitive platyrrhines, the Hapalidae, in which insertion is upon all five digits (Hill, 1957, p. 149).

Compared more broadly, this muscle, having extended its insertions from the manus proper into the digits, is characteristic of mammals, in most of which it arises from the radial epicondyle (as in all primates except the potto and some apes). "Insertion regularly is upon digits II-V in all primate forms except Perodicticus," in which the tendon to II is absent; however, the tendon to V is frequently missing in the chimpanzee -- 4 of 14 -- and in man -- 27 per cent of Chinese (Straus, 1941, p. 45). So at least this one feature of Saimiri, if not an individual anomaly, might be regarded as a progressive trait, correlated with the possible "tendency in some primate groups for ext. dig. V proprius to concentrate upon and consequently to assume control of the fifth digit" (Straus, 1941, p. 46). However, the somewhat more proximal insertions of Saimiri nearer their metacarpal base positions in reptiles, should also be considered.

Extensor digiti quinti proprius (extensor digiti minimi). Arising in common with the extensor of the middle digits and extending down the forearm along the latter's ulnar side, this very slender, fusiform muscle remains entirely tendinous to 8 mm. below the humerus (2 mm. from its separation), where its tendon is only 0.9 by 0.6 mm. (Figs. 8-10). On the ulnar surface, distally tendon fades rapidly, but it continues across the entire radial surface to 23 mm. below the epicondyle. Maximum dimensions of 1.3 mm. wide by 1.8 mm. thick are attained at 22 mm., the point where a thin tendon on the ulnar surface begins its thread-like course to the muscle's dorsal superficial surface, reached 37 mm. below the humerus. The fleshy portion extends an additional 15 mm. on the deep aspect, to 13 mm. above the tip of the ulna. The tendon, with a mid-line of cleavage and dimensions of 0.7 by roughly 0.1 mm., passes through a ligamentous tunnel on the radial side of the ulnar styloid process and a few millimeters more distally undergoes bifurcation, with one of the equal branches inserting upon the dorso-ulnar aspect of the fourth metacarpal-phalangeal joint capsule, while the other inserts upon the same aspect of the fifth joint capsule. This muscle thus acts as an adductor of the hand as well as an extensor.

Extensor digiti quinti proprius is very similar in both Callimico and the Hapalidae to its form in Saimiri, but at least in Callimico the tendon of insertion to the fourth digit fuses to that of the common extensor to the same digit (Hill, 1959, p. 54; Hill, 1957, p. 149). In Cebus the muscle is only distally separate from the common extensor (Hill, 1960, p. 349). Nevertheless, this muscle is "practically constant" in Tarsius and all higher primates (Hill, 1955, p. 41). In strepsirhines its tendon joins that of the common extensor to the fifth digit (Hill, 1953, p. 65).

This muscle in most mammals appears to be derived from the premammalian extensor humero-ulnaris or the extensor humero-dorsalis, or possibly both (Straus, 1941, p. 47).

Extensor carpi ulnaris. This muscle is thin and flat (3.2 by 0.6 mm.) near its origin, tendinously from the distal-ulnar aspect of the lateral epicondyle, mainly fleshily from the ligament between the epicondyle and the proximal end of the ulna, and by very thin tendon from the ulna, 10 to 15 mm. distal to the ulna's proximal tip (Figs. 8-10). Superficial tendon of condylar origin extends across the radial 2.2 mm. of the muscle at its proximal end; it gradually narrows as it extends distally, obliquely crossing the superficial surface to the ulnar border of the muscle and terminating on that border 27 mm. from the humerus.

The muscle gradually narrows and thickens distally, achieving maximum cross-sectional area 20 mm. below the humerus, with dimensions of 2.9 by 1.8 mm.

The tendon of insertion occurs almost throughout only on the deep surface of the fleshy portion. It begins as a thin ribbon 19 mm. below the humerus and broadens to 1.9 mm. at 23 mm.; distal to the latter point of greatest breadth, it narrows -- to 1.3 mm. where it appears superficially at 41 mm. below the epicondyle -- but thickens as the muscle narrows and the force of additional fascicles accumulates. The fleshy portion extends down the mid-line to 47 mm. below the epicondyle, where the tendon is 1.1 by 0.2 mm. It narrows further to 0.8 mm. before broadening to 1.2 mm. as it passes over the ulnar styloid process to insert upon the ulnar (medial) aspect of the fifth metacarpal bone near its base.

Unlike the muscle in the present specimen, extensor carpi ulnaris of Callimico arises by two heads, from the epicondyle and the olecranon (Hill, 1959, p. 54). The present specimen manifests a somewhat intermediate condition between that condition and the origin in many primates (and other mammals) from the epicondyle alone. The insertion at the base of the fifth metacarpal is common to all primates and to many other mammals (Straus, 1941, p. 48).

D. Deep Dorsal Muscles

Most of the deep muscles of the forearm's extensor surface appear to have evolved through migration of origins up from the hand, just as the superficial muscles have migrated distally (Straus, 1941).

Anconeus. This muscle is apparently represented by a few very short fibers between the area of the lateral epicondyle and the olecranon, but it is not sharply distinguishable.

It is poorly (though better) developed in Callimico (Hill, 1959, p. 55).

Supinator. This fairly thick, triangular muscle, U-shaped in cross-section, arises from the lateral epicondyle, the orbicular ligament of the radius (immediately deep to the origin of extensor carpi ulnaris), and from a small area of the dorsoradial aspect of the ulna just above to slightly below the distal tip of the humerus, 10 to 15 mm. distal to the proximal end of the olecranon (Figs. 9 and 10). Dorsally, it is 6.5 mm. wide immediately below its origin; but it also wraps around the lateral (radial) surface of the radius both at the muscle's origin and more distally, and at its proximal end it is 3.9 mm. wide on this radial aspect almost perpendicular to the first. Glistening superficial tendon of origin extends across both dorsal and radial surfaces proximally except for the ulnar two-thirds (4.3 mm.) of the dorsal surface; this tendon extends 27 mm. below the humerus, almost to the distalmost limit of the muscle. Insertion occurs over almost the entire dorsal, radial (lateral), and volar surfaces of the proximal portion of the radius. On the volar surface, it extends to (and to some extent fuses to) the tendon of insertion of biceps. The dorsal line and the radial-volar line of distal muscle termination converge obliquely on the dorsolateral aspect of the radius fully 30 mm. distal to the humerus and some 31 mm. from the proximal end of the 66-mm.-long radius; thus the muscle extends almost half the length of the bone. Consistent with its great length, the superficial tendon fibers parallel the shaft of the radius, as do the muscle fibers ulnar from the tendon on the dorsal surface; marked obliquity is encountered in the volar fibers, however. Maximum thickness of 2.5 mm. above the radius occurs near the origin on the dorsal surface.

The form of supinator in Saimiri, markedly atypical for primates, is approached in Callimico, in which longitudinal fibers are also unusually numerous and the muscle extends down the upper third of the radius (Hill, 1959, p. 55). Its robusticity in Saimiri is likely even exceeded in another platyrrhine, Cebus (Hill, 1960, p. 349), in which its origin also spreads to the proximal part of the ulna, as in catarrhines, and insertion extends to the middle of the radial shaft, as in the present specimen.

Abductor pollicis longus (extensor ossis metacarpi pollicis). This broad, thick muscle manifests a very extensive fleshy origin from the dorsoradial quadrant of the ulna from 8 to 26 mm. beyond the proximal end of that bone, and from the interosseus membrane (which extends almost as high as the point at which supinator traverses the interosseus cavity) over almost the entire surface of that fairly thick membrane from its anterior end 24 mm. below the tip of the olecranon to its distal end 47 mm. beyond the olecranon tip ulnarly and some 10 mm. farther radially, where the membrane extends obliquely down the radius along the deep surface of the abductor, largely functioning as this muscle's tendon of origin. Extensive but thinner fleshy origin also occurs from the ulnar half of the dorsal surface of the radius along the termination-border of supinator and slightly beyond, from 15 to 40 mm. below the distal tip of the lateral epicondyle. The muscle at 18 mm. below the humerus is 5.5 mm. wide, 1.9 mm. of which is assignable to the thinner radial portion. At mid-belly, the breadth is 6.2 mm. (of which 2.2 mm. is attached to the radius). Radially from the central tendon, the belly ends at the distalmost tip of the radial origin. On the ulnar side, the fleshy portion extends 11 mm. farther, 1 mm. short of contacting the tendon of flexor carpi radialis brevis as the latter passes beneath the abductor's tendon. Somewhat unexpectedly, since the muscle is not truly bipennate but reveals fascicles exclusively almost parallel to the major axis, a broad, central, superficial tendon begins only 17 mm. below the humerus. It reaches its maximum breadth of 2.7 mm. at 30 mm. distal to the humerus, where it covers most of the ulnar but none of the radial portion of the muscle. At 40 mm. its location is again quite central. At the point the belly terminates, the tendon is the heaviest of the dorsal surface of the forearm -- 1.9 by approximately 0.3 mm. It constricts only slightly as it crosses the radial styloid process as a single tendon -- unlike the double-tendoned chimpanzee muscle, if the interpretations and associated terminology of Straus (1941, p. 208) are followed -- to insert upon the volar half of the radial aspect of the proximal end of the first metacarpal bone.

The abductor of Callimico is very similar, although it lacks a radial origin (Hill, 1959, p. 55). More similar in its massive, broad origin is the muscle in Cebus, with origin from the membrane, the proximal two-fifths of the ulna, and the second fourth of the radius. However, insertion is by two tendons, to the trapezium and to the base of the first metacarpal; the Hapalidae also exhibit two tendons (Hill, 1960, pp. 349-350).

Extensor pollicis et indicis longus (extensor pollicis longus). Arising fleshily deep to extensor carpi ulnaris from the dorsoradial aspect of the ulna immediately distal to abductor pollicis longus, from 26.5 to 40 mm. below the proximal end of that bone, as well as from a small, distal portion of the ulnar side of the interosseus membrane, this very long, slim muscle manifests tendon of insertion only 4 mm. distal to its most distal area of origin (Figs. 8-10). Extending gradually toward the radial side of the antebrachium as it proceeds distally alongside and at the same depth as abductor pollicis longus, it is fused to extensor digitorum profundus along the upper two-thirds of its belly's ulnar aspect, but only along approximately the deepest 35 per cent of the adjoining surfaces; more distally, the fusion is proportionately more extensive but less intensive. The fleshy portion terminates 32 mm. from the proximal tip, measured along the muscle, which is some 16 mm. above the tip of the radius.

The transverse breadth of the muscle at the distal end of its origin is 1.8 mm., while its thickness is 1.4 mm., cross-sectionally of oval outline flattened on the deep surface. The muscle maintains quite constant dimensions for the short distance to the start of the insertion tendon, but below that point begins very slowly to attenuate. From only 2 mm. below its point of appearance, the tendon maintains a constant width of 0.5 mm. and thickness of roughly 0.1 mm. to the wrist area, but there it narrows to 0.25 mm. and does not subsequently enlarge appreciably.

Immediately to the ulnar side of the muscle's insertion tendon but some 10 mm. distal to the tendon's proximal end (measured along the muscle) arises a second, much narrower (only 0.15 to 0.2 mm.) tendon in the muscle mass of the first; this tendon arises in the distal belly area where differentiation from extensor digitorum profundus is far less marked. The two tendons proceed adjacently into the wrist just to the ulnar side of the radius and deep to the tendon of extensor digitorum communis. Separation occurs just distal to the wrist; the longer tendon inserts narrowly upon the base of the thumb just ulnar to its mid-line, and the shorter tendon does so just radial from the mid-line of the index finger, where it fans out into a very thin membranous slip which is superficial to the similar (but somewhat heavier) termination of the common extensor at that locus.

Some comparative anatomical data for this muscle will be considered after the description of extensor digitorum profundus.

Extensor digitorum profundus. From the dorsoradial aspect of the ulna deep to extensor carpi ulnaris and immediately distal to the deep extensor of the thumb and index finger (and at the same depth), from 40.5 to 68.5 mm. distal to the proximal end of the ulna, extending to within 9 mm. of the ulna's distal end, arises this broader, quite surely stronger, cross-sectionally rectanguloid, parallel muscle (Figs. 8-10). The muscle is transversely broadest (4.0 mm.) just above the distalmost portion of the origin; at this broadest point, it is 0.8 to 1.0 mm. thick, a thickness maintained quite uniformly almost throughout the fleshy portion. On the radial border, a superficial tendon appears 7 mm. above this most distal point of origin, while, successively more ulnar, two similar tendons appear at 0.5 and 2 mm. below the distal tip of the origin. The belly extends along the ulnar border and deeply to some 1.5 mm. above the distal end of the ulna.

As the three tendons (among which the most ulnar is roughly 0.5 mm. wide, the others 0.4 mm.) begin to cross into the wrist immediately adjacent to the index tendon on one side and the ulna on the other, all three fuse to one another. Shortly above the insertions, the broad (4.0 mm.), thin combined tendon undergoes incipient bifurcation. The radial portion, presumably representing the two more radial tendons nearer the wrist, inserts broadly (1.6 mm.) at the end of the third metacarpal, immediately deep to the superficial extensor's insertion of similar breadth and location. The ulnar division, maintaining partial fusion with the other, inserts broadly across the entire distal end of the fourth metacarpal bone.

The deep extensors of Callimico are fairly similar to the two muscles described here; but contrastingly the two bellies in Callimico arise "along a strip dorsal to the origin of the ulnar head of the abductor pollicis longus," both "give rise to tendon just above the wrist," and the proximal belly is larger and supplies the first three digits with tendons, while the shorter distal muscle supplies the third and fourth (Hill, 1959, p. 55).

Apparently slightly more similar to the situation in Saimiri is that in the Hapalidae, in which an extensor indicis arises from the proximal two-thirds of the ulna. A radial tendon terminates upon the first two digits, while the other, from the ulnar side, extends to the third (Hill, 1957, p. 150). The same general pattern of insertions of the two muscles as that occurring in the present specimen "may occur in Alouatta and commonly in Callithrix" (Straus, 1941, p. 213).

Among tarsiers and the vast majority of platyrrhines, the longer extensor typically extends to the first two digits, as in the present specimen. In all other primates, a specialized extensor pollicis longus and a second extensor to additional digits is the rule, although the tarsier-platyrrhine pattern apparently occurs with moderate frequency in individual gorillas and humans (Straus, 1941, pp. 210-211). For example, in the primitive strepsirhine primates, the proximal part of extensor digitorum profundus inserts upon the pollex, while the distal part extends to the next two or three (in rare individuals, four) digits (Hill, 1953, p. 66).

Interestingly, among the fourteen deep extensor patterns for Didelphis (opossum) and fourteen primate species for which Straus (1941, Fig. 19) has provided diagrams, none conform to the present specimen.

5. DISCUSSION

When the musculature of the present specimen of Saimiri is compared to the anatomically better-known chimpanzee and man, the present writer notes two most striking contrasts: first, the majority of the muscles are decidedly slimmer proportionately in the monkey; second, the vast majority of the monkey's muscles exhibit fiber alignment almost perfectly parallel to the main axis of the muscle, while a large proportion of the muscles in the other forms are pennate. It would seem that there must be one or more basic factors underlying such striking and consistent contrasts.

The fundamental explanation for both phenomena becomes readily apparent when principles of geometrical similitude are considered intensively (Edwards, 1963c). These mechanical principles have already been considered for general bodily form and function of some primates (Edwards, 1963f), and for the specific size and form of certain muscles in primates (Edwards, 1965e); therefore, only the general interpretations relevant to the present observations will be given here. In proportion to body-weight -- which involves gravitational force resisting support and movement -- larger primates are weaker primates, which must thus make some adaptations to compensate in part for the greater weakness.

One adaptation in larger primates, such as chimpanzees and humans, is the development of relatively heavier musculature, for other factors being equivalent, strength is proportionate to cross-sectional muscle area. But increased thickness cannot alone compensate for the increased needs of most muscles in much larger primates, for muscle mass must increase by much more than the fourth power of increasing muscle length to maintain equivalent function in geometrically similar primates.

Because of the limitations on increased thickness, such expedients as obliquity of muscle fascicles in pennate muscles are utilized as additional partial compensations where mobility is less significant than strength. For example, the exceptional case of extensor digitorum communis of the squirrel monkey may be considered. This is the only true bipennate muscle of the squirrel monkey forearm; even this muscle is far from typically bipennate, for there are no significant areas of attachment below the proximal origin, so the fascicles are nearly parallel. The bipennate form here encountered is one means by which a muscle can assume an approximately fusiform shape, which enables muscles to have relatively high maximal force when extended while achieving high mobility -- though with much less force in the latter part of the full range of contraction. Since high mobility is not required for this muscle, the belly is concentrated in the upper half of the antebrachium with fairly large cross-sectional area for strength; on the other hand, additional strength through accessory origins and marked obliquity of bipennate muscle fibers is unnecessary in Saimiri because of its small size and thus relatively great strength without such adaptations.

It may also be observed that all forms of selective pressure related to strength become greater in larger animals, as theoretical and actual "tolerances" decline. The writer hopes to test the strength of squirrel monkeys in the fairly near future. When this is done, it seems quite certain that, contrary to the findings for the chimpanzee with its superior strength (Edwards, 1965g), the squirrel monkey or other small primate will manifest much greater strength per unit of body-weight, but appreciably less strength even than in humans per unit of cross-sectional muscle area. It appears likely that such inferiority of the monkey scores will be maintained even after adjustment has been made for such structural factors as fascicle obliquity. Despite the demands of arboreality, these monkeys have been less subject to high selective pressure for maximum structural and functional efficiency of muscles than larger primates, likely including culture-protected man, at least for the ancestrally more consistently active and generally functionally more crucial lower extremities of man.

It might also be hoped that the foregoing studies might shed a little further light on a very different type of problem -- the phylogeny of Saimiri and its relatives.

Hill (1960, p. 251) observes that "Saimiri . . . has been differently treated by almost every writer on the Primates," and proceeds to cite some of the contrasting taxonomic interpretations. Weber and Pocock aligned it with Cebus, a classification which Hill follows but with marked uncertainty, assigning the two genera as the sole occupants of the subfamily Cebinae (1960, pp. 250-251). There is not even agreement as to whether Saimiri is very primitive (many writers) or highly "specialized" (Hill, 1959, pp. 109 and 110). But by different writers the term "specialized" receives widely varying usage anyway, ranging from aberrantly adapted (usually with losses of parts) for an atypical (and generally narrow) habitat and/or ecologic niche (the usage the present writer would prefer), to markedly changed relative to phylogenetic cousins, to merely at variance with an often quite arbitrarily chosen standard type.

As implicit in the foregoing comparisons, the anticipated close similarities between the squirrel monkey and its presumed closest platyrrhine relatives do not obtain. Apparently the musculature of the thorax and pectoral limb is as similar to that of Saimiri in the primitive marmosets as in the American monkeys, and just as similar in the tarsier, considered by a large proportion of taxonomists to be less closely related to Saimiri phylogenetically than is man.

In fact, comparisons further afield yield even less anticipated results. The forearm flexors of the strepsirhines reveal no fundamental contrasts for pronator teres, flexor digitorum sublimis (which has a tendinous connection with the deep flexors), flexor carpi ulnaris, or pronator quadratus. The deep flexors of the lower primates manifest fewer differences than those of most of the platyrrhines compared (Hill, 1953, p. 64). On the other hand, flexor carpi radialis contrasts in insertion (although not in origin), as does palmaris longus by being present in strepsirhines and suspensor radialis by being absent, but these contrasts with strepsirhines also occur between Saimiri and almost every other species of the New World primates.

In assessing the comparative data, there must also be considered the brachial musculature, with its aberrant near-absence of coracobrachialis (with only a minute slip across the shoulder-joint and a larger slip inserting upon biceps) and its primitive longitudinal separation of brachialis into two heads.

For contrasts with other species and for interesting analyses of form and function, suspensor radialis seems to be the most notable feature encountered in this Saimiri subject, and it has accordingly been considered extensively. However, as discussed, its very uniqueness sharply reduces the phylogenetic significance of suspensor radialis, quite possibly a relatively recent "specialized" adaptation.

The muscle which may hold the greatest phylogenetic significance is flexor carpi radialis. Thus it will next be given intensive consideration, in part as a study in method applicable to some of the other unusually primitive (conservative) traits noted, such as the separation of brachialis.

It would be simplest to dismiss the insertion of flexor carpi radialis in the present squirrel monkey subject as an individual anomaly, but the extremeness and highly specific nature of this divergence from other forms militate against such an interpretation.

It seems more probable, therefore, that the odd insertion is characteristic of Saimiri. Yet much more primitive primates, such as lemurs and even Tupaia already manifest the general mammalian condition of inserting upon the metacarpals. Thus, although significant in respect to its characterizing Saimiri, it apparently lacks the significance of representing survival from an early primate ancestor, and represents instead a 'chance" evolutionary regression (Straus, 1942, p. 312).

The presumed functional reason for the assumed evolutionary retrogression can at present be no more than hinted at by the writer. "In some respects the primitive mammalian form is as evident [in the Cebidae] as in the hands of the Callithrichidae [the most primitive platyrrhines]. Thus in the Cebidae the first digit branches off, as a rule, very close to the base of the index finger, and is but slightly differentiated from the other digits" (Midlo, 1934, p. 356). Not only does Saimiri retain the primitive 3-4-2-5-1 digital length formula -- also retained in the great apes and man (Midlo, 1934, pp. 348-349) -- but also the non-specialization of the thumb is indicated by the deep extensor, which simultaneously operates the first two digits (Straus, 1941, p. 211). This non-specialization is evident in Midlo's Saimiri (Fig. 12, p. 358) and in some of the illustrations for the present paper; on the present specimen, the "free length" measurements, by Midlo's methods (1934, pp. 343-345), are as follows: I., 12.0 mm.; II., 19.0 mm.; III., 21.8 mm.; IV., 21.5 mm.; V., 16.7 mm.

Yet it should also be considered that since some reptiles exhibit the same "advanced" form while some mammals lack it, as noted, it seems that here may be represented a relatively recent ongoing evolutionary trend "in the superficial series toward distal displacement. This is particularly evident in the marginal sectors . . . ." (Straus, 1942, p. 312). So perhaps an unaltered survival of a more primitive condition is represented, after all.

According to the unaltered survival hypothesis, the present writer interpretation that all neotropical primates are most likely descended from a single invasion of South America by a few members of a single species of island-hoppers from North America (Edwards, 1961) is probably incorrect. Instead, if the muscle has survived unaltered in insertion, American primates are more likely descended from three forms which had had a long period of evolutionary isolation in North America, independently descended from pre-tarsioid or tarsioid forms with the carpal attachment. By parallel evolution, two of the branches developed the more distal insertion, but the third remained more conservative in this respect and reached South America first. Before there had been much time for its adaptive radiation, the other two forms arrived in rapid succession and, with one or more advantageous characteristics, quickly filled the remaining arboreal primate niches. But Saimiri could not be displaced from its original niche as a result of its prior adaptation to it, because it too (as compared with its in some respects more "progressive" competitors) had some compensating features of value, such as its organization into large societies (Sanderson, 1957, pp. 76-77), and because of its large numbers with resultingly more frequent appearance of advantageous mutations, and greater likelihood of their permanent incorporation into the more heterozygous gene pool (Li, 1955).

Thus the squirrel monkey, by this last hypothesis, is sharply distinct (much more so than has been recognized) from both the marmosets and their relatives on the one hand, and the neotropical monkeys on the other; the latter are especially resembled in many respects, but largely by parallel evolution to similar environments and ecologic niches since ancestral divergence occurred in North America. By similar parallel evolution (based on a broadly applicable potential advantage), the more distal insertion of flexor carpi radialis developed in an early strepsirhine (after the ancestor of Saimiri had diverged from it) ancestral to extant strepsirhines, tarsiers, and catarrhines, developed in an early primate similar to and ancestral to Tupaia, and (after the ancestral primate had diverged from it) developed in the insectivore common ancestor of all or almost all non-primate placentals. Parallel developments also occurred in one or more phylogenetic lines leading to most modern marsupials and in several reptilian lines.

The foregoing hypothesis may seem too much to build from a single brick, but it cannot presently be ruled out, however less probable it may appear. Methodologically, it exemplifies the possibility that interpretations based on the assumption that an atypical characteristic in a taxonomic group must necessarily represent a secondary development -- even if the predominant feature is also much more frequent in less closely related groups -- may be fallacious. To the present writer, it seems probable that for many groups -- not only the primates but especially those groups in which form tends even more to be determined by relatively uniform function -- the role of parallel evolution to similar form and similar function or size (as dictated by geometrical similitude) has generally been markedly underrated. However, in the case here considered, the necessity of postulating many seemingly improbable independent sequences of identical transition in the insertion of flexor carpi radialis must be emphasized.

The comparative anatomical data considered in this paper do not show that squirrel monkeys are more closely related to tarsiers or lemurs than to their South American relatives, however. They do seem to emphasize the very conservative nature of Saimiri, and the likelihood that its forelimb has retained its primitivity atypically in comparison with the rest of the body.

A little more specifically, no close relationships seem reflected in the comparisons given in this paper. Therefore, the present writer would suggest that Saimiri be allocated to a separate group, presumably at the subfamily level, until substantial grounds for its closer affiliation with other forms are discovered.

In closing, Hill's statement that "no complete account of the musculature of any genus of Cebidae has been published" (1960, p. 23) may be noted. The primitive nature in many respects of Saimiri further underscores its research significance. But the possibility that many of the very unusual characteristics noted in the present specimen may be mere individual anomalies cannot be ignored. The regular features -- and the anomalies -- of Saimiri can only be determined by careful study of a series of Saimiri specimens; regions other than the thorax and upper extremities should also receive attention.

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APPENDIX

Figures 1 through 10

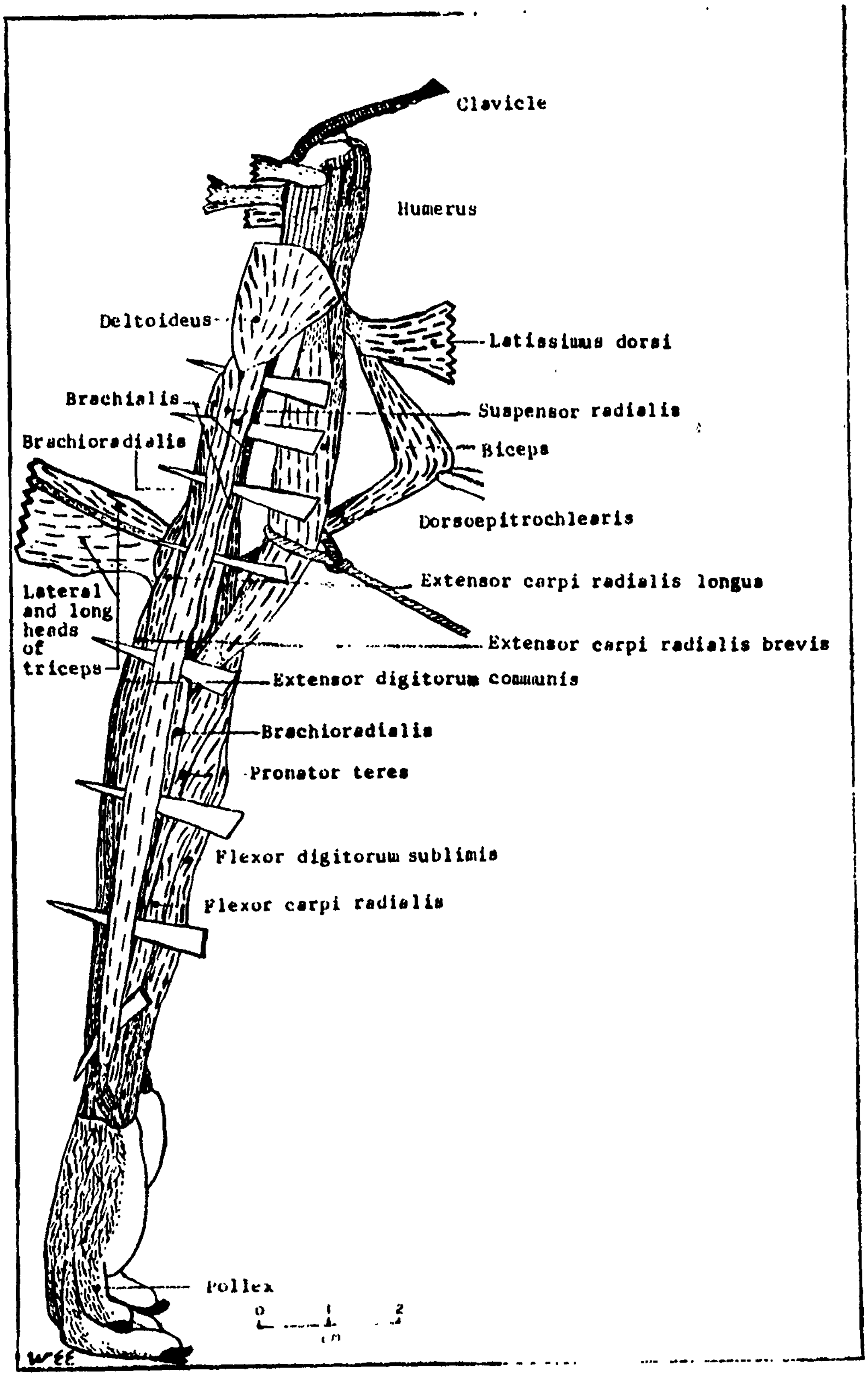

Figure 1

Lateral View of Musculature of Right Upper Extremity With Portions of Brachial Muscles Removed or 'splaced

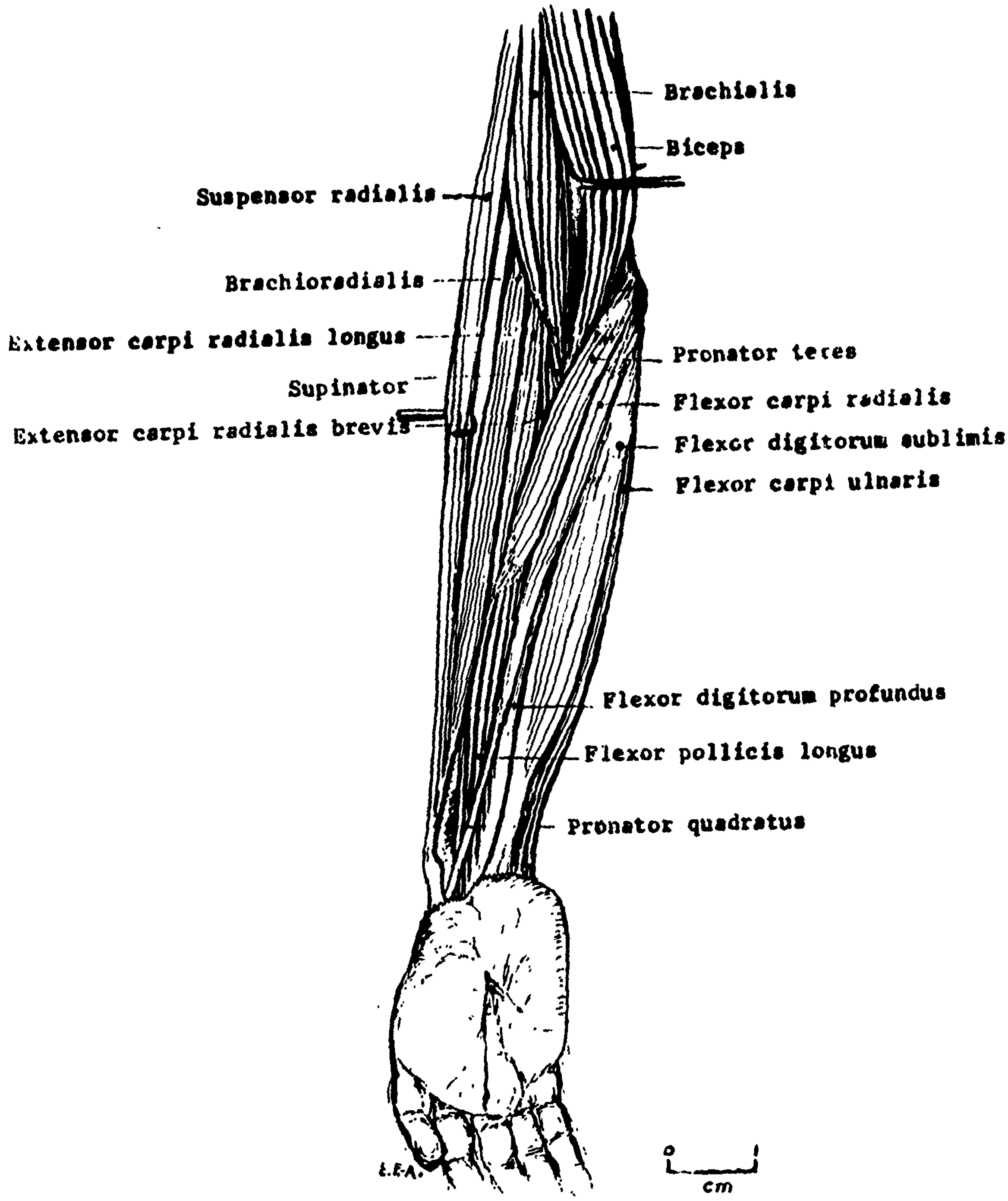

Figure 2

Flexor (Volar) Surface of Right Antebrachium and Distal Half of Brachium With Dermis Removed

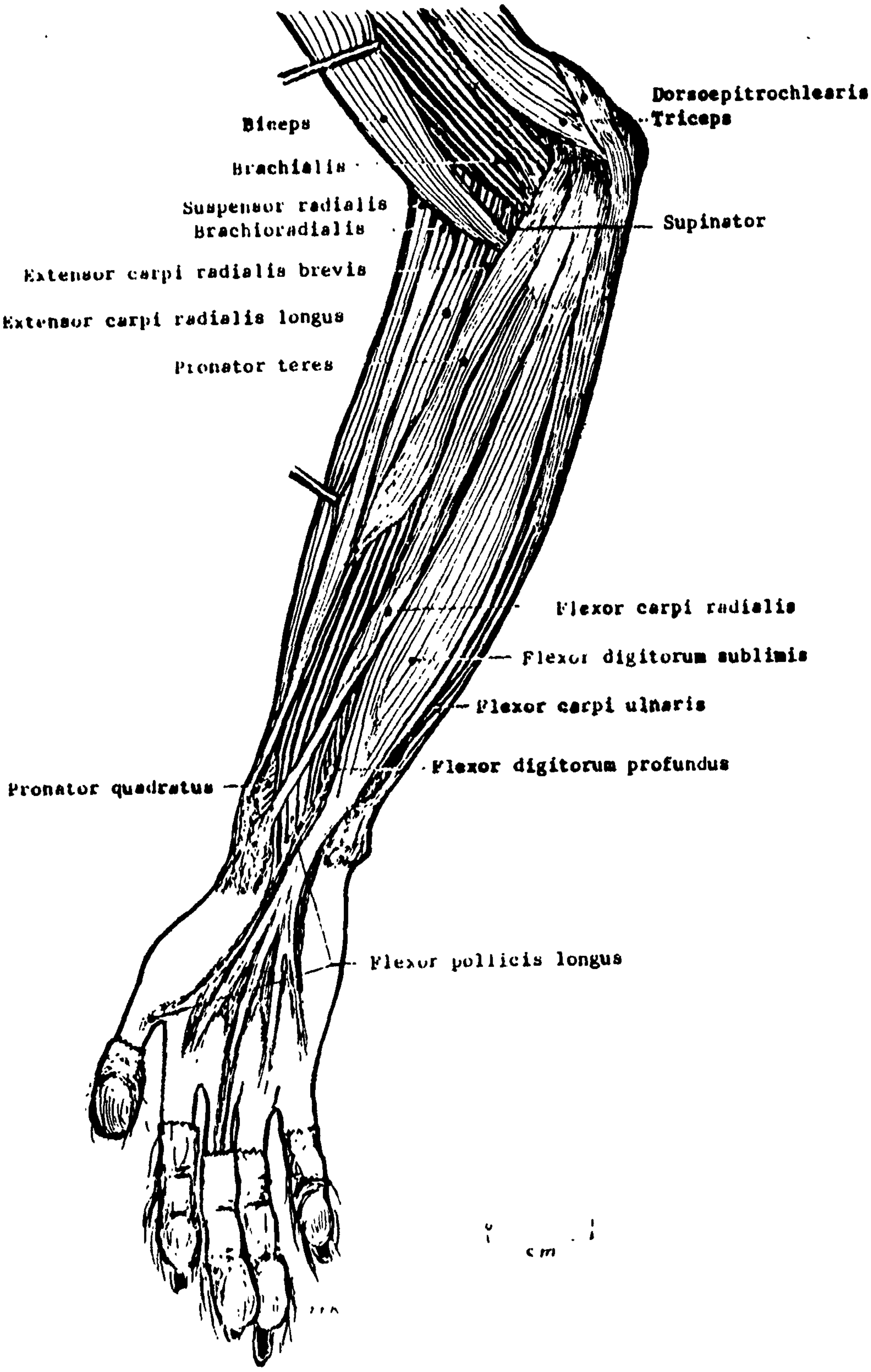

Figure 5

Flexor Surface of Antebrachium and Palm, with Dermis Removed

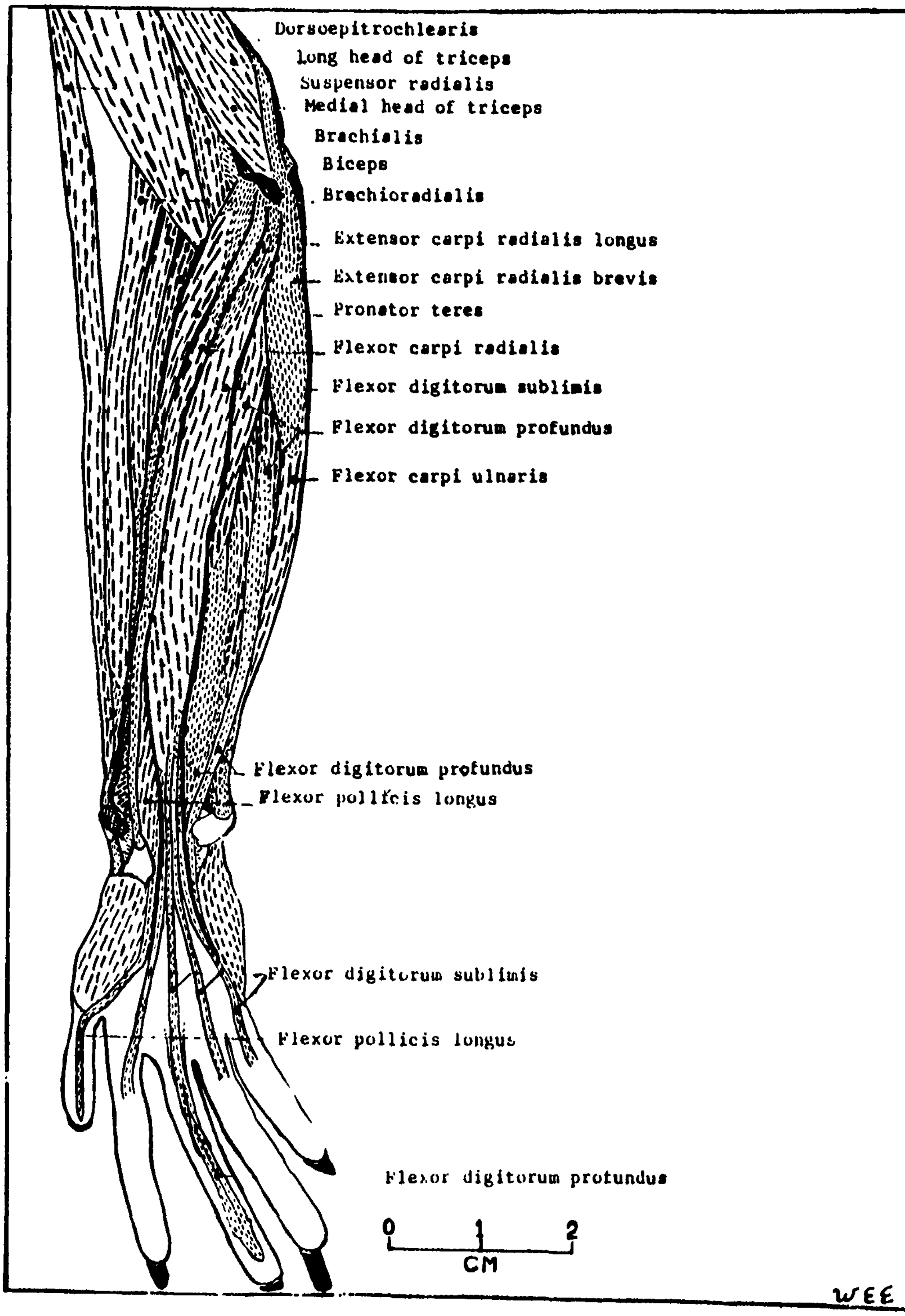

Figure 4

Flexor Surface of Antebrachium and Manus, with Dermis Removed

Note the tendons to the digits, including the relationship of the tendons to III. Flexor digitorum sublimis has been somewhat displaced radially to expose a portion of Flexor digitorum profundus.

Suspensor radialis is in assumed approximate position upon contraction.

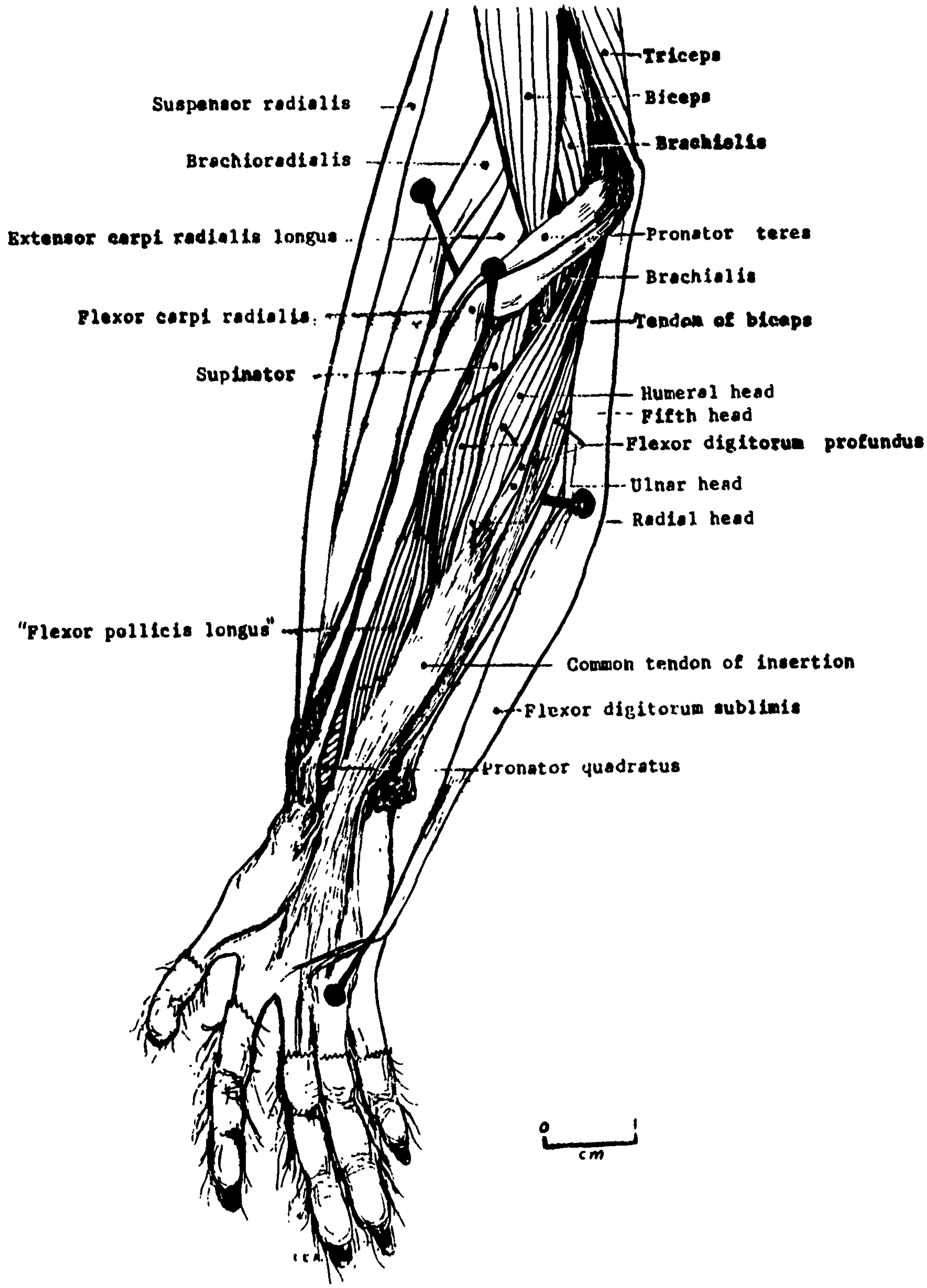

Figure 5

Anterior View of Antebrachium
With Superficial Flexors Displaced to Expose Deep Flexors

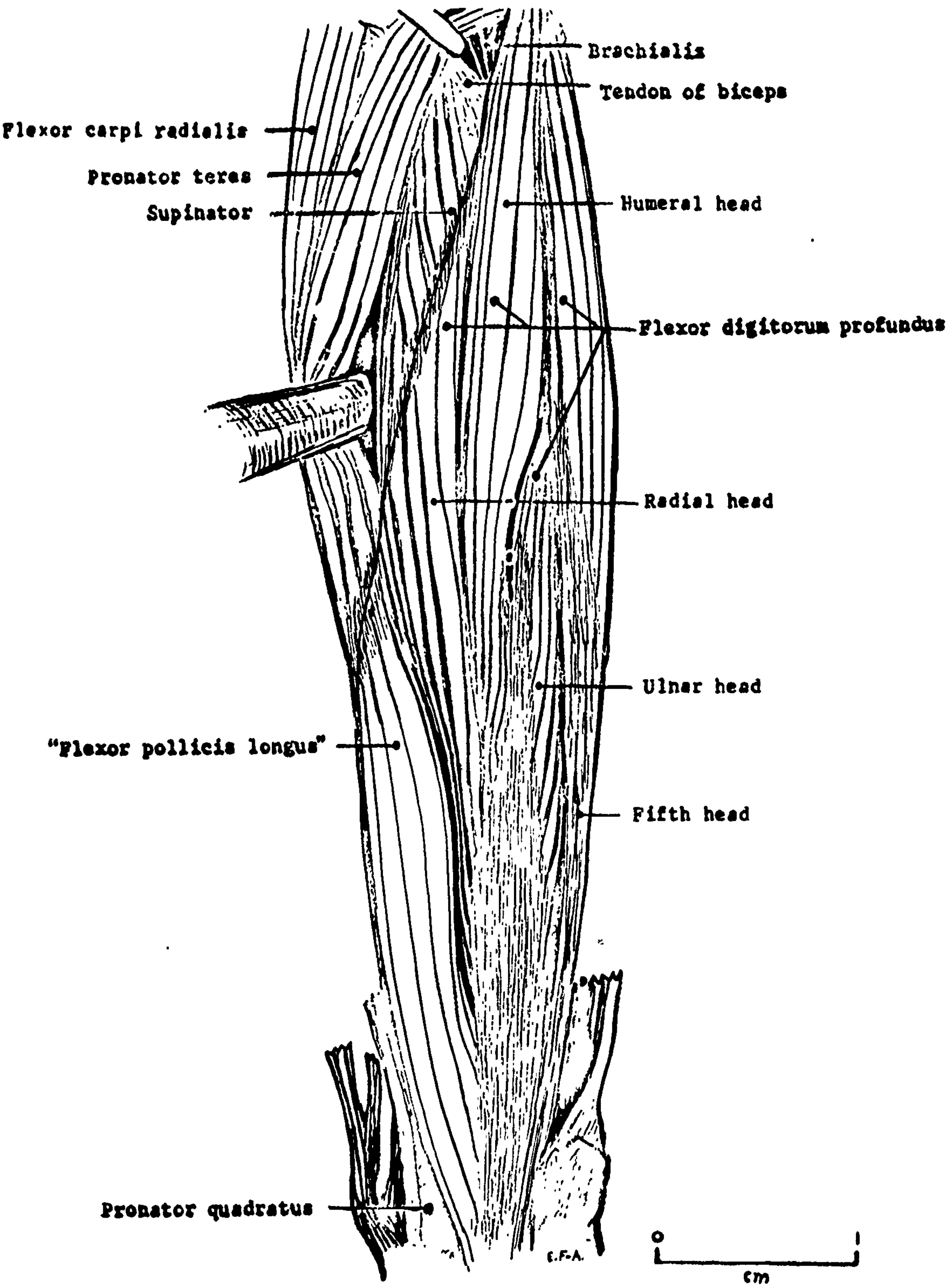

Figure 6

Anterior View of Deep Flexor Layer of Right Antebrachium
With Most Superficial Flexors Removed

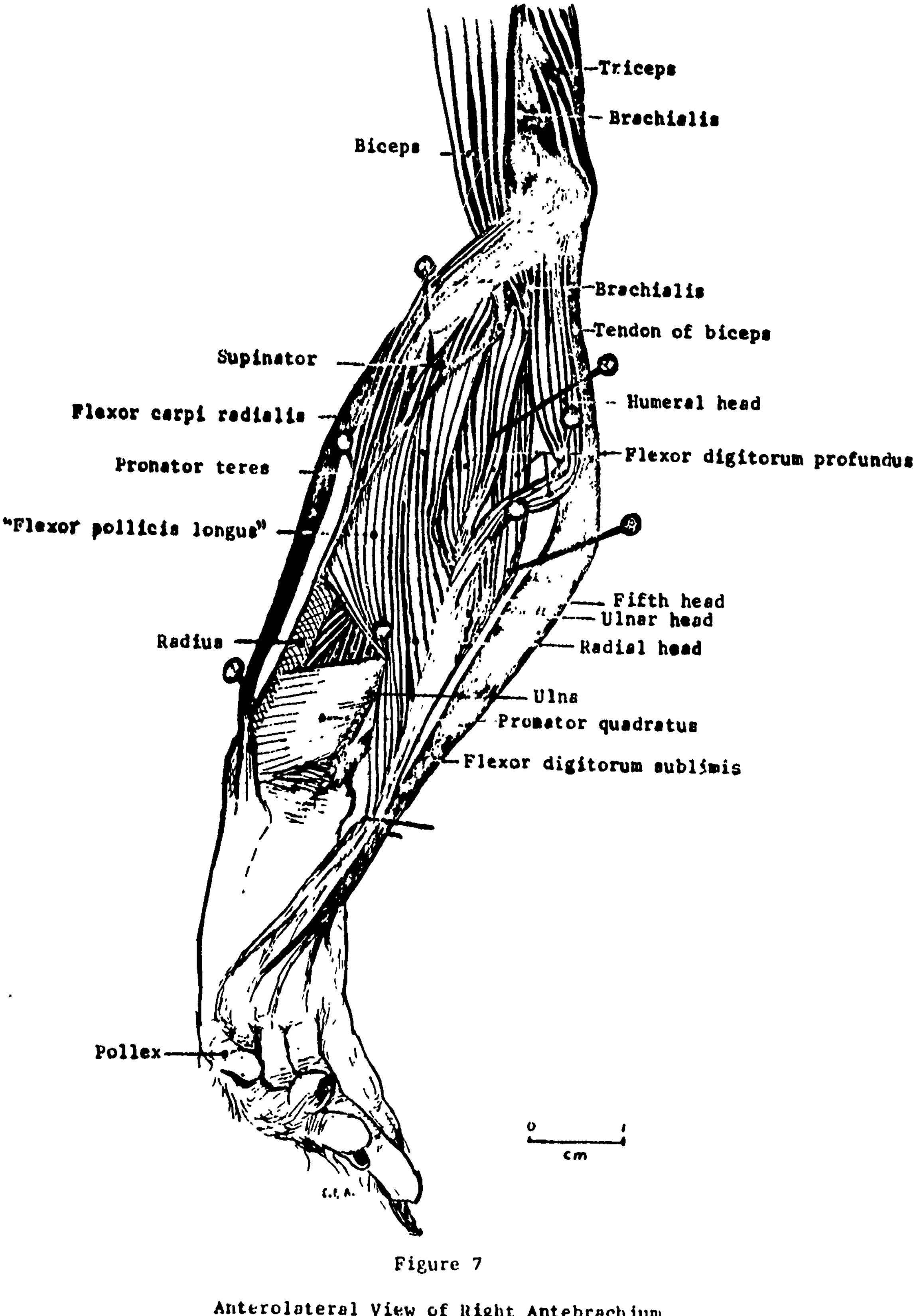

Figure 7

Anterolateral View of Right Antebrachium
With Most Musculature Displaced to Reveal Deepest Flexors

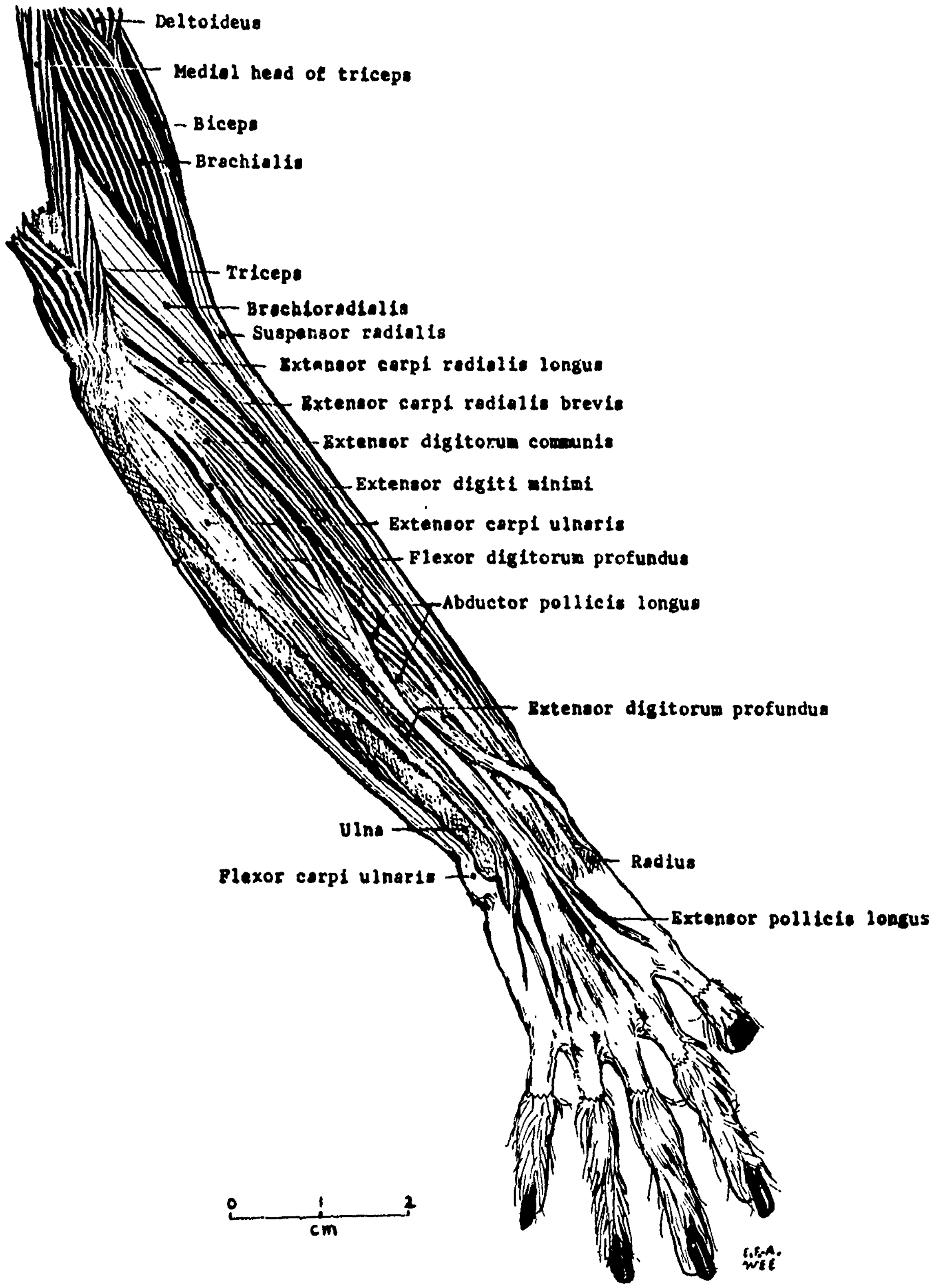

Figure 8

Extensor (Dorsal) Surface of Right Antebrachium and Manus
With Dermis Removed

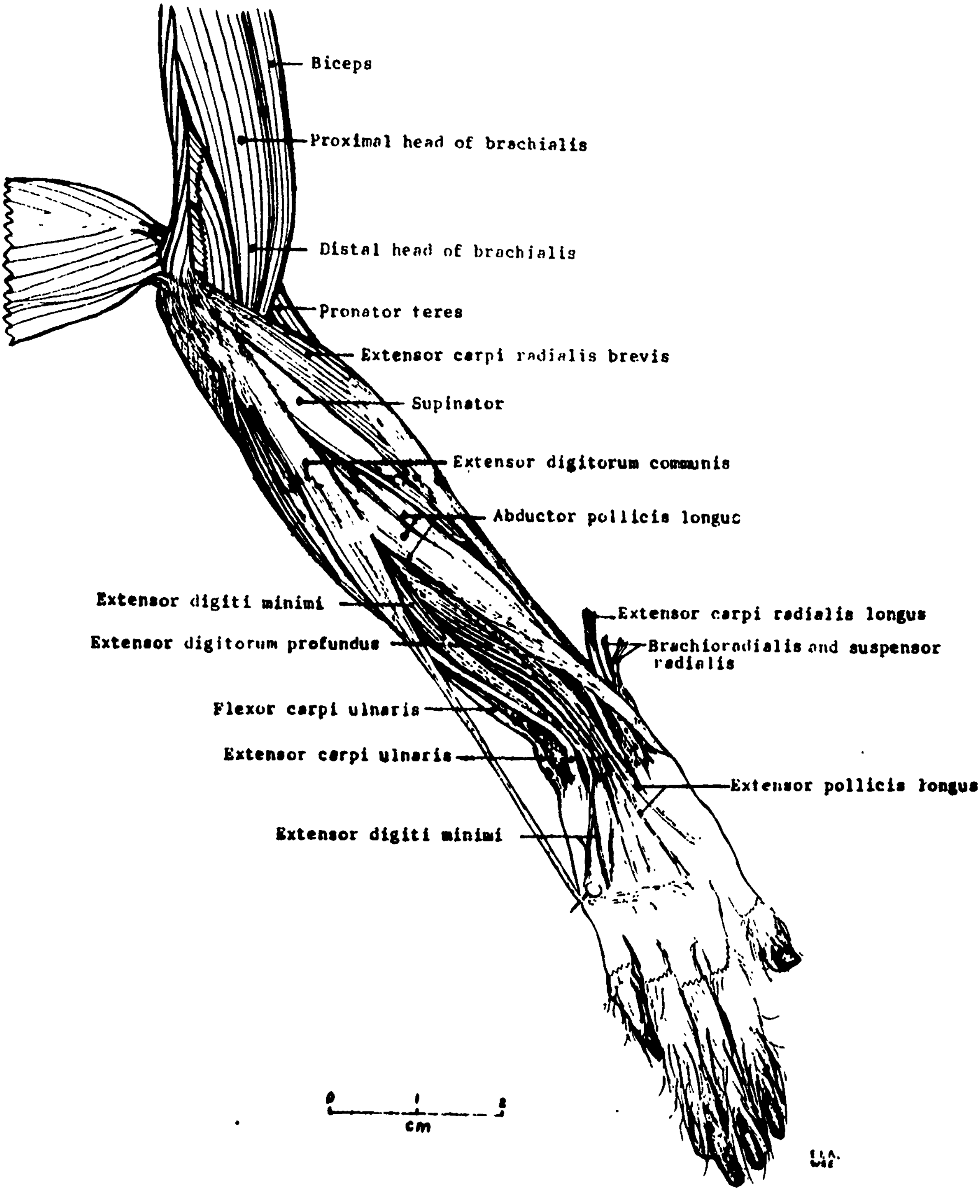

Figure 9

Dorsal Surface of Antebrachium
With Extensor Digitorum Communis Displaced to Reveal Underlying Structures

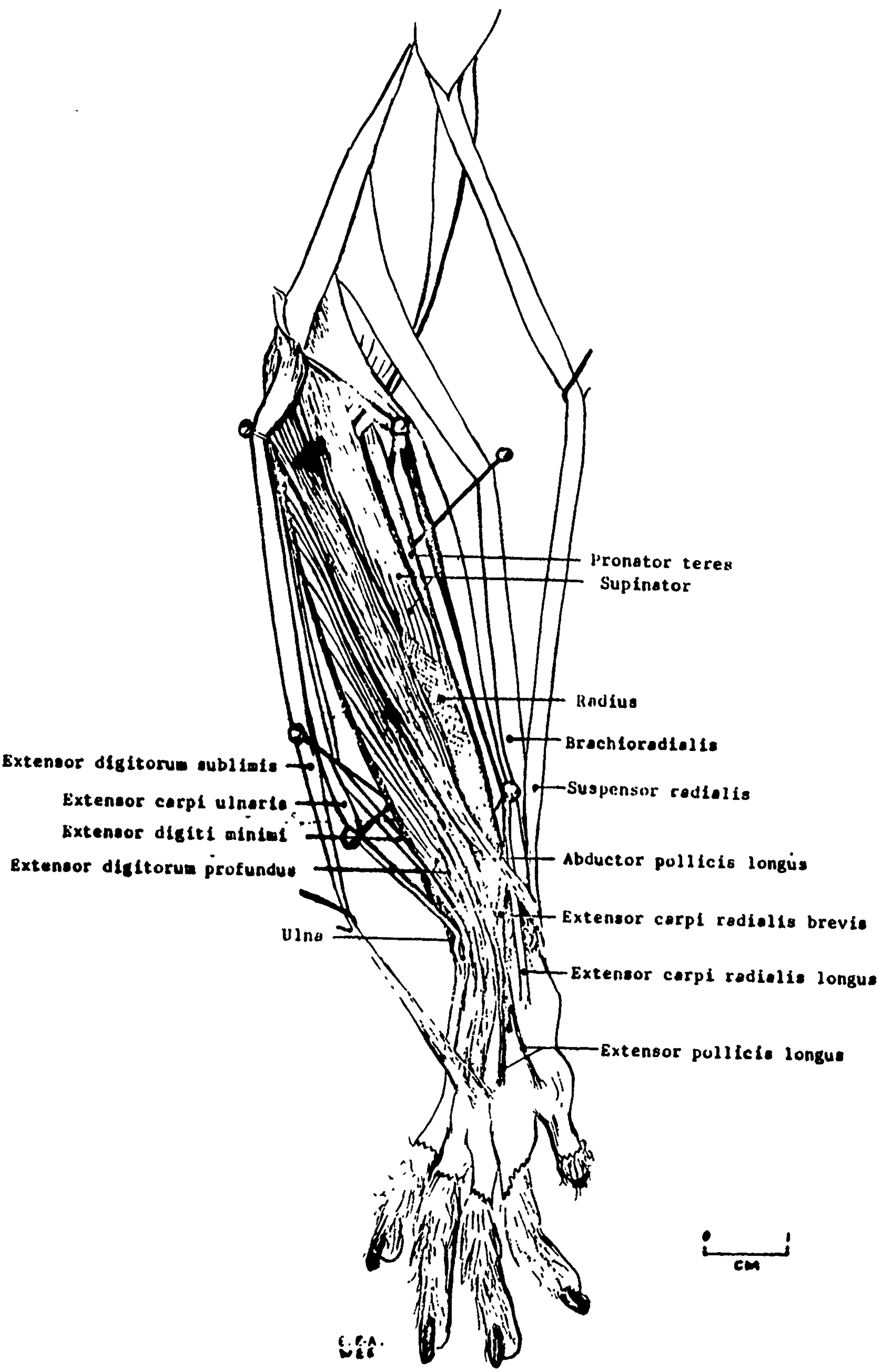

Figure 10

Posterolateral View of Deepest Musculature of Extensor Surface of Antebrachium

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13 ABSTRACT

The antebrachial musculature of a female squirrel monkey (Saimiri) is quantitatively described in detail and illustrated by the photo-etching process. Comparisons with data from the literature on other platyrrhines and non-platyrrhine primates indicate marked taxonomic distinctiveness and primitivity in many features.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Squirrel Monkey Strength Endurance Physiology Musculoskeletal anatomy Antebrachium						

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