A COMPARISON OF LIMB MUSCLE MASSES IN CERTAIN MAMMALS, WITH A BRIEF MYOLOGY OF THE MOLE (SCAPANUS TOWNSENDII) AND THE BAT (CORYNORHINUS RAFINESQUII)

by

S. VON BERTHELSDORF

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[redacted]

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PREFACE

This paper is a report of four years of study on the muscle weights of a series of mammals. During the first two years the work was largely confined to the dissection, drawing, and weighing of the muscles of the two species of bats here included. The dissections and weight determinations of the animals other than bats were done during the following two years.

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A COMPARISON OF LIMB MUSCLE MASSES IN CERTAIN MAMMALS

Introduction

It has been noted (Larsell, 1935) that the major difference in the cerebella of two closely related species of bats was the presence of a fissure, and it has been suggested that a study of the differences in the musculature be made.

The animals here studied include the long eared bat (Corynorhinus rafinesquii), the short eared bat (Myotis californicus), the Western mole (Scapanus townsendii), the domestic cat (Felis domesticus), the white rabbit (Oryctolagus), and the white rat (Rattus R. albinicus).

An attempt is here made to compare the limb muscle masses in this series of specialized mammals. Comparisons can be accurately interpreted only through definite, standard ratios. Therefore the muscle masses are expressed in this paper in terms of percent per total body weight and in percent per total limb muscle weight.

The cerebella of the above and other mammals have been studied and described largely by Dr. O. Larsell. It is hoped that the data presented in this study may furnish a basis of comparison of muscle groups with cerebellar fissures, lobes, and areas. If a relationship exists between unusually developed musculature and unusually developed cerebellar areas, the correlation should have a bearing on the problem of functional localization in the cerebellum.

Because available material on the anatomical descriptions of the bat and mole has been very limited, it has been necessary to include a brief discussion and a few illustrations of these mammals to make possible the identification of their muscles. Examination of the illustrations of these mammals will show that the remarkable specialization in the limb structure has made this necessary.

Literature on this field is very limited. In von Bardeleben's "Handbuch der Anatomie des Menschen" a section is devoted to the weights of the fresh muscles of the right and left leg and arm of a muscular man and a slender woman. The weights were tabulated and differences indicated in percent. However, the method of procedure followed by von Bardeleben could not be employed in the study of small mammals because of the great variation in moisture content in the muscles of the latter, as shown by repeated weighings. It was therefore necessary to dessicate all muscles after dissection so that a constant weight on repeated weighings could be obtained.

To assure accepted nomenclature of the muscles, the names employed in standard textbooks of anatomy were used so far as possible. The muscles of the mole and the bats had to be studied and named without a specific reference. The standard references on mammalian myology, embryology, and comparative anatomy were employed in working out the homologies.

Material and Methods

The myology of two species of bats was first studied in search of any marked differences. The animals were preserved in a ten percent formalin solution before dissection, the interval of preservation varying from a few days to three years.

The bats (and most of the muscles of the mole) were dissected under a binocular dissecting microscope or with the aid of a binocular loupe. No marked differences in myology could be found in the two species of bats by the method of dissection.

An attempt was then made to determine differences in the weight of the muscles of the two species. It was very evident that the dissection of the bat was not possible on an unpreserved specimen; that the weight of a muscle preserved in a solution would probably include an unknown and variable amount of preservative; and that even if these factors were disregarded, the evaporation of water during the course of the dissection and weighing would make the resulting weights far too inaccurate. Therefore the muscles were dried as follows:

The muscles were dissected out and placed on glass slides that were labeled with the name of the muscle. Usually both right and left sides were dissected at the same time and placed on the corresponding sides on the same slide. They were dessicated in an oven maintained at a temperature of 55° to 60°. The muscles were examined and weighed at variable intervals until no significant change of weight was evident; this required about four or five days for the small animals (bats, moles) and twelve to fourteen days for the larger animals. A higher temperature was tried (200°) but showed no advantage other than a more rapid and somewhat more nearly complete dehydration. Because of the inconvenience in the use of the hotter oven and because the corrected dehydration was limited to less than five percent, this was discontinued.

The time necessary for relatively complete dehydration of the muscles of the different animals varied in general with the size of the muscles: only those readings that were consistant after repeated weighing are recorded in the tables. Since the animals had been preserved in a ten percent formalin solution, decomposition was held at a minimum. No other preservative or hardening agent was used.

The preparation of the muscles of the larger mammals required a modification of technique in drying and weighing. Gummed labels were pressed against the wet muscles for identification and then placed in the same oven and at the same temperature as before. Since the weight of the labels after drying was several grams less than before, it was necessary to first dry, weigh and record the individual weight of each label; then attach it to the wet muscle, dry the muscle with the label attached, and weigh and record on that label the actual weight of the dried muscle. On succeeding rabbits and cats the process was speeded up at the cost of slight inaccuracy by using the figure of 133 milligrams as the average weight of a dried label (a series weighed 136.4 to 131.0 mg.). Small muscles that were estimated to weigh less than 100 milligrams were dried on glass slides lest the percent of error be too great.

The fat content of the muscles of the rat, cat and rabbit was exceedingly variable not only among the species of animals but also in the muscles of each individual. It was found that the figures for the fat rats could be brought in better correlation with the others by leaving them in xylol twentyfour hours, changed once, drying again in the same oven, and reweighing. Since this process made the readings of the animals in a series more consistant, the fat content of all rat, rabbit and cat muscles was extracted. There was no appreciable change in the weights of the mole or bat muscles in going through this process so that with them the fat extraction process was omitted.

All bats dissected, both Myotis and Corynorhinus , were females. Of the other animals used most were young adult females except the moles, which were all males. As a rule any available material was used.

The wet weights of the muscles of some of the cats, rats, and rabbits were recorded and kept for reference. The same muscles however were also dried and the fat extracted. In this way another ratio could be obtained - that of wet to dry weight. This figure may be used as a means of rough comparison with the muscle weights for man, given in von Bardeleben's "Handbuch der Anatomie des Menschen." Such a comparison however, must be made with reservation, for it is only an assumption that the wet to dry ratio in the smaller animals is the same as in man. Indeed, all figures are only approximate and would undoubtedly be changed in some degree if a larger series of animals of each species were studied. As long as a constant ratio is used in the comparison of the muscles, some degree of significance can be attached to unusual variations in muscle group weights.

The muscles are arranged in the tables in a standard series and are listed both as single and grouped muscles. The cutaneous maximus was included only because it is accessory to the latissimus in some of the animals studied. The weight of this muscle was not included in the sum total of the limb muscle weights or the total percentage figures because it is not strictly a limb muscle, and because an indefinite and exceedingly variable amount of fascia was included with the muscle fibres. This would have very much increased the degree of error in all of the muscles.

All weights and percentages have reference to the weights of dried muscles unless indicated otherwise. The individual weights of the muscles are indicated in most cases with headings to show the group weights, the latter being distinguished by means of the percent symbol. It was not practical to dissect out the musculature of the hand or foot because in the smaller animals the weights of these muscles could not be obtained with the apparatus available; consequently they were entirely omitted.

The weights of the tendons introduced a variable factor of error in the dried muscles. Because it is difficult to state just where the muscle ends and the tendon starts, it was decided upon to cut all tendons at a standard point. The problem presented itself largely in the flexors and extensors of the hand and foot, so that here the tendons were all cut at the annular ligaments of the wrist and ankle. All other muscles were divided at the periosteum of the origins and insertions. However, even in animals such as the bat, with its bunched muscles and long tendons, the muscle weight was so much greater than the tendon weight that the factor of error was negligable.

GENERAL OBSERVATIONS

The weight ratios of the six species of animals studied are expressed in terms of percent per total muscle weight and in percent per body weight. This offers two means of comparing the muscle mass. Examination of the percentage tables will seem to show however a certain degree of inconsistency, particularly evident in the heaviest and the lightest of muscles. Compare for example the weights of the patagial and the pectoral muscles of the Myotis and Corynorhinus in the terms of the two different percentages:

Patagials	Dry weight	Percent per body weight	Percent per total dry muscle weight
Myotis	0.3 mg	0.005% (of 6.30gm)	0.20% (of 151.5mg)
Corynorhinus	0.5 mg	0.005% (of 9.42gm)	0.14% (of 368.5mg)
Pectorals			
Myotis	61.4 mg	0.976% (of 6.30gm)	40.53% (of 151.5mg)
Corynorhinus	145.2 mg	1.545% (of 9.42gm)	39.50% (of 368.5mg)

This apparent lack of proportion exists because the limb muscle mass per body weight is not the same in the Myotis and Corynorhinus; nor is it the same in any of the other mammals, and interpretations must be made with that in mind.

It is noteworthy that in the different species of animals there are many more variations in the musculature and skeletal structure of the upper limbs than of the lower limbs. The musculature of the upper limbs shows marked alterations in muscle mass, action, shape, and relationship.

In contrast to the many changes evident in the upper limb, the hind limb seems to be quite constant in its anatomy. Although the pelvis of the mole is altered in shape, made long and slender and lacking in a pubic arch, yet the muscle masses and relationship of its constituent parts remain quite constant and resemble that of the rat. This is true to even a greater degree in the other animals studied.

OBSERVATIONS ON THE WEIGHTS AND RATIOS IN THE INDIVIDUAL SPECIES

THE RAT

A series of fourteen rats was dissected. Of these only six were used in the determination of muscle weights, while the others were discarded for various reasons.[1] The muscles of the rat show a distribution of muscle mass with about 36% of the weight in the fore limbs and 64% in the hind limbs. The total dry muscle weight of fore and hind limbs on one side showed an average of 4.755 grams.

The rats used were of both sexes and were adults of two or three years of age. The average live weight of these was 200 grams; eviscerated, the weights were from 72% to 79% of the live weight. Although wet weights are not indicated in the tables, it was observed that the wet muscles weighed about four times as much as the same muscles after they were dried. Fat extraction materially altered the weights of only the cutaneous maximus, the serratus anterior, iliopsoas, and to a lesser extent the pectoralis, trapezius, rhomboids, and latissimus dorsi. Other muscles showed little change but were nevertheless passed through the same process for the sake of uniformity.

[1] At first, group weights were taken instead of weights of the individual muscles; these groups were found to be functionally inconsistant in the other species, and it was found to be advisable to determine the individual weights. Wet weights only were taken in some rats and were found too variable to use. Emaciated rats, which had been used for previous experiments were found to have muscle weights far below average and therefore could not be included with the normal readings. Fat in the muscles was not accounted for and certain fat loaded muscles showed inconsistant and often too high readings, so that all had to be discarded. Dried muscles were twice accidently dropped and scattered.

The muscle weights and percentages are indicated in tables #1 and #2. The weight ratios of the rat may be used as a basis of comparison with the other animals in this study.

In the lower limb the largest of all muscle groups is the flexor group in the thigh, constituting 18% of the total dry muscle weight; secondly the shank muscles, collectively making up 13% of the weight, the calf muscles contributing more than half of this; thirdly the glutei, collectively making up 11% of the total dry muscle weight; then the quadriceps femoris group with 9%, then the iliopsoas, adductors and lastly the external rotators of the thigh, constituting the lesser masses.

In the fore limb the cutaneous maximus accounts for about 13% of all the limb dry muscle weight; however, it is not considered as a part of the limb musculature and is included in the table only because it is accessory to the latissimus dorsi. The largest group included in the forelimb is the triceps, constituting 5% of the combined limb muscle weight; secondly the pectoralis group with 4.78%, the latissimus dorsi with 4%, the trapezius with 3.64%, the serratus anterior with 3.43%, and the other muscles progressively of smaller weights. It is noteworthy that the muscles on the ventral surface of the brachium are the smallest in muscle mass in the rat.

TABLE I

Rat[1] Lower limb muscles	Average dry weight in a 200 gram rat	Percent of body weight (times 10^{-2})	Percent of total dry muscle weight (4.799 grams)
Iliopsoas	265 mg	13.3%	5.57%
Iliacus	195		
Psoas	70		
(Quadratus lumborum)	60		
Gluteus maximus and Tensor fascia lata	157 mg	7.9%	3.30%
Glutei, lesser	375 mg	18.8%	7.90%
Medius	313		
Minimus	62		
Small external rotators	78 mg	3.9%	1.64%
Pyriformis	27		
Obturators	26		
Gemelli and quadratus femoris	25		
Hamstrings	839 mg	42.0%	18.40%
Biceps femoris	372		
Semitendinosis	163		
Semimembranosis	210		
Gracilis	94		
Quadriceps femoris	430 mg	21.5%	9.05%
Adductors of the thigh	243 mg	12.2%	5.11%
Adductor longus	16		
Adductor brevis	94		
Adductor magnus	62		
Pectineus	26		
Caudofemoralis	45		
Lower leg muscles	630 mg	31.5%	13.50%
Dorsiflexors	189		
Plantar flexors	106		
Calf muscles	335		
Total, lower limb	3017 mg	151.1% (10^{-2})	64.47%
Total, upper limb	1782 mg	117.5% (10^{-2})	36.92%
Total, both limbs	4799 mg	2.68%	100%

[1] In this table and in all others, all weights indicated are averages of right and left muscles. The weights of the muscles indicated in the sub-headings add up to the weight of the group. The figures under "Percent per body weight" are expressed in the power of 10^{-2} because these are easier to read than figures preceded by a confusing number of zeros.

TABLE II

Rat Upper limb muscles	Average dry weight in a 200 gram rat	Percent of body weight (times 10^{-2})	Percent of total dry muscle weight (4.799 grams)
Trapezius	173 mg	8.7%	3.64%
Acromio	78		
Clavo	47		
Spino	48		
Latissimus dorsi	190 mg	9.5%	4.00%
Levator scapulae	10 mg	0.5%	0.25%
Rhomboideus	92 mg	4.6%	1.93%
Major and minor	47		
Occipito	45		
Sternocleidomastoid	59 mg	3.0%	1.24%
Sterno	15		
Cleido	44		
(Cutaneous maximus)	623	31.1%	13.10%
Pectoralis	227 mg	11.4%	4.78%
Major	84		
Minor	143		
Subclavius	10 mg	0.5%	0.25%
Serratus anterior	163 mg	8.2%	3.43%
Deltoid	65 mg	3.2%	1.37%
Spino	33		
Acromio	32		
Supraspinatus	76 mg	3.8%	1.60%
Infraspinatus	63 mg	3.1%	1.33%
Teres minor	5 mg	0.3%	0.13%
Teres major	50 mg	2.5%	1.25%
Subscapularis	85 mg	4.3%	1.79%
Biceps brachii	28 mg	1.4%	0.59%
Brachialis	34 mg	1.7%	0.71%
Coracobrachialis	5 mg	0.3%	0.13%
Triceps	237 mg	11.9%	4.99%
Forearm	210 mg	10.5%	4.4[illegible]%
Flexors	134		
Extensors	76		

THE CAT

Although the musculature of the cat is quite similar to that of the rat in a number of respects, certain obvious differences are present. A live cat weighing 2000 grams lost approximately 50% of its weight on being skinned and eviscerated, while only 25% of the body weight of the rat is lost in this process. Thus, the cat has a relatively lesser amount of musculature and bone tissue than the rat. Also, the distribution of muscle mass between fore and hind limbs of the cat varies markedly from that of the rat; in the former, 49% of the limb muscle mass is in the fore limbs, 51% is in the hind. In the latter the distribution is 36% to 64%, fore limb and hind limb respectively.

With the exception of the glutei, the sequence of muscle mass of the individual muscles in the hind limb is in the cat very similar to that in the rat. The gluteal group of the cat is only about a fourth as large proportionately as in the rat.

The muscle masses in the fore limb however do not correspond so well. The largest group of muscles in the forelimb of the cat is the antebrachial musculature, constituting 7.66% of the dry muscle weight; the flexors make up about two thirds of this. Secondly the triceps with 7.10%, the pectorals with 6.0%, latissimus dorsi with 4.39%, and then other muscles all of lesser weights.

As a rule most of the forelimb muscles of the cat are heavier than those of the rat. Inconsistancies of this generalization are conspicuous, such as the serratus anterior and the trapezius, which in the cat are relatively smaller than in the rat. Of the latter muscle, part may be considered to have migrated ventrally in its development to make up part of the levator scapulae, for this is nearly ten times the greater in the cat.

The wet to dry ratio was taken but is not indicated in the tables because it is irrelevant. It was found that the total wet muscle weighed approximately 4.5 times the total dried muscle. Although most of the muscles were quite consistant to this ratio, the smaller muscles showed marked variation.

TABLE III

Cat Upper limb muscles	Average dry weight in a 2000 gm. cat	Percent of body weight (times 10^{-2})	Percent total limb muscle wt. (37.44gms)
Trapezius	698 mg	3.5%	1.86%
Acromio	168		
Clavo	283		
Spino	247		
Latissimus dorsi	1646 mg	8.2	4.39
Levator scapulae	583 mg	4.3	2.28
Rhomboids	819 mg	4.1	2.18
Sternocleidomastoid	474 mg	2.4	1.26
Sterno	238		
Cleido	236		
Pectoralis group	2254 mg	11.3	6.00
Serratus anterior	728 mg	3.6	2.00
Deltoid	786 mg	3.9	2.09
Spino	204		
Acromio	203		
Clavobrachialis	379		
Supraspinatus	1149 mg	5.7	3.63
Infraspinatus	904 mg	4.5	2.40
Teres minor	47 mg	0.2	0.12
Teres major	586 mg	2.9	1.56
Subscapularis	1064 mg	5.3	2.84
Biceps brachii	554 mg	2.7	1.48
Brachialis	305 mg	1.5	0.81
Coracobrachialis	20 mg	0.1	0.05
Triceps	2659 mg	13.3	7.10
Forearm muscles	2875 mg	14.8	7.66
Flexors	1692		
Extensors	1183		

TABLE IV

Cat Lower limb muscles	Average dry weight in a 2000 gm. cat	Percent of body weight (times 10^{-2})	Percent total limb muscle wt. (37.44gms)
Iliopsoas	1297 mg	6.5%	3.46%
Iliacus	897		
Psoas	400		
Gluteus maximus and Tensor fascia lata	572 mg	2.9	1.52
Gluteus medius and minimus	876 mg	4.3	2.30
Small external rotators	863 mg	4.3	2.30
Pyriformis	108		
Obturator externus	217		
Obturator internus and gemelli	374		
Quadratus femoris	164		
Hamstrings	5669 mg	28.3	15.10
Biceps femoris	2110		
Semitendinosus	590		
Semimembranosus	1942		
Gracilis	470		
Sartorius	556		
Quadriceps femoris	3269 mg	16.4	8.67
Adductors of the thigh	2032 mg	10.3	5.41
Adductor longus	9		
Adductor brevis and magnus	1724		
Pectineus	32		
Caudofemoralis	18 7		
Lower leg muscles	4685 mg	23.4	12.50
Peronei, long & short	341		
Dorsiflexors	968		
Plantar flexors	912		
Calf muscles	2464		
Total, lower limb	19.254 grams	$96.3(10^{-2})$	51.26%
Total, upper limb	18.185 grams	$90.3(10^{-2})$	48.09%
Total, both limbs	37.44 grams	1.86%	100%

THE RABBIT

Dissections were made of four adult rabbits of unknown age and of both sexes. Although the live weights were exceedingly variable (5000, 4500, 2320, and 1420 grams each) the eviscerated and skinned bodies of the first three showed comparatively little variation in weight, averaging 1530 grams. The last rabbit had been used in an experiment (a study of the capillary action of the ear) and had died during anaesthetization. Because its muscle weights were far below the average they were not included, although it was actually found later that the inclusion of this rabbit would not have materially altered the ratios. As a whole, the muscle weights of the healthy rabbits were very similar in spite of the very great variation in live body weight.

The average live weight of the first three rabbits was 3940 grams. The total dry muscle weight averaged 61.78 grams; the wet muscles averaged 274 grams. It was observed that in the forelimbs the wet weights of the muscles were not in proportion to the dry; this is probably because these muscles were relatively smaller than the muscles of the hind limbs, and therefore lost a greater amoint of water while in the rpocess of dissection. The weight of the wet muscles as a whole was found to be 4.7 times the weight of the dry. Fat extraction very much decreased the weight of the majority of the muscles. This was especially evident in muscles adjacent to regions of fat, such as the iliopsoas, latissimus dorsi, cutaneous maximus, trapezius, serratus anterior, and pectorals.

There is a distribution of 32.3% of the muscle mass in the fore limb and 67.3% in the hind. This is a fairly close correlation with that of the rat (36% in the fore limb, 64% in the hind).

The largest muscle group in the fore limb of the rabbit is the pectoralis, making up 5.5% of the total dry muscle weight. The second largest group is the triceps with 5%, then the serratus anterior, the forearm muscles, the latissimus dorsi, and then the other muscles in decreasing order. The cutaneous maximus of the rabbit is only about a fifth the relative size of that of the rat.

In the lower limb the hamstring muscles are the major group with the ratio of 18%. However, it was anticipated that this mass would be much larger, for the figure obtained from the same group in the rat was also 18%. The second largest group is made up of the adductors of the thigh, with 11.45%. This is a marked increase compared to the rat, for in the latter the adductors are one of the minor groups of the lower leg. The other muscle groups in sequence of mass include the quadriceps femoris, 11%; the lower leg muscles collectively with 10%; the glutei collectively about 9%; then the iliopsoas and lastly the small external rotators collectively, making up 6% and 2% respectively.

TABLE V

Rabbit Upper limb muscles	Average dry weight in a 3940 gm. rabbit	Percent of body weight (times 10^{-2})	Percent total limb muscle wt.(62.05gms)
Trapezius	873 mg	2.2%	1.04%
Upper	463		
Lower	410		
Latissimus dorsi	1600 mg	4.1	2.59
Levator scapulae	111 mg	0.3	0.18
Rhomboideus	821 mg	2.1	1.33
Major	383		
Minor	437		
Cranioclaviculars	604 mg	1.5	0.98
Sternomastoid	217		
Cleidomastoid	144		
Basioclavicularis	243		
Pectoralis group	3373 mg	8.6	5.45
Primus	218		
Secundus (Major)	471		
Tertius (Minor)	1516		
Quartus	992		
Pectoscapularis	176		
Serratus anterior	2031 mg	5.2	3.29
Deltoid	553 mg	1.4	0.90
Proper	194		
Superior abductor	121		
Inferior abductor	238		
Supraspinatus	1394 mg	3.9	2.26
Infraspinatus	1079 mg	2.7	1.75
Teres minor	32 mg	0.1	0.05
Teres major	1034 mg	2.6	1.68
Subscapularis	934 mg	2.4	1.51
Biceps brachii	532 mg	1.4	0.86
Brachialis	175 mg	0.4	0.28
Coracobrachialis	72 mg	0.2	0.17
Triceps	3117 mg	7.9	5.04
Forearm muscles	1982 mg	4.8	3.22
Flexors	1265		
Extensors	717		

TABLE VI

Rabbit Lower limb muscles	Average dry Weight in a 3940 gm. rabbit	Percent of body weight (times 10^{-2})	Percent total limb muscle wt.(62.05gms.)
Iliopsoas	3760 mg	9.5%	6.08%
Iliacus	709		
Psoas	3051		
Gluteus maximus and Tensor fascia lata	3304 mg	8.4	5.35
Lesser glutei	2320 mg	5.9	3.76
Medius	1139		
Minimus	1181		
Small external rotators	1041 mg	2.6	1.69
Piriformis	222		
Gemellus superior	47		
Gemellus inferior	125		
Obturator internus	221		
Obturator externus	185		
Quadratus femoris	241		
Hamstrings	11008 mg	28.0	17.84
Tensor fascia cruris	149		
Biceps femoris	7311		
Semitendinosus	310		
Semimembranosus	2069		
Gracilis	1059		
Sartorius	110		
Quadriceps femoris	6817 mg	17.3	11.04
Adductors of thigh	7068 mg	17.9	11.45
Longus	2507		
Brevis	257		
Magnus	4080		
Pectineus	224		
Lower leg muscles	6416 mg	16.3	10.40
Long and short peronei	523		
Dorsiflexors	1383		
Plantar flexors	825		
Calf muscles	3685		
Total, lower limb	41.73 grams	1.059%	67.61%
Total, upper limb	20.32 grams	0.518%	32.58%
Total, both limbs	62.05 grams	1.577%	100.(19)%

THE MOLE

Of a series of moles the muscles of four dissections were dried and their weights were recorded. The weights of the living moles ranged from 117.6 to 134.4 grams and averaged 125.6 grams. The weight skinned and eviscerated was approximately 64 grams, constituting nearly 51% of the live weight. This figure is practically the equivalent to that of the cat (50%) but decidedly less than that of the rat (75%).

The upper limb musculature constitutes more than 77% of the total limb mass; the lower limb muscles make up about 22%. This is in marked contrast to the muscle mass distribution of any of the mammals discussed so far.

The fat content of the muscles was relatively slight, and since the fat extraction process did not alter the muscle weights to an appreciable degree, that process was omitted.

It is evident on inspection of the drawings of the mole that the pectoral girdle is displaced cranially and that it is surrounded by bunched, heavy muscles.

The outstanding muscle of the forelimb is the teres major, which is enlarged to so great an extent that it alone makes up nearly 19% of the total limb muscle mass. Its size makes all other scapular muscles seem insignificant. The caudal portion of its origin lies under the latissimus dorsi, and the two muscles insert together on a tubercle of the humerus, adjacent to the points of insertion of the cutaneous maximus and pectoralis major. The combined action of these muscles is transmitted from the humerus to the hand by a heavy tendon that largely replaces the forearm flexors. These large muscles work together to bring about adduction of the extended forearm, the motion used in pressing the dirt away from the front to the sides as the animal progresses in making its tunnel.

The cutaneous maximus would, if included, constitute about 13% of the limb muscle mass. This is six times the ratio of the same muscle of the rabbit (2.39%).

The pectoral group makes up 15.4% of the limb muscle mass. It consists of a large pectoralis major; a small dubdivision of the major that lies deep and inserts on a separate tubercle of the humerus; two suprapectorals of which one is superficial, the other is deep; and lastly a pectoralis minor. The suprapectorals lie transversely across the neck, in a straight line from one humerus to the other, and with little more than a thin, fibrous interruption at the midline. These muscles are suprasternal. The clavicle lies deep to these muscles and at the caudal border.

The subscapularis is the second largest muscle of the scapula. Its insertion is below that of the pectoralis major, and its action is evidently coordinate with the teres major.

The identification of the deltoid is not certain because of the marked rearrangement of the landmarks. Its origin seems to have migrated down along the spine of the slender scapula to cover the infraspinatus and the origin of the triceps.

The trapezius of the mole has developed a confusing structure along with the interposition of a spicule of bone; this lies longitudinally between the scapulae and extends from about the last cervical spine to the fifth or sixth thoracic spines, a distance of about twelve millimeters. The spicule serves as both origin and insertion of the trapezius and rhomboids, and the action of these muscles is directed first on the spicule and then transmitted to the scapulae.

The trapezius is subdivided into: the spinotrapezius, with origin in the fascia immediately lateral to the lumbar spine and insertion on the caudal tips of the scapula; the occipitotrapezius, with origin on the occiput and insertion with the spinotrapezius on the caudal tips of the scapula; the occipitospicularis, lying beneath the above muscle and inserting along the entire length of the spicule; and the spiculoscapularis, lying superficial to the occipitotrapezius, with its origin along the full length of the spicule and insertion with the other muscles on the inferior tip of the scapula.

There is a strong interscapular tendon connecting the caudal tips of the scapulae and attached to the interscapular spicule and adjacent musculature. This tendon offers the scapular muscles a good anchor for leverage in the digging motions of the forelimb.

The rhomboids lie deep to the above structures. Their insertion is primarily on the interscapular tendon. The other scapular muscles are insignificant in size and are hidden under the teres major, subscapularis, or deltoid.

The triceps is the largest brachial muscle. The fibres of origin of the long head extend along nearly the whole length of the scapula.

The biceps is a flat muscle. It has an unusually long, slender tendon of origin that passes up a boney tunnel in the humerus to the scapula. This tunnel is about four millimeters long and describes an arc of fully 90°.

The brachialis has its origin in a deep concavity at the proximal portion of the humerus; it then curves around the bone to bury itself between the short, thick muscles of the forearm on the ulna.

The scaphoantibrachialis lies on the lateral surface of the arm. It is a slender band of muscle fibres extending superficially from the scapular fascia to the distal end of the forearm. Its dried weight is only four milligrams.

The extensor group of the forearm muscles outweighs the flexor group. This is because the flexors are to a large extent replaced by a heavy tendon that carries the action of the shoulder muscles into the hand. This makes the forearm and hand function largely as a unit with the brachium and scapula.

The hind limb musculature is overshadowed by the markedly developed fore limb; consequently the ratios of the hind limbs are all low. The lower limb muscle mass constitutes only about 21.5% of the total in contrast to the 64.5% found in the rat. The sequence of muscle mass among the individual muscles is identical with that of the rat except for the gluteal group. This group is relatively much greater in the rat.

The hamstrings make up the heaviest group with 5.4% of the total dry muscle weight; secondly the lower leg muscles with 4.5%, the quadriceps femoris with 3.56%, and other muscle groups progressively smaller.

The skeletal structure of the mole shows as much adaptation as the musculature. Because of the marked increase of muscle mass of the shoulder girdle the thorax seems to lie far posteriorly. The manubrium is as long as the sternum, is blade-like, and serves as an added source of origin for the pectorals.

The clavicle is about seven millimeters wide and only three millimeters long. This brings the scaphohumeral joint close to the sternoclavicular. There is also established a wide articulation of the clavicle with the humerus.

The scapula is little more than three centimeters long and about six millimeters wide. It is quite uniformly long and slender and has sharp ridges that indicate the scapular spine and the axillary and vertebral margins. There is no coracoid process and no acromion. The articular end lies far ventral because of the shortness of the clavicle; the caudal end lies near the spine of the fourth thoracic vertebra, and is attached to its opposite by a short, heavy ligament. Thus the scapula lies at a 45° angle with the long axis of the body and lies adjacent to the cervical structures.

The humerus is flat and disc shaped, is about two centimeters long and one and one half centimeters wide. The bicepital foramen lies deep in the bone at the proximal end.

The radius is fifteen millimeters long, the ulna is twentytwo; the olecranon process makes up about a third of the length of the ulna. The end of the olecranon lies over the middle of the scapula and so gives the long head of the triceps a great mechanical advantage. Supination and pronation of radius over ulna is not possible; this action is replaced by motion of the brachium and antebrachium as a unit on the broad clavehumeral and scaphohumeral articulations.

The carpus has a prepollex, the Falciforme, that lies lateral to the radial side of the carpals and materially increases the transverse diameter of the hand. It has no phalanx. There is an os centrale present. The phalanges of the hand are as short as the carpals; the distal phalanx of each digit has long, heavy nails that nearly double the area of the hand. The nails are not split as in the European mole.

The pubic symphysis of the pelvis is open. The ilium and ischium are slender and make the pelvis unusually long and narrow, with the acetabulum approximately at its center. The sacrum has a small, blade-like dorsal protrusion along the midline that gives an added site of origin for the glutei.

The hind limb shows relatively little modification and is a typical pushing type of limb. The tibia and fibula are fused but leave a large foramen in the upper third of the crus.

TABLE VII

Mole Upper limb muscles	Average dry weight in a 120 gram mole	Percent of body weight (times 10⁻²)	Percent total limb muscles (2.951 grams)
Trapezius	155 mg	12.9%	5.24%
Spinotrapezius	24		
Occipitotrapezius	32		
Occipitospicularis	69		
Spiculoscapularis	29		
Latissimus dorsi	188 mg	15.7	6.35
Levator scapulae	45 mg	3.8	1.52
Rhomboideus	69 mg	5.8	2.33
Major	55		
Minor	14		
Sternocleidomastoid	55 mg	4.6	1.86
Pectoralis group	430 mg	36.0	14.57
Major	267		
Deep major	28		
Minor	44		
Deep suprapectoral	22		
Superficial "	69		
Subclavius	27 mg	2.2	0.92
Serratus anterior	51 mg	4.3	1.73
Deltoid	70 mg	5.8	2.36
Supraspinatus	16 mg	1.3	0.54
Infraspinatus	10 mg	0.8	0.34
Teres minor	10 mg	0.8	0.34
Teres major	550 mg	46.0	18.64
Subscapularis	184 mg	15.4	6.26
Biceps brachii	68 mg	5.7	2.30
Brachialis	40 mg	3.3	1.35
Scaphoantibrachialis	4 mg	0.3	0.15
Triceps	250 mg	20.4	8.48
Forearm muscles	150 mg	12.5	5.09
Flexors	65		
Extensors	85		

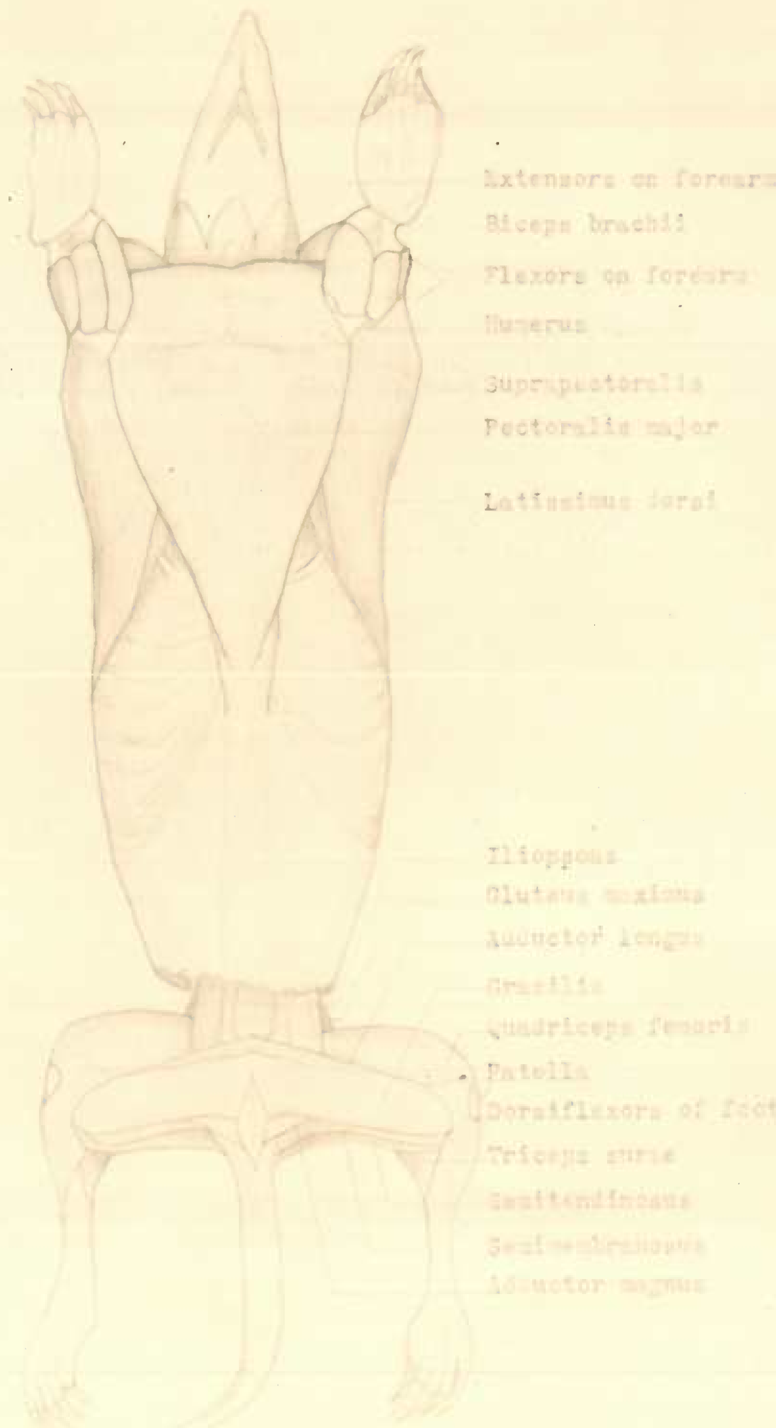
TABLE VIII

Mole Lower limb muscles	Average dry weight in a 120 gram mole	Percent of body weight (times 10^{-2})	Percent total limb muscle (2.951 grams)
Iliopsoas	55.0 mg	4.6%	1.86%
Iliacus	10.5		
Psoas	44.5		
Gluteus maximus and Tensor fascia lata	36.0 mg	3.0	1.22
Gluteus medius and minimus	47.0 mg	3.9	1.59
Small external rotators	25.0 mg	1.1	0.85
Piriformis	2.5		
Gemelli	2.5		
Obturator externus	3.5		
Obturator internus	2.0		
Quadratus femoris	14.5		
Hamstring muscles	160.0 mg	13.4	5.40
Biceps femoris	65.0		
Semitendinosus	33.5		
Semimembranosus	45.0		
Gracilis	7.5		
Sartorius	9.0		
Quadriceps femoris	105.0 mg	8.8	3.50
Adductors of the thigh	70.0 mg	5.8	2.36
Longus	5.0		
Brevis	20.0		
Magnus	30.0		
Pectineus	11.0		
Caudofemoralis	4.0		
Lower leg muscles	135.0 mg	11.3	4.50
Peronei, long and short	13.5		
Dorsiflexors	38.5		
Plantar flexors	23.0		
Calf muscles	60.0		
Total, lower limb	633 mg.	51.9%(10^{-2})	21.34%
Total, upper limb	2318 mg.	192.9%(10^{-2})	78.51%
Total, both limbs	2.951 grams	2.448%	100% (-0.15)

Plate I Western mole (Scapanus townsendii) X 1.75

Ventral aspect. This shows the large pectorals; the latissimus dorsi covers the teres major from this aspect. Note the cranial displacement of the shoulder girdle, the pronated position of the forelimbs.

The abdomen and its contents lie over the leg muscles from the ventral aspect. Therefore this has been cut away to expose the lower limb musculature



Scapanus Townsendii (Western Mole)
Ventral aspect

(Note: The viscera and lower abdominal musculature have been removed to show the lower limbs).

Plate II Western mole (Scapanus townsendii) X 1.75

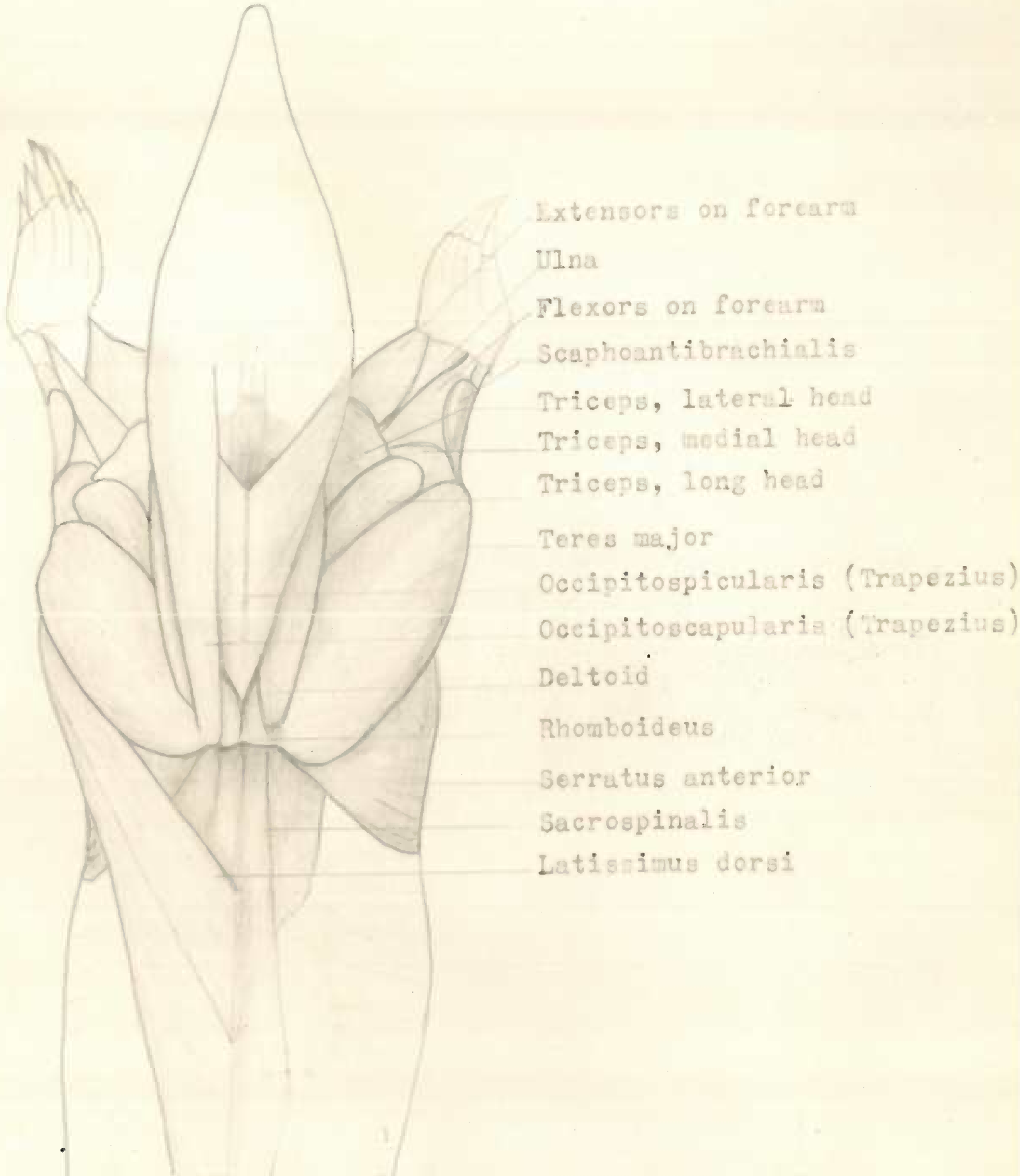
Dorsal aspect. This shows the large teres major, the complicated structure of the trapezius, the large latissimus dorsi. One of the origins of the cutaneous maximus is seen lateral to the spinotrapezius origin.

Note the unusual muscle relationships of the upper girdle and the relative size of the fore and hind limb musculature.

Thomomys townsendii (Eastern male)
Dorsal aspect

Plate III   Western mole (Scapanus townsendii) X 1.75

Dorsal aspect. On the left, the spiculoscapularis and the spinotrapezius have been removed; on the right these and the occipitoscapularis and latissimus dorsi have been removed. This exposes most of the deltoid and the dorsal portion of the serratus anterior.



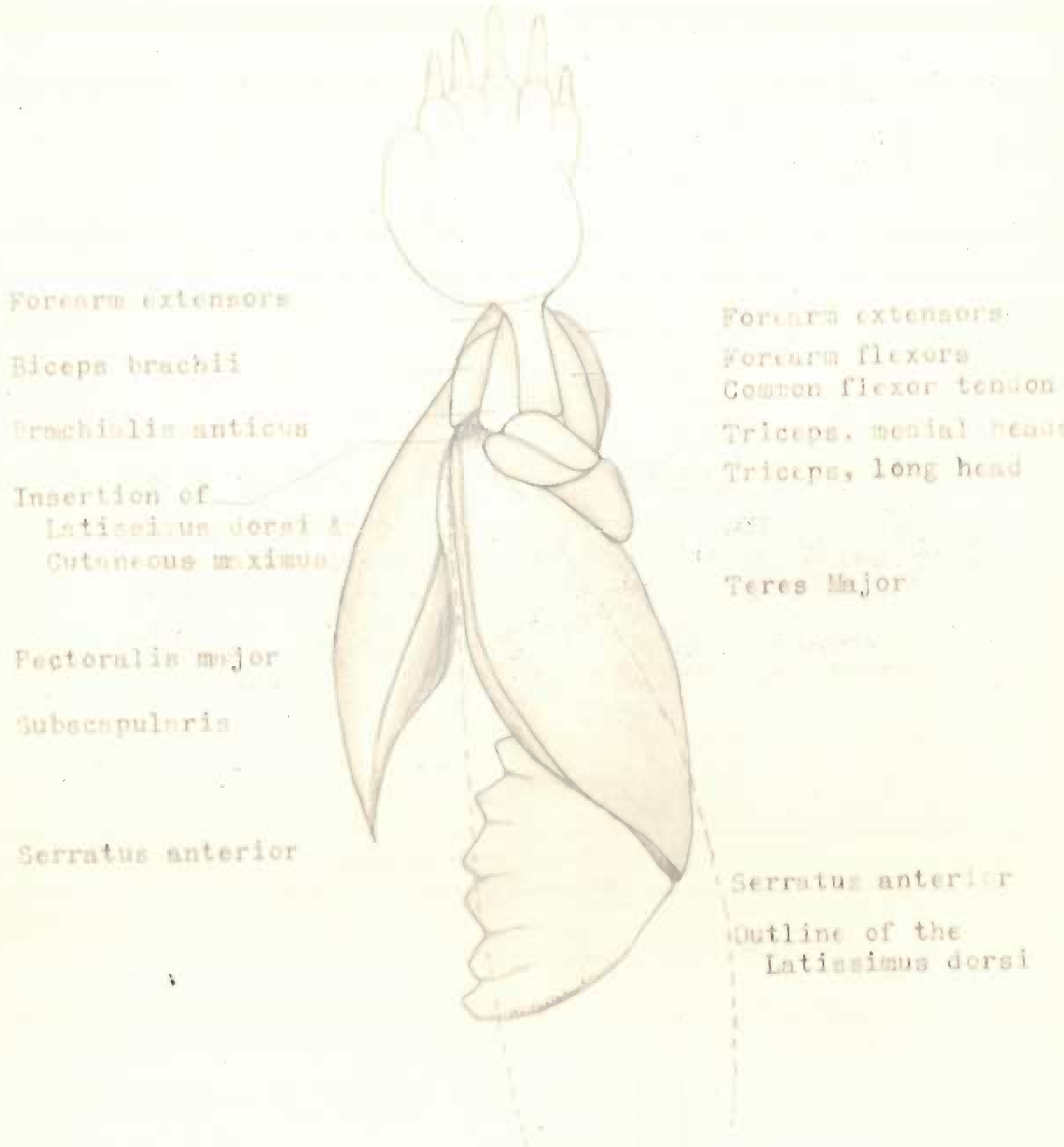
Scapanus Townsendii (Western mole)

Dorsal aspect
Showing the arrangement of the
Trapezius and deeper musculature.

Plate IV Western mole (*Scapanus townsendii*) X 1.75

Lateral aspect of left forelimb. The latissimus dorsi is removed and shown in outline. This exposes the teres major and serratus anterior. The pectoralis major is seen from the side and the thickness of the muscle is evident.

The digits of the manus are numbered. Note how the hand is made wider by the presence of the extra carpal.



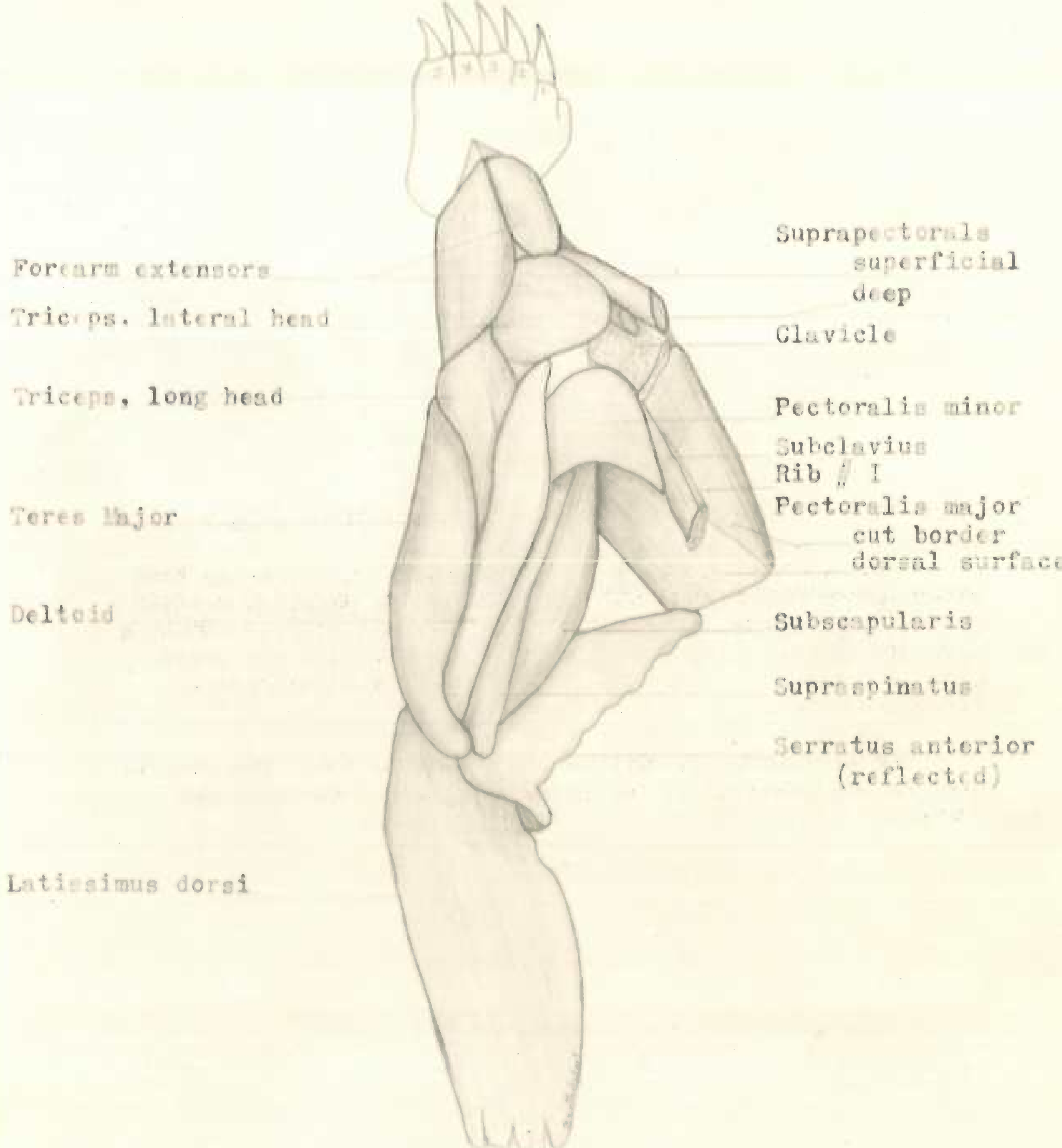
Scapanus Townsendii (Western mole)

Left forelimb Lateral aspect

Plate V   Western mole (Scapanus townsendii)   X 1.75

Dorso-medial aspect of left forelimb. The limb has been pulled laterally and ventrally to expose the scapular muscles to best advantage. The trapezius and rhomboideus are removed. Note the unusual length of the deltoid, which has its origin along the entire length of the scapula and thus covers the infraspinatus.

The pectoralis is seen from a dorsal aspect. The attachment to the pectoral of the opposite side is seen as a cut surface.



Scapanus Townsendii (Western mole)

Left forelimb, dorso-medial aspect

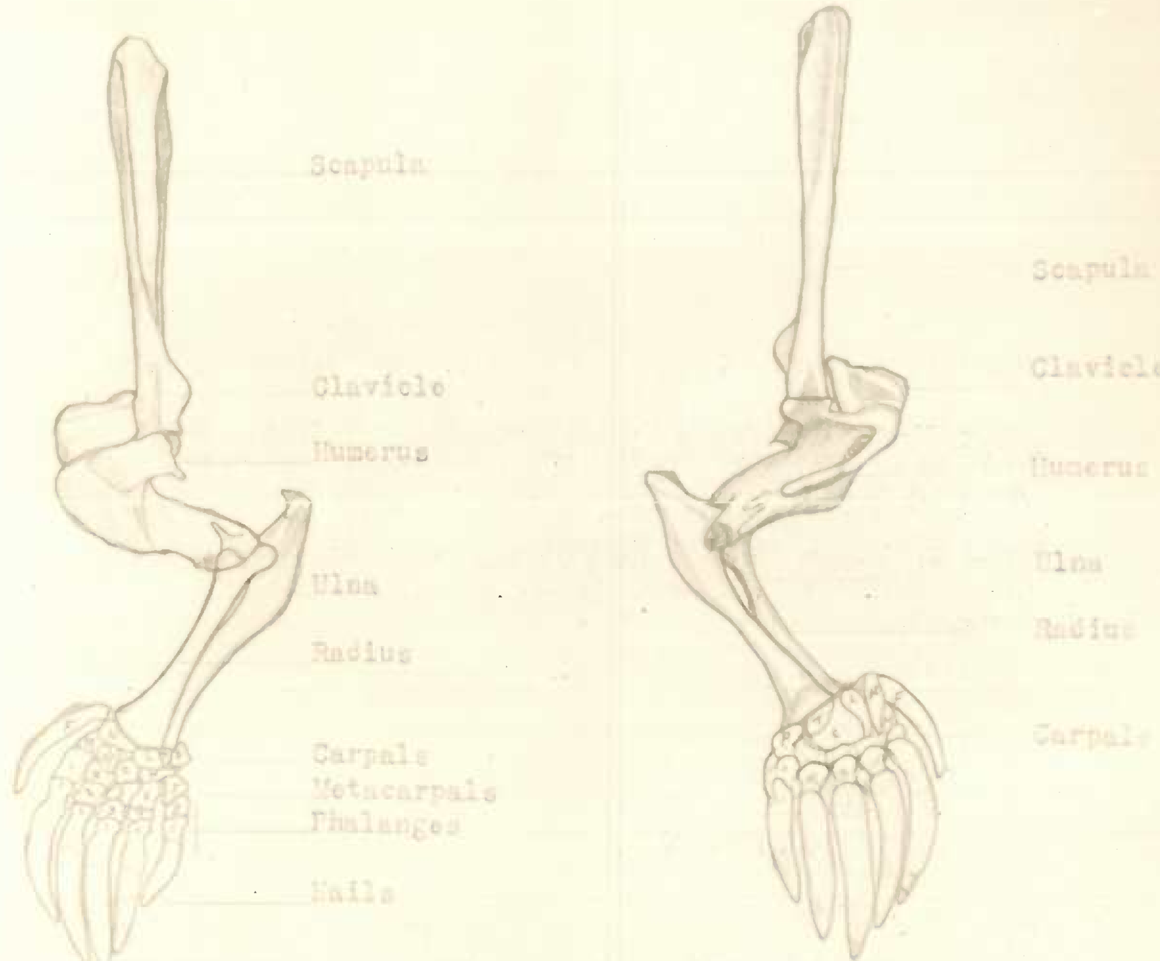
Plate VI Western mole (Scapanus townsendii) X 1.75

Articulated skeletal structure of the upper limb. The humerus is seen from its lateral aspect. There is no coracoid process on the scapula.

Note the large, strong, long nails, and the extra carpal on the ulnar side,,the falciforme. The carpals are indicated by letter as follows:

N naviculare
L lunatum
T triquetrum
P pisiforme
C[1] centrale
M multiangular (2)
C capitatum
H hamate

The metacarpals and phalanges are numbered. Only two rows of phalanges are present.



Extensor surface   Flexor surface

Upper limb, articulated
Western mole
(Scapanus townsendii)

Plate VII Western mole (Scapanus townsendii) X 1.75

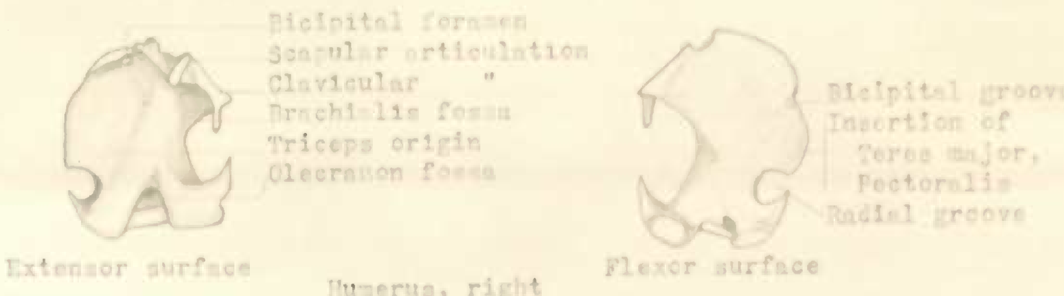
Disarticulated skeletal structure of the shoulder girdle.

With the exception of the scapula the bones tend to be short and thick. The humerus has a large articulating surface for the clavicle. A groove and foramen are present for the tendon of the long head of the biceps. There are several large nutrient foramina present, the largest being in the olecranon fossa and in the radial groove.

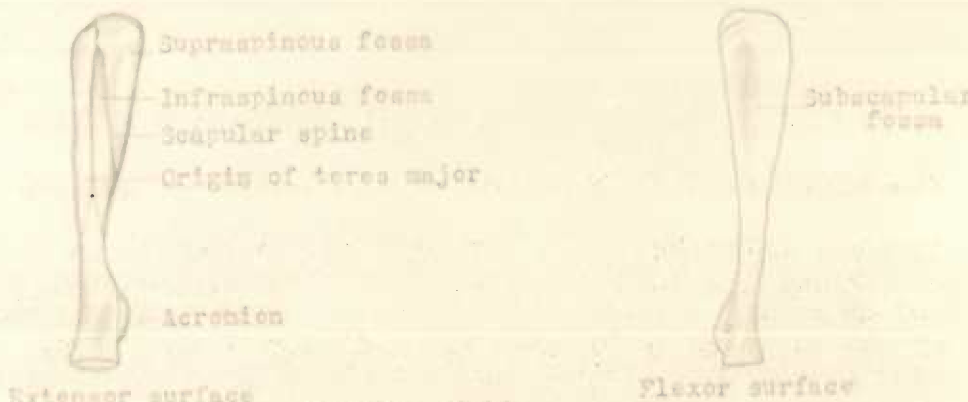
The scapula shows little resemblance to that of other mammals. The origin of the teres major is fairly large. The infraspinous fossa is small and contains the small infraspinatus muscle.

The clavicle is very short and thick and articulates with the humerus.

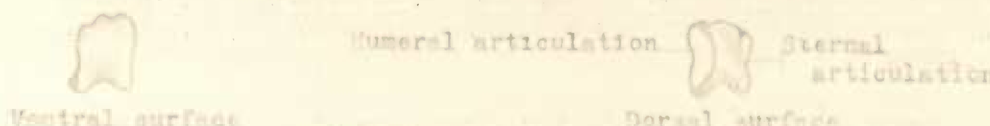
There is no evident supination or pronation of the forearm, though the radius and ulna are connected only by ligaments. The acromion is large and gives the triceps a mechanical advantage. The ulna articulates with the carpals.



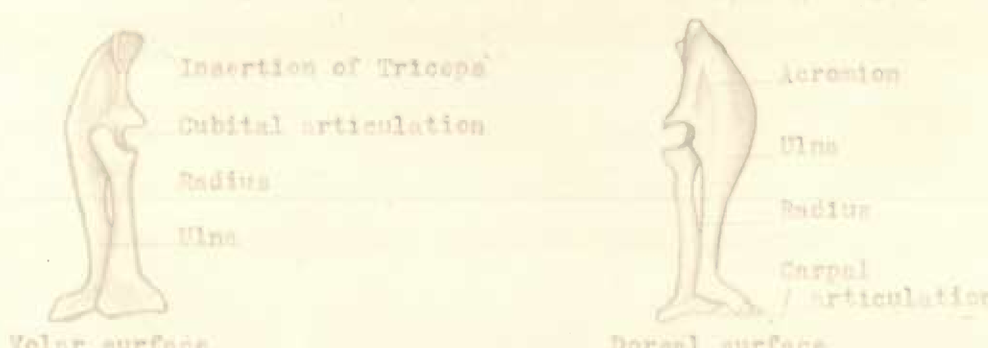
Humerus, right



Scapula, right



Clavicle, right



Radius and Ulna, right

Shoulder girdle, disarticulated
Western mole (Scapanus townsendii)

THE LONG EARED BAT (CORYNORHINUS)

The live weight of a series of bats (Corynorhinus) ranged from 8.76 to 10.15 grams. These bats were all females and were all obtained from one source. Out of a series of about thirty bats obtained in the course of three summers (for purposes other than the study of myology) only one male was found; his live weight was 6.2 grams, about two thirds the weight of the females.

The total dried muscle of the limbs weighs 368.5 milligrams, which is 3.9% of the live weight. This exceeds the ratios of the rat (2.67%), the cat (1.86%), the rabbit (1.57%), and the mole (2.45%). The upper limb musculature constitutes 88% of the total limb muscle mass; the lower limb only 12%. This distribution of mass is most closely approached by the mole with its 78.5% distribution in the upper limb and 21.5% in the lower. All these ratios show a marked contrast to those of the mammals discussed so far.

The pectoralis group is unusually large, constituting 39.5% of the total muscle mass. This far exceeds the percentages of the same muscle in any of the other animals, as inspection of the table of comparisons will show. The pectoralis major may be divided into two rather indefinite portions, an upper and a lower. At the site of approximate division a small fibre passes out to the patagial muscle. The pectoralis minor is merely a slender slip lying beneath the major.

The next largest muscle is the subscapularis, weighing 9.09% of the total muscle mass; then the serratus anterior with 8.15%, the combined antebrachial muscles with 6.73%; of the latter, the extensor muscles make up three fifths of the mass, the flexors only two fifths. It is evident that the extensor pollicis longus and the abductor pollicis longus contribute most of the weight of the extensor group and serve to draw the 'leading edge' of the manus forwards. Because the hand muscles of the bat are so extremely fine it was not possible to dissect these muscles out and be certain that only muscle tissue was removed; furthermore, the balances available were inaccurate at tenths of a milligram, and the weights of the hand muscles were confined to this small range. The abductor digiti quinti appears to be the largest of hand muscles. It extends up the ulnar side of the radius for a distance of about ten millimeters - about a fourth of the length of that bone. This muscle serves to oppose the action of the abductor and extensor pollicis, and draws the manus back against the antebrachium as in the position of rest. The origin of the muscle gives it a decided mechanical advantage that compensates for its relatively small size. The lumbricals are also at an advantage because the antero-posterior diameter of the carpals is increased.

There is an unusual muscle present in the bat that so far has been noted in only two other mammals - the duck-bill (Ornithorhynchus) and the Australian porcupine-anteater (Echidna). It is an accessory muscle adapted in the bat for flight, and here termed "patagialis." Its origin is principally on the occiput with an accessory origin on the upper border of the pectoralis. The patagialis is a slender muscle that extends over the top of the deltoid for a distance of about seven millimeters and then inserts into a long strand of elastic tissue. This strand passes the full length of the brachium and antebrachium to attach to the distal end of the radius. It serves as the anterior support for a fold of skin that increases the surface area of the membrane of flight when the forelimb is extended. The dry weight of this muscle is only 0.5 milligrams, and the muscle makes up only 0.14% of the limb musculature. It is evident that the weight of the muscle is not the criterion of its importance. Here again the site of origin has placed the muscle at a mechanical advantage that compensates for the poverty of muscle mass.

The muscles of the limbs tend to group their mass at the proximal ends of the long bones, while the tendons are slender and very long. It was found that there is relatively little variation in the sites of origin and insertion of the muscles of the bat as compared with the rat, but the natural positions of the limbs as well as the skeletal changes have altered somewhat the action and relationships of the muscles. The deltoid is in part synergistic with the pectoralis major. The clavicular origin of the deltoid overlies the clavicular origin of the pectoralis. The lower portion of the pectoralis has many fibres that are directly continuous with the rectus abdominus.

The muscle termed "costoscapularis" is probably an anterior slip of the rhomboid. The origin is on the anterior surfaces of the second, third and fourth ribs, just beneath and lateral to the origin of the serratus anterior. This slip passes over the shoulder, has a few fibrous insertions on the coracoid process on its way over, and passes on to insert with the levator scapulae and upper portion of the rhomboideus minor on the vertebral border of the scapula.

The subclavius is a wide, flat muscle, largely membranous at its origin on the tubercle of the first rib. The membranous tendon passes down to become continuous with the fascia covering the intercostal interspaces.

The levator scapulae is primarily a medial rotator of the scapula;

it is aided in this action by the costoscapularis, and is only secondarily an elevator of the scapula.

The two outstanding features of the myology of the pelvic girdle are the meagerness of the muscle mass and the modification of muscle action, secondary to the unique position of the femur (in external rotation , flexion, and marked abduction).

The largest muscle mass in the lower limb is the iliopsoas, which makes up 9.6% of the total muscle mass. This muscle lies outside of the body cavity in its lower portion. The second largest mass is the hamstring group with 9.4%. The constituents are the semitendinosus, semimembranosus, and gracilis. There is no sartorius. The position of abduction of the thigh brings the wide gracilis to a functionally important position. There is no biceps femoris or any muscle to replace it other than a few fine fibres of the quadriceps femoris that lie on the lateral side of the popliteal vessels and that insert along the lateral side of the tibia.

The next largest group consists of the adductors, in which is here included the adductors longus, brevis and magnus, the pectineus, and the caudofemoralis. This group totals 8.0% of the muscle mass.

No tensor fascia lata is to be found. The division between the lesser glutei is indistinct and separation inaccurate. The rectus femoris is the major constituent of the quadriceps femoris. The small external rotators of the thigh could not be removed with accuracy, and undoubtedly some of the muscle fibres were left in the surrounding fascia in the dissections. This was evident by the inconsistencies of the weights of this group in the different bats. The caudofemoralis is well developed and serves as a muscle of flight, acting on both the femur and the caudal vertebrae.

The outstanding adaptation of the skeletal structure of the bat is the lengthening of the bones used in flight. The humerus has along its antero-lateral border a long and very prominent ridge that corresponds to the deltoid tuberosity of other animals. It is about five millimeters long and serves as the point of insertion of the pectoralis major as well as the deltoid.

The ulna consists solely of a small spicule of bone. It is only seven millimeters long, and of this length the olecranon process constitutes more than half. The ulna is attached to the radius only by ligaments and without ossification. There is a limited supination and pronation of the radius in the radiohumeral articulation, extending over a range of about ten degrees. The carpus is set at a marked ulnar abduction so that the fifth phalanx can be brought to lie parallel with the antebrachium. This position allows a motion analogous to pronation and supination, but actually is a flexion and extension through the carpus. All the phalanges are long except the thumb, which is short, grasping, and has a sharp claw.

The shape and structure of the trunk has also altered the function of the limbs. There is a marked kyphosis of the spine from the first few cervical to the first caudal vertebrae; this forms a complete semicircle that subtends a diameter of about 3.2 centimeters. The ventral thoracic and abdominal wall lies along this diameter, the xyphoid process lying at the central point. The first three cervical vertebrae show marked lordosis that brings the head into the proper plane. The vertebrae are successively smaller, from first cervical to terminal caudal.

As in the mole and as in most bats, there is no pubic symphysis. However, the pubis lies at a distance ventrally from the acetabulum and thus gives a greater mechanical advantage to the adductors of the thigh. The femur is at right angles to the pelvis and is directed dorsally with an external rotation. The digits are all short and all have claws. The hallux lies parallel with the other digits. There are nine caudal vertebrae, long and slender. They support the caudal portion of the flying membrane that extends from the lower limbs.

TABLE IX

<u>Corynorhinus</u> Upper limb muscles	Average dry weight in a 9.42 gms bat	Percent of body weight (times 10^{-2})	Percent total limb muscle wt. (368.5gms)
Trapezius	16.6 mg	17.6%	4.50%
Upper	14.2		
Lower	2.4		
Latissimus dorsi	5.7 mg	6.0%	1.55
Levator scapulae	4.5 mg	4.8	1.22
Rhomboideus	3.5 mg	3.7	0.95
Sternocleidomastoid	3.0 mg	3.2	0.82
Pectoralis	145.2 mg	154.5	39.50
Major, upper	39.5		
Major, lower	94.4		
Minor	4.1		
Costoscapularis	7.2		
Patagiala	0.5 mg	0.5	0.14
Subclavius	2.2 mg	2.3	0.60
Serratus anterior	30.0 mg	32.0	8.15
Deltoid	10.1 mg	11.7	2.99
Supraspinatus	3.0 mg	3.2	0.82
Infraspinatus	15.8 mg	16.8	4.30
Deep	8.4		
Superficial	7.4		
Teres minor	0.3 mg	0.3	0.08
Teres major	3.7 mg	3.9	1.00
Subscapularis	33.5 mg	35.6	9.09
Biceps brachii	12.7 mg	13.5	3.45
Long	7.6		
Short	5.1		
Brachialis	0.3 mg	0.3	0.08
Coracobrachialis	0.7 mg	0.7	0.19
Triceps	10.5 mg	11.1	2.84
Forearm muscles	24.8 mg	26.4	6.73
Flexors	9.7		
Extensors	16.1		

TABLE X

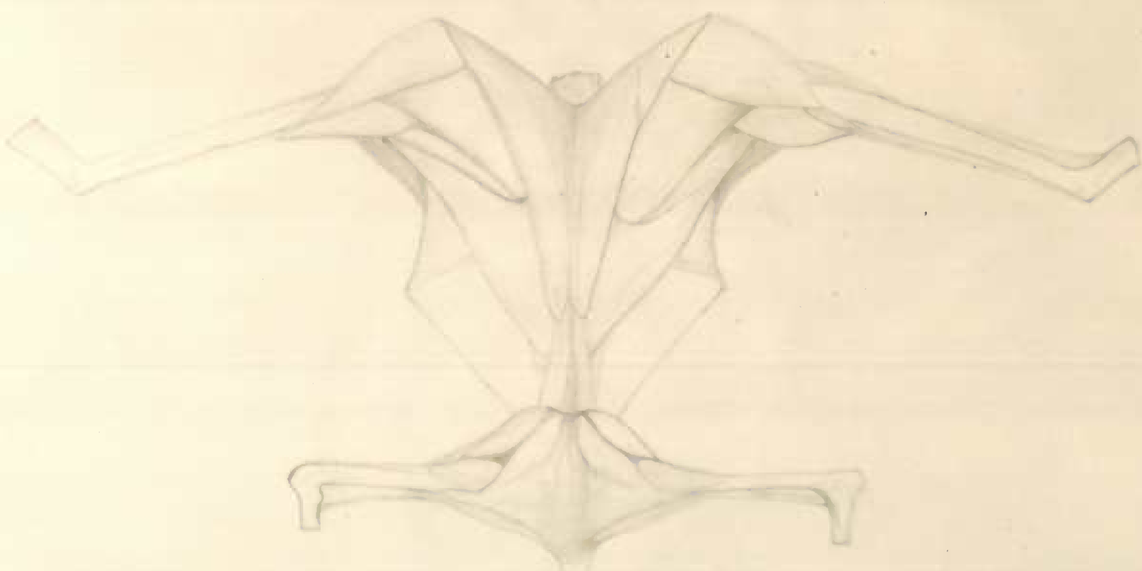
Corynorhinus Lower limb muscles	Average dry weight in a 9.42 gm. bat	Percent of body weight (times 10^{-2})	Percent total limb muscle wt. (368.5gms)
Iliopsoas	9.6 mg	10.2%	2.60%
Iliacus	4.1		
Psoas	5.4		
Gluteus maximus	3.6 mg	3.8	0.98
Lesser glutei	3.3 mg	3.5	0.90
Small external rotators	1.3 mg	1.4	0.35
Hamstring muscles	9.4 mg	10.0	2.55
Semitendinosus	2.3		
Semimembranosus	3.4		
Gracilis	3.7		
Quadriceps femoris	4.0 mg	4.3	1.09
Adductors of the thigh	8.0 mg	8.5	2.16
Adductor longus	2.0		
Adductor brevis	0.5		
Adductor magnus	3.0		
Pectineus	1.5		
Caudofemoralis	1.0		
Lower leg muscles	5.7 mg	6.1	1.55
Peronei long and short	1.0		
Dorsiflexors	1.2		
Plantar flexors	2.0		
Calf muscles	1.7		
Total upper limb	323.6 mg	3.45%	89.00%
Total lower limb	44. 9 mg	0.48%	12.18%
Total both limbs	368.5 mg	3.927%	100 % (-1.18)

Plate VIII Long eared bat (Corynorhinus rafinesquii) X 3

Note the relative masses of the fore and hind limbs, the long tendons, the long and slender limb bones, the position of abduction and flexion of the lower limbs.

The muscles of the hind limb can not be very clearly indicated in this drawing.

Long eared bat
(Corynorhinus rafinesquii)
Ventral aspect

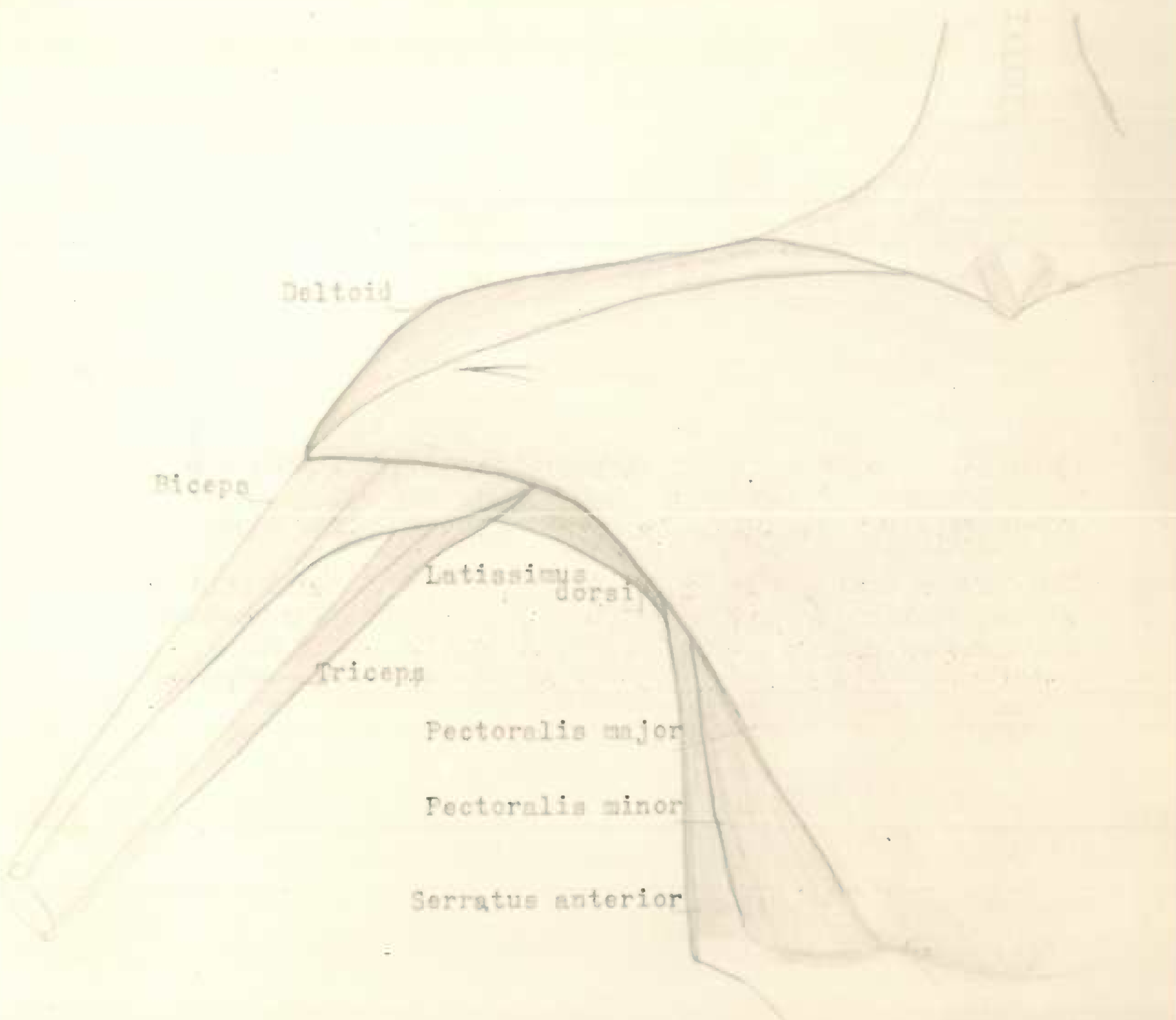


Long eared bat
(Corynorhinus rafinesquii)
Dorsal aspect

Plate IX   Long eared bat (Corynorhinus rafinesquii) X 8

Anterior aspect of superficial musculature of upper limb.

Note the unusually large pectorals. There is a small slip of muscle fibres on the upper lateral portion of the pectoral that sends a slender strand of connective tissue to the patagiale, supporting the leading edge of the wing membrane.

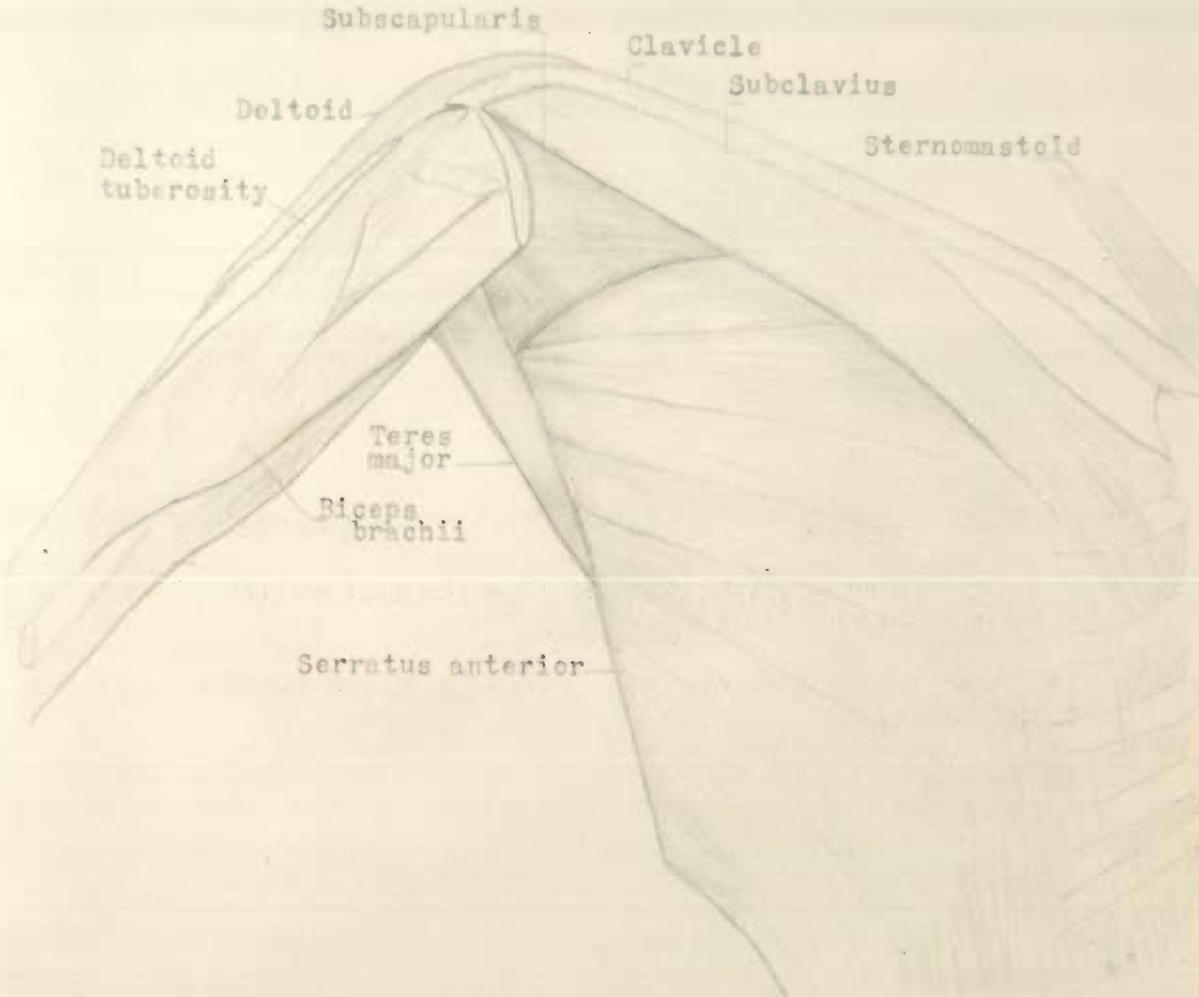


Long eared bat (Corynorhinus rafinesquii)
Superficial musculature; anterior aspect

Plate X Long eared bat (Corynorhinus rafinesquii) X 8

Anterior aspect of upper limb with the pectoralis and clavicular deltoid removed.

The shoulder has been retracted laterally to expose the subscapularis.



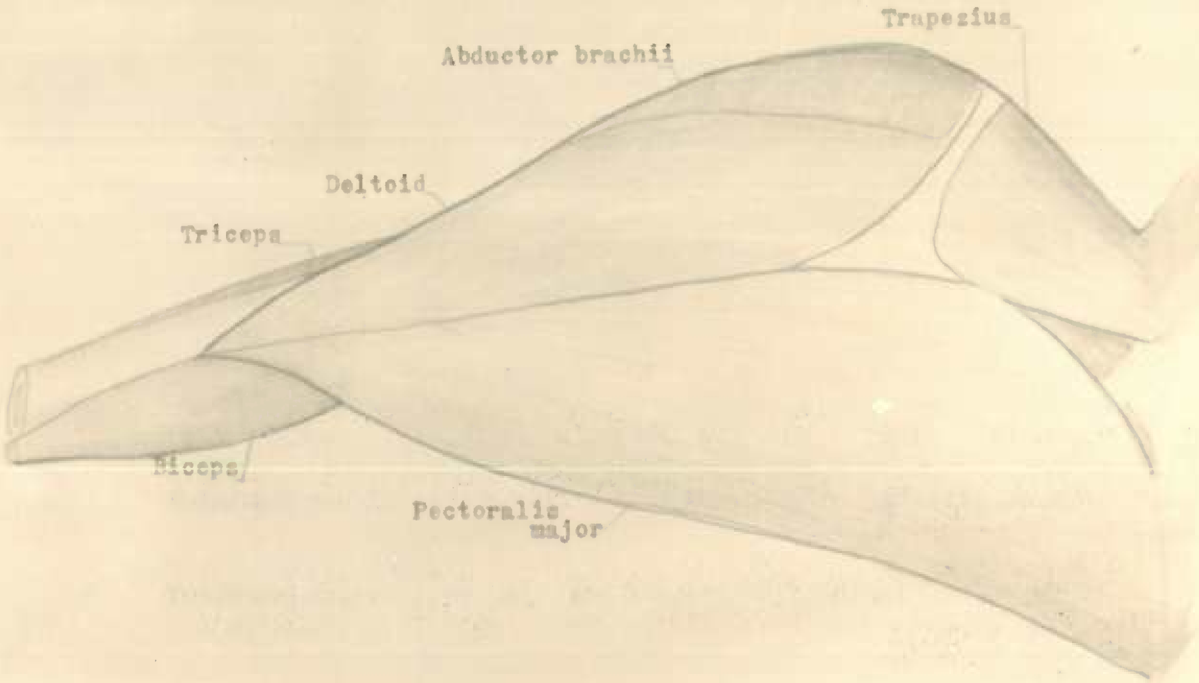
Long eared bat (Corynorhinus rafinesquii)

Ventral aspect; pectorals and clavicular deltoid removed

Plate XI Long eared bat (Corynorhinus rafinesquii) X 8

Cranial aspect. The bat is decapitated for better exposure of the muscles.

The shoulder is wide and tapering. The clavicular portions of the deltoid and pectoralis are synergetic in abduction of the humerus.

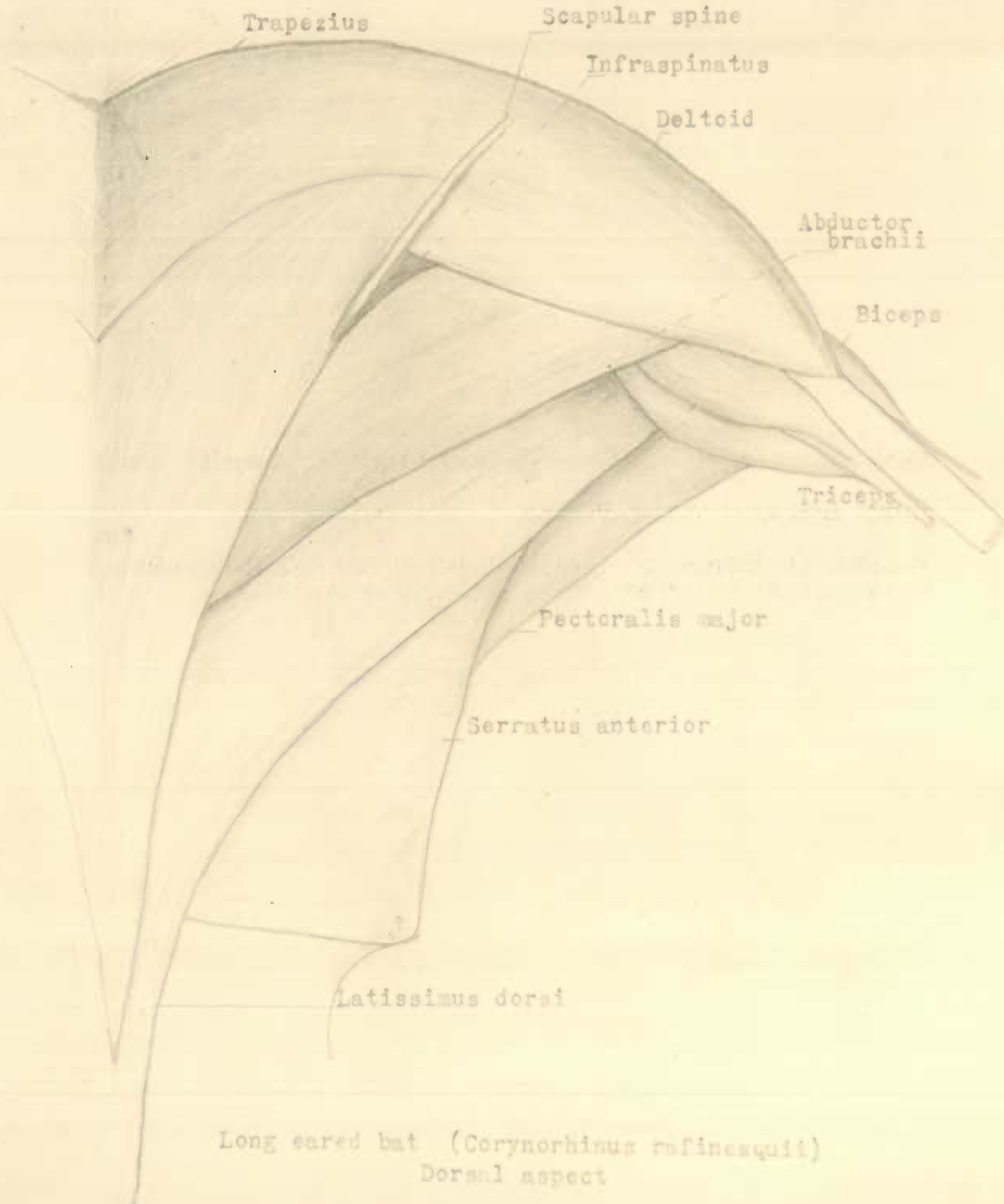


Long eared bat (Corynorhinus rafinesquii)
Cranial aspect

Plate XII   Long eared bat (Corynorhinus rafinesquii) X 8

Dorsal aspect of the upper limb

The abductor brachii is accessory to the deltoid, lies deep to the latter, and superficial to the infraspinatus.

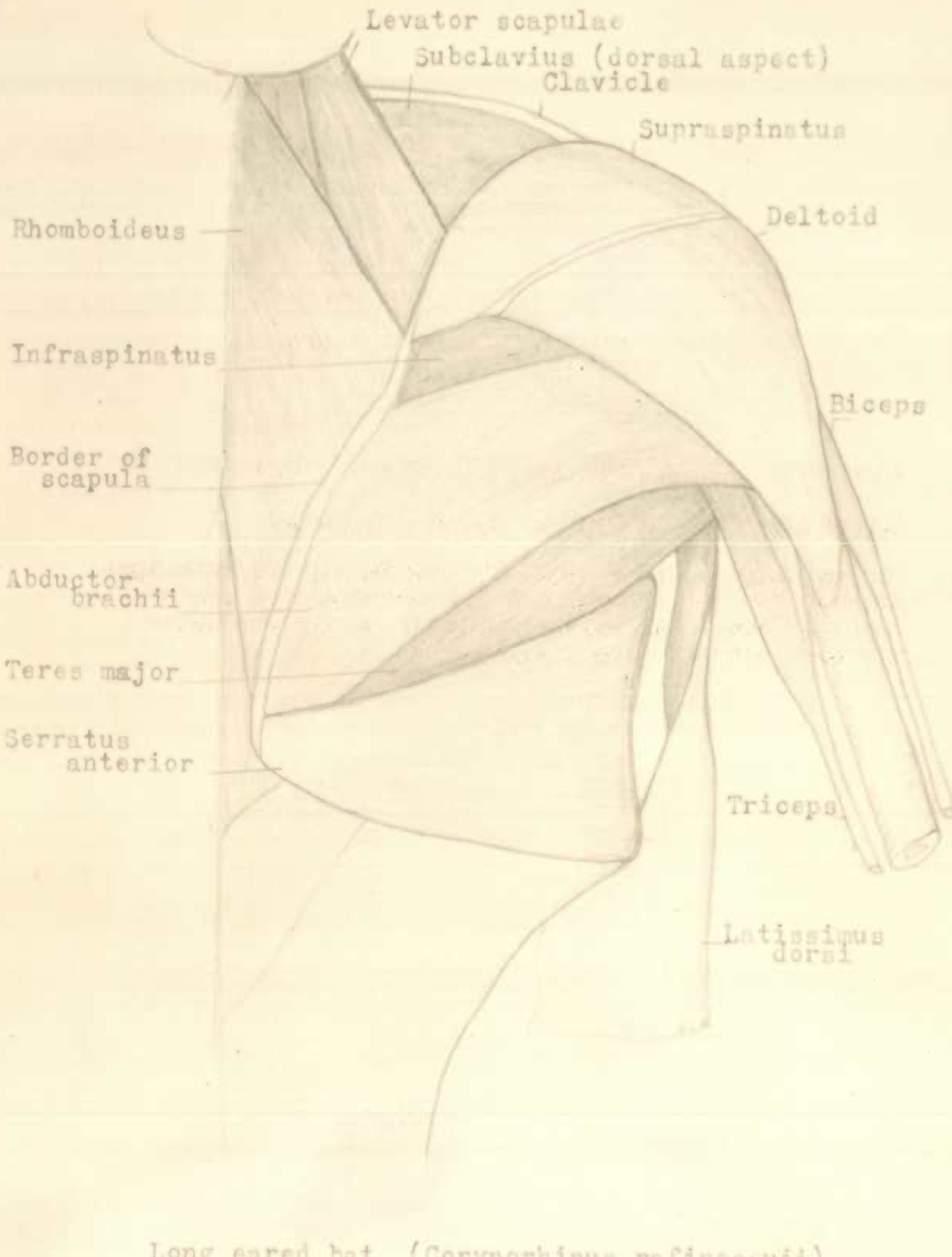


Long eared bat (Corynorhinus rafinesquii)
Dorsal aspect

Plate XIII Long eared bat (Corynorhinus rafinesquii) X6

Dorsal aspect of upper limb. Deeper musculature.

The trapezius has been completely removed and the latissimus dorsi reflected. This exposes the rhomboids, the levator scapulae, the dorsal aspect of the subclavius, the supraspinatus, and the teres major.



Long eared bat (Corynorhinus rafinesquii)

Dorsal aspect: trapezius removed, latissimus dorsi reflected

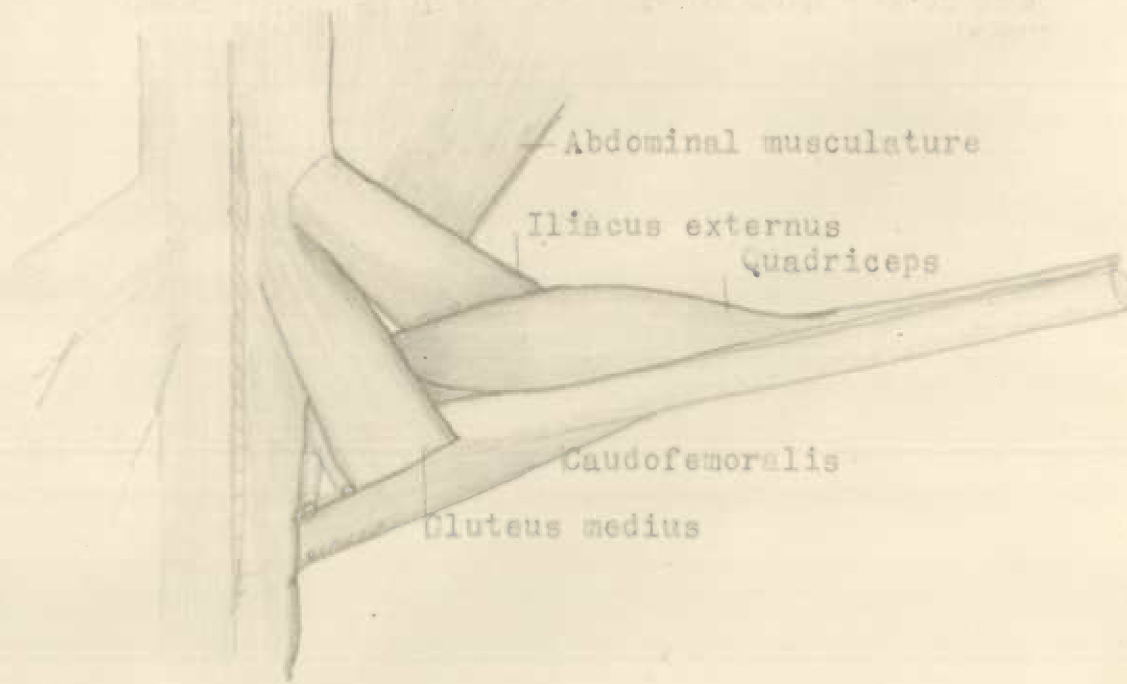
Plate XIV   Long eared bat (*Corynorhinus rafinesquii*) X 8

Dorsal aspect of the lower right limb, superficial and deep musculature.

Note the size of these muscles as compared to those of the previous drawings.

There is an external iliacus present. The muscle labeled "gluteus medius" is termed "gluteus tertius" by Macalister. There is no gluteus minimus. The caudofemoralis is fairly large.

Hind leg, right. Superficial musculature, dorsal
Long eared bat (Corynorhinus rafinesquii)

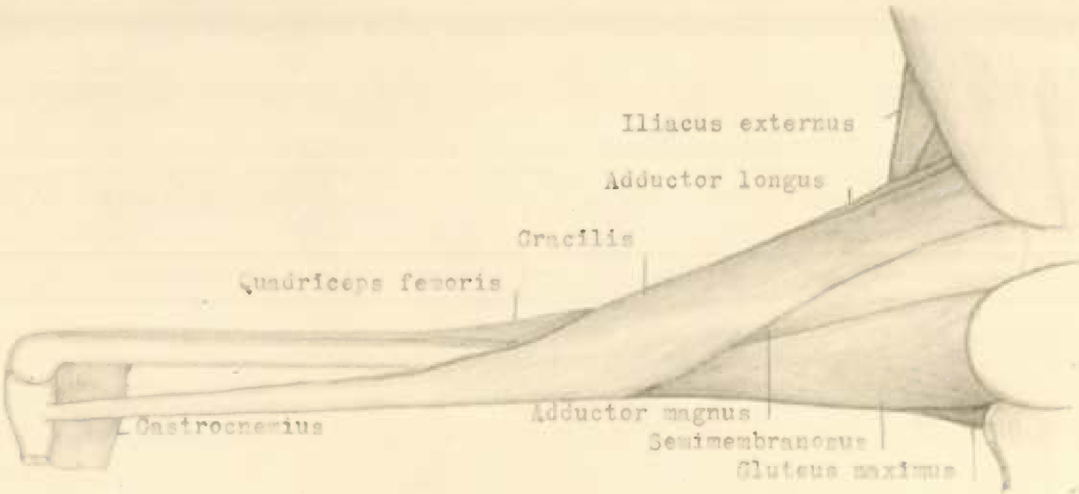


Hind leg, right. Deep musculature, dorsal
Long eared bat (Corynorhinus rafinesquii)

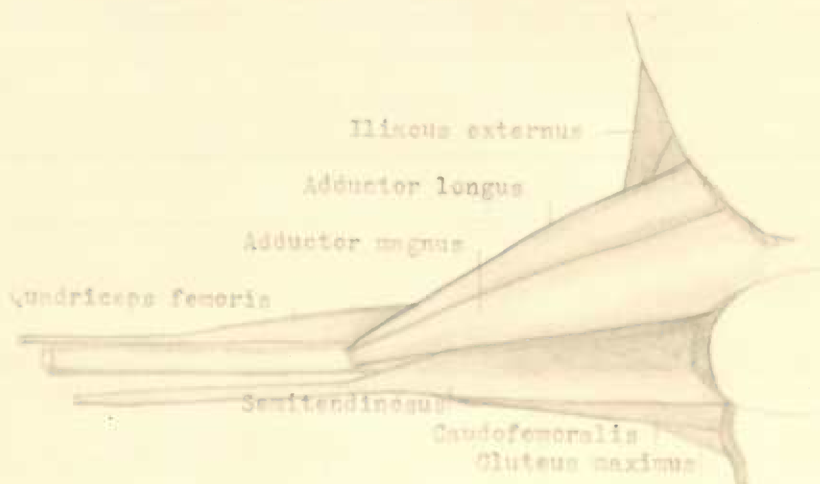
Plate XV   Long eared bat (Corynorhinus rafinesquii) X 8

Ventral aspect of the lower right limb, superficial and deep musculature.

Note the absence of a biceps femoris and sartorius.



Hind leg, right. Superficial musculature, ventral
Long eared bat (Corynorhinus rafinesquii)



Hind leg, right. Deep musculature, ventral
Long eared bat (Corynorhinus rafinesquii)

THE SHORT EARED BAT (MYOTIS)

Several differences were noted between the Myotis and the Corynorhinus, though the variations were not sufficiently great so as to be detected by dissection alone.

The average live weight of the Myotis is 6.3 grams; of the Corynorhinus, 9.4 grams (females of both species). The total dry muscle weight of the limbs is 151.5 milligrams in the Myotis, in the Corynorhinus, 368.5. There is evident therefore a relatively greater muscle mass per body weight in the larger bat, the Corynorhinus. The dried muscle mass of the Myotis constitutes 2.4% of the body weight; of the Corynorhinus, 3.9%. The distribution between limbs is about 90% in the upper and 10% in the lower limb; the Corynorhinus shows an 88% - 12% distribution.

The muscles of the two bats may be compared as follows;

Muscles greater in the Corynorhinus include:

<u>All</u> lower leg muscles

A few upper limb muscles, including;

Forearm muscle mass
Biceps brachii
Deltoid
Trapezius
Subclavius

Muscles greater in the Myotis include:

Most upper limb muscles, including;

Subscapularis
Serratus anterior
Pectoralis group
Latissimus dorsi
Supraspinatus
Triceps
Rhomboids
Levator scapulae
Patagialis

Because all specimens of the Myotis were decapitated it was not possible to compare the weights of the eviscerated and skinned animals. Fortunately all the bats had been weighed before decapitation. No sternocleidomastoid muscle weights were obtainable because of the decapitation. The trapezius was found to be intact in most cases. The Teres minor and brachialis muscles could not be distinguished and were therefore omitted from the tables. It is most likely that these fibres were included in the surrounding muscles, though they may have passed unrecognized in the connective tissues.

Note that the forearm and biceps muscle mass of the Myotis is decidedly less than that of the Corynorhinus, although the triceps is slightly greater in the former.

Although all the lower limb muscles are greater in the Corynorhinus, the ratios of the lower leg muscle masses are very similar. The adductors of the thigh show the greatest difference, and are the greater in the Corynorhinus.

TABLE XI

Myotis Upper limb muscles	Average dry weight in a 6.3 gram bat	Percent of body weight (times 10^{-2})	Percent total limb muscle wt. (151.5mg)
Trapezius	6.7 mg	10.6%	4.43%
Upper	5.4		
Lower	1.3		
Latissimus dorsi	3.1 mg	4.9	2.02
Levator scapulae	2.2 mg	3.5	1.45
Rhomboideus	1.6 mg	2.5	1.05
Pectoralis group	61.4 mg	97.6	40.53
Major, upper	13.6		
Major, lower	42.3		
Minor	1.4		
Scaphocostalis	3.7		
Patagialis	0.3 mg	0.5	0.20
Subclavius	0.8 mg	1.3	0.53
Serratus anterior	14.6 mg	23.2	9.64
Deltoid	3.7 mg	5.9	2.44
Supraspinatus	1.6 mg	2.5	1.05
Infraspinatus	6.5 mg	10.6	4.29
Deep	3.9		
Superficial	2.6		
Teres minor			
Teres major	1.2 mg	1.9	0.79
Subscapularis	15.9 mg	25.2	10.50
Biceps brachii	3.8 mg	6.0	2.50
Brachialis			
Coracobrachialis	0.5 mg	0.8	0.33
Triceps	4.5 mg	7.2	2.97
Forearm muscles	7.6 mg	12.1	5.01
Flexors	1.8		
Extensors	5.8		

TABLE XII

Myotis Lower limb muscles	Average dry weight in a 6.3 gms bat	Percent of body weight (times 10^{-2})	Percent total limb muscle Wt. (151.5mg)
Iliopsoas	3.7 mg	5.9%	2.44%
Iliacus	1.4		
Psoas	2.3		
Gluteus maximus	1.4 mg	2.2	0.93
Lesser glutei	1.3 mg	2.6	0.86
Small external rotators	0.6 mg	1.0	0.40
Hamstring muscles	2.3 mg	3.7	1.52
Semitendinosus	0.5		
Semimembranosus	0.9		
Gracilis	0.9		
Quadriceps femoris	1.3 mg	2.1	0.86
Adductors of the thigh	2.6 mg	4.1	1.72
Longus & brevis	0.3		
Magnus	1.4		
Pectineus	0.7		
Caudofemoralis	0.2		
Lower leg muscles	2.3 mg	3.7	1.52
Dorsiflexors	0.9		
Plantar flexors	1.2		
Calf muscles	0.2		
Total, upper limb	136.0 mg	2.16%	89.73%
Total, lower limb	15.5 mg	0.25%	10.25%
Total, both limbs	151.5 mg	2.41%	100% (-0.02)

SUMMARY

An attempt is here made to compare the muscle masses of the limbs in six series of specialized mammals. The purpose is to obtain data for the comparison of muscle mass with cerebellar lobes and fissures. The animals dissected included the rat, cat, rabbit, mole, and two species of bats. The weights of the muscle groups about the limbs of the various animals is expressed in two ways: in percent of total limb muscle mass; and in percent of live weight of the animal.

Because the moisture content of the muscles produced errors and variations in weights, all muscles were dried till no significant change in weight was evident. As a rule the wet muscle was found to weigh from four to four and a half times the weight of the dry. Fat was dissolved from the muscle tissue by means of xylol.

The distribution of muscle mass between the fore and hind limbs was found to be approximately as follows:

Limb	Rat	Cat	Rabbit	Mole	Myotis	Corynor.
Fore. .	36%	49%	32%	77%	90%	88%
Hind. .	64%	51%	68%	23%	10%	12%

The percent of total dried limb muscle tissue per body weight can be compared as follows:

Rabbit	Cat	Myotis	Mole	Bat	Corynorhinus
2.12%	3.72%	4.84%	4.90%	5.36%	7.86%

The above figures, arranged according to degree, show the rabbit to be the least and the Corynorhinus to be the most muscular of the mammals studied.

The cat shows a fairly equal distribution of muscle mass without any one group outstanding over that of the other mammals here studied. It also shows a generalization of dexterity and function of limbs without a particular or outstanding specialization.

The rat has a relatively large hind limb muscle mass that lies particularly in the hamstrings, the glutei, and the muscles of the shank. The mass of the forelimb is about half that of the hind.

The rabbit has also a relatively large hind limb muscle mass. This lies particularly in the hamstrings, though is fairly well distributed about the lower limb. The adductors are in the rabbit twice the mass in the rat; otherwise the hind limb groups of these two animals are very nearly equal. Most of the groups in the forelimb are very much below the ratios of mass in comparison with the other animals.

The mole has a very large teres major; there is also a large pectoralis group and a large subscapularis. The pectorals, although much larger than the same group in most other mammals, is still much smaller than the pectoral group of the bats. The Trapezius, rhomboids, latissimus dorsi, and triceps are all somewhat larger than the same in the other mammals studied.

Both species of bats studied show remarkably large pectorals. Various small differences exist between the muscle masses of the two bats, but none are very outstanding. The hamstring muscles of the Corynorhinus are larger than those of the Myotis at a ratio of 5:3. The adductor group is also definitely larger in the Corynorhinus. With a few exceptions, the fore limb muscles are relatively larger in the Myotis; the hind limbs are relatively larger in the Corynorhinus.

Because there is no available anatomical description of the bat or mole it has been necessary to include a brief discussion of the myology of these animals and to identify with illustrations the muscles of the limbs.

In the following summaries of tabulations the muscle masses are arranged in corresponding groups and according to function as near as possible. A direct comparison of ratios of muscle groups in the different species can be made.

Interpretation is simplest in terms of percent per total muscle weight. The tabulations in percent per live body weight are confusing because the amount of total limb muscle per body weight is so exceedingly variable in the different species, as indicated above, and ranges from 2.12% to 7.86%.

TABLE XIII

Summary of Tabulations, Expressed in Percent of Total Limb Muscle Weight

Muscle groups	Rat	Cat	Rabbit	Mole	Myotis	Corynorhinus
Trapezius Sternocleidomastoid Rhomboids	6.81%	5.30%	3.30%	9.43%	4.43%	5.45%
Latissimus dorsi	4.00	4.39	2.59	6.35	2.02	1.55
Levator scapulae Serratus anterior	3.68	4.28	3.47	3.25	10.69	9.10
Pectoral group Subclavius Patagials	5.03	6.00	5.45	15.49	42.26	40.24
Deltoid Supraspinatus Infraspinatus Teres minor Teres major Subscapularis	7.47	12.64	8.15	28.48	19.07	18.28
Biceps brachii Brachialis anticus Coracobrachialis	1.44	2.34	1.26	3.80	2.83	3.72
Triceps	4.99	7.10	5.04	8.48	2.97	2.84
Antebrachial muscles	4.42	7.66	3.22	5.09	5.01	6.73
Iliopsoas	5.57	3.46	6.08	1.86	2.44	2.60
Gluteal muscles Tensor fascia lata Deep rotators	12.84	6.12	10.80	3.66	2.19	2.23
Quadriceps femoris	9.05	8.67	11.04	3.56	0.86	1.09
Biceps femoris Semitendinosus Semimembranosus Gracilis Sartorius Tensor fascia cruris	18.40	15.10	17.84	5.40	1.52	2.55
Thigh adductors Pectineus Caudofemoralis	5.11	5.41	11.45	2.36	1.72	2.16
Peronaei Dorsiflexors Plantar flexors Calf muscles	13.50	12.50	1[illegible].40	4.50	1.52	1.55

TABLE XIV

Summary of Tabulations, Expressed in Percent of Body Weight ($\cdot 10^{-2}$)

Muscle groups	Rat	Cat	Rabbit	Mole	Myotis	Corynorhinus
Trapezius Sternocleidomastoid Rhomboids	16.3%	9.9%	5.7%	23.3%	13.1%	24.5%
Latissimus dorsi	9.5	8.2	4.1	15.7	4.8	6.0
Levator scapulae Serratus anterior	8.7	7.9	5.6	8.1	26.7	36.8
Pectoral group Subclavius Patagials	11.9	15.5	8.6	38.2	99.4	157.3
Deltoid Supraspinatus Infraspinatus Teres minor Teres major Subscapularis	17.2	22.0	13.1	70.1	46.1	71.5
Biceps brachii Brachialis Coracobrachialis	3.4	4.3	2.0	9.3	6.8	14.5
Triceps	11.9	13.3	7.9	20.4	7.2	11.1
Antebrachial muscles	10.5	14.4	4.8	12.5	12.1	26.4
Iliopsoas	13.3	6.5	9.5	4.6	5.9	10.2
Gluteal muscles Tensor fascia lata Deep rotators	30.6	11.5	16.9	8.0	5.8	8.7
Quadriceps femoris	21.5	16.4	17.3	8.8	2.1	4.3
Biceps femoris Semitendinosus Semimembranosus Gracilis Sartorius Tensor fascia cruris	42.0	28.4	28.0	13.4	3.7	10.0
Thigh adductors Pectineus Caudofemoralis	12.2	10.2	17.9	5.8	4.1	8.5
Peronaei Dorsiflexors Plantar flexors Calf muscles	31.3	23.4	16.3	11.3	3.7	6.1

The five outstanding muscle groups of each species studied and the masses expressed in percent of total limb muscle weight are arranged in sequence of size of muscle mass as follows:

Rat

Hamstring muscles (Biceps, etc.)	18.40%
Shank muscles (Peronaei, etc.)	13.50
Gluteus group and deep rotators	12.84
Quadriceps femoris	9.05
Scapular muscles	7.47

Cat

Hamstring muscles (Biceps, etc.)	15.10%
Scapular muscles (Deltoid, etc.)	12.64
Shank muscles (Peronaei, etc.)	12.50
Quadriceps femoris	8.67
Forearm muscles	7.66

Rabbit

Hamstring muscles (Biceps, etc.)	17.84%
Adductor muscles of the thigh	11.45
Quadriceps femoris	11.04
Gluteal group and deep rotators	10.80
Shank muscles (Peronaei, etc.)	10.40

Mole

Scapular muscles (Deltoid, etc.)	28.48%
Pectoral group	15.49
Trapezius group	9.43
Triceps	8.48
Latissimus dorsi	6.35

Myotis

Pectoral group	41.26%
Scapular muscles (Deltoid, etc.)	19.07
Serratus anterior & levator scapulae	10.69
Forearm muscles	5.09
Trapezius group	4.43

Corynorhinus

Pectoral group	40.24%
Scapular muscles (Deltoid, etc.)	18.28
Serratus anterior & levator scapulae	9.10
Forearm muscles	6.73
Trapezius group	5.45

BIBLIOGRAPHY

von Bardeleben, Karl (Editor) Handbuch der Anatomie des Menschen
Volumes II/2 Teil 1; II/2 Teil 2a & 2b
Gustav Fischer, Jena 1908 - 1912

Bensley, B.A. Practical Anatomy of the Rabbit
University Press, Toronto P. Blakiston 1910

Campbell, Berry "The shoulder anatomy of the moles. A study in phylogeny and adaptation."
American Journal of Anatomy, Vol. 64, No.1; Jan.'39

Coues, Elliot Osteology and Myology of Didelphys Virginiana
Memoirs of the Boston Society of Natural History
Volume 11; Part 1. Number XII 1872

Cunningham, Daniel Johannes Textbook of Anatomy
Edited by Arthur Robinson Fifth Edition
Oxford University Press New York 1931

Davison, Alvin Mammalian Anatomy with special reference to the Cat
Revised by Frank A. Stromsen Sixth Edition
P. Blakiston's son & Co. Philadelphia 1937

Donaldson, Henry H. The Rat. Reference Tables and Data
Memoirs of the Wistar Institute of Anatomy and Biology
Number 6 Philadelphia 1915

Ellenberger, W. and Baum, H. Anatomie des Hundes
Paul Barney Berlin 1891

Freeman, R. Austin "The Anatomy of the shoulder and upper arm of the mole (Talpa europaea)"
Journal of Anatomy and Physiology, Normal and Pathological
Volume XX Part 2 January 1886

Gegenbauer, Carl Vergleichende Anatomie der Wirbelthiere
Wilhelm Engelmann Leipzig 1898

Gray, Henry Anatomy, Descriptive and Surgical
Edited by W.W. Keen A new American from the eleventh English edition Lea Brothers and Co. Philadelphia 1887

Green, Eunice Chace Anatomy of the Rat
Transactions of the American Philosophical Society
Philadelphia 1935

Hamaker, Webb Manuscript

Horsburgh, David B. and Heath, James P. Atlas of Cat Anatomy
Stanford University Press
Stanford University, California 1938

Howell, A. Brazier "The phylogenetic arrangement of the muscular system." The Anatomical Record
Volume 66 Number 3 October 1938

Kingsley, J.S. Textbook of Vertebrate Zoology
Henry Holt and Company New York 1908

Larsell, O. Textbook of Neuroanatomy and the Sense Organs
D. Appleton-Century Company, Incorporated
New York, London 1939

--------- "Comparative morphology of the membranous labyrinth and lateral line organs in their relation to the development of the cerebellum."
The Cerebellum Chapter VII
Association for Research in Nervous and Mental Disease
Volume VI Williams Wilkins Company 1929

--------- and Dow, Robert Stone "The development of the cerebellum in the bat (Corynorhinus) and certain other mammals."
Journal of Comparative Neurology
Volume 62 Number 2 October 15, 1935

Macalister, Alexander An Introduction to the Systematic Zoology and Morphology of Animals
Printed at the University Press Dublin 1878

Mackenzie, William C. Action of Muscles
Paul Hoeber, Inc. 1930

McMurrich, J.P. The Development of the Human Body; a Manual of Human Embryology
P. Blakiston's son and Co. 1923

Piersol, George A. (Editor) Human Anatomy
J.B. Lippincott Company Philadelphia and London 1923

Reighard, J. and Jennings, H.S. Anatomy of the Cat
Henry Holt and Company New York 1901

Riley, Henry Alsop "The mammalian cerebellum. A comparative study of the arbor vitae and folial pattern."
The Cerebellum Chapter II
Association for Research in Nervous & Mental Disease
Volume VI Williams Wilkins Company

Ritchie, Arthur David   The Comparative Physiology of Muscular
        Tissue   The University Press 1928

Sisson, Septimas   A Textbook of Veterinary Anatomy
        W.B. Saunders Co.   Philadelphia and London   1910

--------- The Anatomy of Domestic Animals
        W.B. Saunders Co.   Philadelphia and London 1914

Weisenburg, Theodore H.   "Cerebellar localization and symptomatology."
        The Cerebellum   Chapter XVIII
        Association for Research in Nervous and Mental Disease
        Volume VI   The Williams and Wilkins Company, Baltimore '29

Wiedersheim, R.   Comparative Anatomy of Vertebrates
        MacMillan and Company   New York   1907

Wilder, Harris, Hawthorne   The History of the Human Body
        Henry Holt and Company   New York   1923