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A myological and osteological comparison of the pelvic appendage of the male and female western meadowlark

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A MYOLOGICAL AND OSTEOLOGICAL COMPARISON OF THE PELVIC APPENDAGE OF THE MALE AND FEMALE WESTERN MEADOWLARK

A Thesis

Presented to

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Master of Science in Biology

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by

Thomas Felix Sourisseau Jr.

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is approved for recommendation to the

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Lee Christianson, Chairman

June Mathias

M. Malloney

Dated 20 April, 1970

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Chapter 1

INTRODUCTION

Sexual dimorphism has been noted to exist in many genera of birds, but it is not until recently that papers have appeared which deal with the actual extent of sexual dimorphism and its possible adaptive significance. The papers of Rand (1952), Sibley (1957), Amadon (1959), and Selander (1966) hypothesize about the possible significance of sexual dimorphism in birds, and the papers of Kilham (1965), Selander (1965), Storer (1966), Ligon (1968), Ingolfsson (1969), and Verner and Willson (1969) examine the relationship between hypotheses on the significance of sexual dimorphism and actual field conditions. None of these papers deals with differences in bone or muscle ratios which may exist between the sexes. A paper by Engels (1938a) on variation in bone length and limb proportion in the coot does examine differences in bone length and limb proportions due to sex, but only in a very cursory manner.

It appears that only the most obvious and well-known sexually dimorphic birds, i.e. woodpeckers, birds-of-paradise, accipitrines, have been studied. In this paper my purpose is to ascertain osteological and myological differences between the sexes of a bird which

does not have a great deal of apparent sexual dimorphism--
Sturnella neglecta neglecta Audubon, A.O.U. 501.1 (American
Ornithologists' Union, 1957).

Chapter 2

MATERIALS AND METHODS

Twenty preserved field collected specimens (10 male and 10 female) of *Sturnella n. neglecta* were used in this study. The specimens were preserved by injecting them with and immersing them in an embalming fluid of the following composition (courtesy of William George, Southern Illinois University):

Formalin	750 cc	
Ethanol (95%)	500 cc	
Glycerin	100 cc	
Phenol	100 cc	
Chloral hydrate	300 gm	dissolved in warm water before use
Sodium sulphate	500 gm	
Water	10 l	

Prolonged immersion in the embalming fluid resulted in some decalcification and muscular shrinkage, but not enough to interfere with the dissections. In the dissections a binocular dissecting scope with an adjustable 7 to 30x objective lens was used. During the dissections drawings of the normal arrangement of the muscles and bones were made twice life-size. After the individual muscles were removed they were stored in a solution of 70% methyl alcohol until they were weighed.

Storage of the dissected muscles in 70% methyl alcohol results in dissolution of muscle fats, but the muscle weights are of importance only when related to one another. Since the average weight of a particular muscle was used as an index of the force of that muscle and not as an absolute measurement of the force, I felt that the absence of the weight of the muscle fats would not affect the interpretation of the data. All identical muscles from the various individuals of the same sex were combined in one vial and the average weight of the muscle was determined.

In the determination of the muscle weight an attempt was made to use only muscle tissue; all large nerves, major blood vessels, and tendons were removed. The muscles were placed in an aluminum foil pan, dried for 70 hours at 70 C and cooled for 25 minutes before weighing. Weights were determined on a torsion balance accurate to one-thousandth of a gram.

Sixty disarticulated museum skeletons (30 male and 30 female) of *Sturnella n. neglecta* were used to determine the skeletal relationships between the sexes. Measurements were made with a dial caliper accurate to one-tenth of a millimeter.

Osteological nomenclature is that of Howard (1929), and myological nomenclature is that of George and Berger (1966).

The length of the following bony elements were recorded: humerus; radius; ulna; carpometacarpus; phalanges I and II of digit II (wing); femur; tibiotarsus; tarsometatarsus; digit III (leg); and the hallux. Measurements were taken between proximal and distal articulating surfaces so that their sums would approximate total limb lengths (see figures 1 and 2). In the determination of the lengths of digit III and the hallux the length of the ungual phalanx from the articulation to the tip of the horny covering was included, in spite of the variability of the length of the horny claw. A synsacral measurement, i.e. the length from the anterior articulating surface of the centrum of the first fused synsacral vertebra to the most anterior surface of the acetabulum, was also taken.

The lengths of the hand, wing, and leg were determined in the following manner:

1. Hand length: the sum of the lengths of the carpometacarpus, and phalanx I and II of digit II (wing).

2. Wing length: the sum of the lengths of the humerus, ulna, and hand.

3. Leg length: the sum of the femur, tibiotarsus, tarsometatarsus, and digit III of the leg.

The data on bone length and muscle weight were analysed by the Student t-test to find if any differences in length or weight existed between the sexes. These data on bone length and muscle weight were also used to create ratios to indicate relative dimensions of the bones and muscles within each sex. The ratios of the bones were determined for each individual in the series, and an average value was obtained. The ratios of the muscles were determined on the basis of average measurements. The data on the ratios of bone length and muscle weight were analysed by the Mann-Whitney U test (Tate and Clelland, 1957).

In both the Student t-test and the Mann-Whitney U test the 5 per cent level of significance was regarded as constituting a significant difference, and the 1 per cent level of significance was regarded as constituting a highly significant difference.

For the purposes of this paper, a muscle is defined as "a group of muscle fibers acting as a single functional unit, possessing the same force arm and similar angles of attachment to the force arm" (Goodman and Fisher, 1962). This definition is necessary to separate accurately two or more muscles which may be fused into a single sheet at their adjacent borders.

A strictly functional interpretation of the origin and insertion of muscles is used. An origin is that attachment of a muscle which is relatively fixed; an insertion is that end which is movable.

Chapter 3

NATURAL HISTORY

To understand any differences or similarities between the sexes of the Western Meadowlark a summary of the natural history is necessary.

DESCRIPTION

The adult male Western Meadowlark is a medium size bird (254-279.4 mm in length) with the following characteristic plumage: the upperparts of the bird are a brownish black color modified by gray feather edgings which cause the black to be thrown into stripes and bars; the median crown-stripe and the posterior portion of the superciliary are a dull white, while the anterior portion of the superciliary, the lower cheeks, chin, upper throat, breast, middle belly, and the edges of the wings are a rich yellow; there is a large black crescent on the upper breast, and the sides and flank are black-streaked and spotted with pale brown on a whitish background; the lateral retrices are white and very conspicuous in flight or on the ground. The bill is variegated--tawny, black, and white (Dawson, 1923).

The adult female Western Meadowlark is similar to the male but smaller is size and paler in color, with some substitutions of brown for black in streaking. The plumage of both sexes is duller and more blended in fall and winter; the normal colors being subdued by a heavy buffy overlay. The immature birds resemble the parents, but are grayer with the yellow more confined, and they lack the jugular crescent (Dawson, 1923).

GENERAL RANGE

The Western Meadowlark is widely distributed throughout western North America, from southern Canada to northern Mexico, and from the eastern borders of the prairies and plains to the Pacific. In winter the bird migrates from the northeastern quarter of its range, but elsewhere it migrates irregularly (Bent, 1958).

In California the Western Meadowlark is a year round resident and is generally distributed throughout the state, except for the arid portions of the desert, broken mountain sections, and dense forests. It breeds from the Lower Sonoran life zone (Colorado Desert, at Indio) to the Lower Boreal life zone (Cottonwood Lakes in Inyo Co., altitude 11,000 ft). The species retires irregularly in winter to the lower levels (Dawson, 1923).

Lanyon (1957) has found that in Wisconsin the Western Meadowlark has well defined limits of moisture tolerance that delineate its range. The birds seem to prefer open, treeless areas of meadow, pasture, or uncultivated grassland. They usually remain in the same general locality throughout the year.

BEHAVIOR

Compared to other icterids like the Brewer's Blackbird, the Western Meadowlark is a poor flyer. It has a peculiar hovering, trembling method of flight which it uses to propel itself for short distances. They fly very little as most of their time is spent walking along the ground in search of food. Grinnell and Storer (1924) found that in spring and early summer Western Meadowlarks are seen chiefly in pairs, but throughout fall and winter they forage in flocks numbering from 10 to 75 individuals. The flock organization is very loose.

TERRITORY

Territorial behavior is well established in the Western Meadowlark (Kendeigh, 1941; Lanyon, 1957). Territories are established and maintained solely by the males and defended for a period of up to four weeks before the females are ready to mate. Songs are given from fence posts, tall weeds, or small trees as an advertisement to other males that the area is occupied. Maintenance of territories continues until fledging of the final brood, though the intensity of maintenance varys with the stage of the breeding cycle. Meadowlarks become gregarious following the late-summer molt and remain in flocks until the establishment of breeding territories the following spring.

Lanyon (1957) found that both sexes exhibited a strong "homing behavior" directed toward the territory of the previous season rather than toward a particular mate, with territories varying in size from 3 to 15 acres, but averaging 7 to 8 acres.

NESTING AND YOUNG

The nesting season of the Western Meadowlark lasts from March to August. In California Meadowlarks normally nest twice each year, usually first in April and May, and again in July and August (Bryant, 1914).

The nest is a well-concealed one, built of dry grasses in a depression in the ground usually in alfalfa, grass, or grain fields. The nest usually has a canopy of dry grass stems arching over the top. Both sexes assist in the construction of the nest (Bendire, 1895). Bryant (1914) found that in California at least 80% of the observed nests were on pasture land. When the birds approach the nest they will often alight on the ground many yards away from the nest and walk through the grass to the nest. They may have well defined paths of travel radiating from the nest (Pearson, 1920).

The eggs are white, speckled sparingly or very sparingly with chocolate, and are variable in shape from elliptical ovate to almost round (Dawson, 1923). In a study of forty-one Sturnella n. neglecta nests Lanyon (1957) found that the clutch size varied from 3 to 6 eggs, with a mean of 4.83 ± 0.13 eggs.

The time of incubation is from 12 to 14 days with only the female incubating the eggs (Bryant, 1914). Fledged broods vary in size from 1 to 5, with a mean of 3.28 ± 0.23 (Lanyon, 1957). The young stay in the nest only a short time (8 to 10 days) and leave the nest before they are able to fly, depending for safety on hiding themselves in the grass (Bent, 1958).

Polygamy is a common occurrence among both Eastern and Western Meadowlarks. Lanyon (1957) found that 53% of the Sturnella n. neglecta males under his observation had more than one mate.

FEEDING

The Western Meadowlark feeds almost exclusively on the ground. It seldom perches in a tree of any kind. The early morning hours are spent in obtaining food, whereas the middle of the day is usually spent quietly hiding in the grass.

Beal (1910) examined 91 stomachs of the Western Meadowlark, collected throughout the year, and found that the food consisted of 70% animal matter to 30% vegetable matter. Broadly speaking, the animal matter was insects and the vegetable matter was seeds. In an examination of 200 Western Meadowlark stomachs, Bryant (1914) found that 63.3% of the food in a year was animal matter, and 36.7% was vegetable matter.

The food is procured not only from the top of the ground, but also by probing beneath the soil and by searching under clods, manure, etc. The Western Meadowlark is particularly fond of sprouting kernels of grain on which it feeds by boring down beside the sprout with its long, awl-like bill, gripping the kernel and pulling it up. The kernel is occasionally eaten, but more often it is simply crushed in the bill to obtain the milk and then dropped. Alfalfa and grain fields appear to be the favorite feeding grounds of these birds in cultivated districts (Bryant, 1914).

Beecher (1951) terms the feeding behavior of the Western Meadowlark as a gaping adaptation. These birds drive the closed bill into the ground and open it powerfully against the resistance of the earth. Foraging in short grass consists of a repeated, spasmodic opening of the mandibles for the purpose of clearing the area at the base of the roots of the grass for an unobstructed view.

Chapter 4

OSTEOLOGY

In this section of the study an analysis of the synsacrum and the bones of the appendages of the male and female Western Meadowlark was made. The only previous work on the osteology of the meadowlark was a descriptive study by Shufeldt (1888) on the skeleton of the genus *Sturnella* and its relationship to the skeletons of other icterids. Shufeldt included no measurements of the elements of the *Sturnella* skeleton in his paper. Although the main purpose of my study was an analysis of the pelvic appendage, non-pelvic elements were included in order to interpret differences in the skeleton and musculature of the pelvic appendage.

To interpret any osteological differences adequately each selected skeletal element was measured and then various ratios of these measurements to one another were calculated. The use of ratios of limb segments as an osteological interpretive device has been popular in American ornithological literature since the appearance of Böker's study on the correlation of wing-segment proportions and type of flight (Böker, 1927). Larson (1930), Burt (1930), Miller (1937), Engels (1938a, 1938b, 1940), Richardson (1942), Fisher (1946), Berger (1952), Goodman and Fisher (1962), and Owre (1967) have all used limb segment ratios to more adequately understand any differences between the birds that they studied.

In this paper three types of ratios are used (after Engels, 1940): intramembral, intermembral, and limb/synsacrum ratios.

To illustrate differences between the sexes within each limb the lengths of the ulna and hand were each expressed in terms of percentage of the length of the humerus; and, the lengths of the tibiotarsus, tarsometatarsus, middle toe, and hallux were each expressed in terms of percentage of the length of the femur (see Table 3).

To illustrate differences between the sexes using a skeletal element other than a segment of the appendages as a standard, ten limb segment/synsacrum ratios were computed (see Table 5). The lengths of the humerus, ulna, hand, femur, tibiotarsus, tarsometatarsus, middle toe, hallux, the total wing length, and the total leg length were expressed in terms of percentage of the synsacrum.

Six intermembral ratios (see Table 4) were calculated, as follows: total wing/total leg; humerus/femur; ulna/tibiotarsus; carpometacarpus/tarsometatarsus; hand/middle toe; and hand/hallux. These ratios give precise indices of specific differences in the length of one limb in relation to the other.

The use of the synsacrum length (i.e., the length from the anterior articulating surface of the centrum of the first fused synsacral vertebra to the most anterior surface of the acetabulum) as a standard for comparison with other skeletal elements is unique to this paper. Previous non-appendage standards have been the "trunk length," and "thoracic length" of Engels (1940); the "rumpflänge" of Böker (1927); and the "length of cranium," "total length of synsacrum," and "length of dorsal region" of Berger (1952). Each of these standards either lacks reliability or is too difficult to measure. As a consequence I have developed the synsacrum length, which shows little variability (see Table 2) and is easy to measure.

Since it has not previously been established that a difference exists in the length of the bones of the appendages of the male and female Western Meadowlark, Tables 1 and 2 have been prepared to illustrate the bone lengths in the two sexes. As is shown by the t-values for each bone pair (except the middle toe and the hallux) a highly significant difference exists between the lengths of the bones of the appendages of the male and female Western Meadowlark. When the lengths are examined it is apparent that in each case (except for the middle toe and the hallux) the bones of the male are longer than the bones of the female.

Tables 3, 4, and 5 illustrate the mean, median, range, and Mann-Whitney U z-values obtained for each of the ratios. Figures 3, 4, 5, 6, and 7 graphically illustrate the differences between the ratios obtained for each sex. In Table 3 (intramembral ratios) it is apparent from the Mann-Whitney U z-values that no significant difference exists between the sexes as concerns the ratios of the ulna, and hand to the humerus; and, the tibiotarsus to the femur. A highly significant difference does exist between the sexes as concerns the ratios of the length of the tarsometatarsus, middle toe, and hallux to the length of the femur. In each of these cases the median ratio value of the female is larger than the male. In Table 4 (intermembral ratios) the z-values indicate a highly significant difference between the sexes for the following ratios: wing/leg; humerus/femur; carpometacarpus/tarsometatarsus; hand/middle toe; and hand/hallux. In each of these cases the median ratio values of the male are larger than the female. There is no significant difference between the sexes for the ulna/tibiotarsus ratio. In Table 5 (limb/synsacrum ratios) the z-values indicate a significant to highly significant difference between the sexes for the ratios of the length of the tarsometatarsus, middle toe, hallux, and leg to the length of the synsacrum. No significant difference exists between the sexes for the ratios of the length of the humerus, ulna, hand, femur, tibiotarsus, and wing to the length of the synsacrum.

Table 1

Length, in Millimeters, of Wing Bones

Bone	Sex	N	X	Range	SD	SE	V	df	t-value for Male, Female Comparison
humerus	male	29	32.1	30.5-34.4	0.93	0.17	2.90	56	11.56**
	female	29	30.0	28.2-33.7	1.44	0.27	4.79		
ulna	male	30	37.6	35.3-39.7	0.99	0.18	2.63	57	11.95**
	female	29	35.3	32.5-39.9	1.73	0.32	4.89		
carpomet.	male	29	18.8	17.2-19.9	0.54	0.10	2.89	56	11.20**
	female	29	17.6	15.4-19.6	0.92	0.17	5.23		
digit II	male	30	14.3	13.5-15.8	0.50	0.09	3.44	58	7.74**
	female	30	13.6	11.7-14.8	0.76	0.14	5.56		

*- significant difference
**- highly significant difference

Table 2

Length, in Millimeters, of Leg Bones and Synsacrum

Bone	Sex	N	X	Range	SD	SE	V	df	t-value for Male, Female Comparison
femur	male	30	30.4	29.0-32.7	0.91	0.17	2.99	58	8.45**
	female	30	29.0	26.8-31.9	1.20	0.22	4.14		
tibiotar.	male	30	52.3	49.4-54.9	1.45	0.26	2.77	54	7.58**
	female	26	50.1	46.2-54.6	2.08	0.41	4.15		
tarsomet.	male	29	37.6	35.8-39.7	1.12	0.21	2.99	57	5.07**
	female	30	36.6	33.1-39.5	1.73	0.31	4.72		
mid-toe	male	30	31.8	28.4-35.8	2.07	0.38	6.49	58	1.25
	female	30	32.4	26.7-38.1	2.36	0.43	7.29		
hallux	male	29	26.2	22.1-30.1	2.10	0.39	8.01	55	1.65
	female	28	26.9	23.0-32.8	2.40	0.45	8.95		
synsacrum	male	30	12.9	11.2-14.3	0.83	0.15	6.43	58	5.25*
	female	30	12.1	10.3-13.7	0.74	0.13	6.10		

*- significant difference
**- highly significant difference

Table 3

Intramembral Ratios

Ratio	Sex	N	X	Median	Range	z-value for Male, Female Comparison
ulna/humerus	male	29	116.8	117	114-120	-0.77
	female	28	117.0	117	114-120	
hand/humerus	male	28	102.9	103	100-109	-1.06
	female	28	103.4	104	96-108	
tibiotarsus/femur	male	30	171.3	171	164-176	-0.06
	female	26	171.4	171	166-176	
tarsomet./femur	male	29	123.2	123	119-129	-2.89**
	female	30	125.6	125	118-132	
mid-toe/femur	male	30	104.2	102	94-118	-3.63**
	female	30	111.2	111	96-130	
hallux/femur	male	29	85.4	84	74-102	-3.17**
	female	28	92.2	92	82-111	

*- significant difference
**- highly significant difference

Table 4

Intermembral Ratios

Ratio	Sex	N	X	Median	Range	z-value for Male, Female Comparison
wing/leg	male	28	67.1	67	64- 69	-3.56**
	female	23	64.8	65	58- 70	
humerus/femur	male	29	104.9	105	100-109	-2.58**
	female	29	103.0	103	95-108	
ulna/tibiotarsus	male	30	71.5	71	68- 75	-1.44
	female	25	70.5	71	65- 75	
carpo./tarsomet.	male	29	49.5	49	47- 51	-3.76**
	female	29	47.6	48	42- 53	
hand/mid-toe	male	29	103.8	104	90-116	-3.48**
	female	29	96.4	97	77-111	
hand/hallux	male	28	126.7	128	104-142	-3.40**
	female	27	115.7	114	89-137	

*- significant difference
**- highly significant difference

Table 5

Limb/Synsacrum Ratios

Ratio	Sex	N	X	Median	Range	z-value for Male, Female Comparison
humerus/synsacrum	male	29	248.2	248	218- 275	-0.22
	female	29	249.0	247	223- 283	
ulna/synsacrum	male	30	291.4	290	254- 325	-0.24
	female	29	292.3	290	259- 326	
hand/synsacrum	male	29	257.0	256	227- 289	-0.37
	female	29	257.8	258	220- 288	
femur/synsacrum	male	30	235.9	237	204- 266	-1.26
	female	30	239.6	241	207- 267	
tibiotar./synsacrum	male	30	405.5	402	364- 453	-1.07
	female	26	411.8	412	368- 451	
tarsomet./synsacrum	male	29	291.8	291	254- 328	-2.12*
	female	30	302.3	306	262- 340	
mid-toe/synsacrum	male	30	247.0	242	200- 297	-3.14**
	female	30	267.7	267	231- 334	

Table 5 (continued)

Ratio	Sex	N	X	Median	Range	z-value for Male, Female Comparison
hallux/synsacrum	male	29	202.4	198	172- 246	-3.01**
	female	28	222.5	221	181- 287	
wing/synsacrum	male	28	797.4	798	700- 890	-0.50
	female	27	803.2	806	713- 898	
leg/synsacrum	male	29	1181.4	1181	1023-1346	-2.17*
	female	26	1225.4	1231	1091-1383	

*- significant difference
**- highly significant difference

Figure 1

Lengths (l) of the Long Bones and the Synsacrum

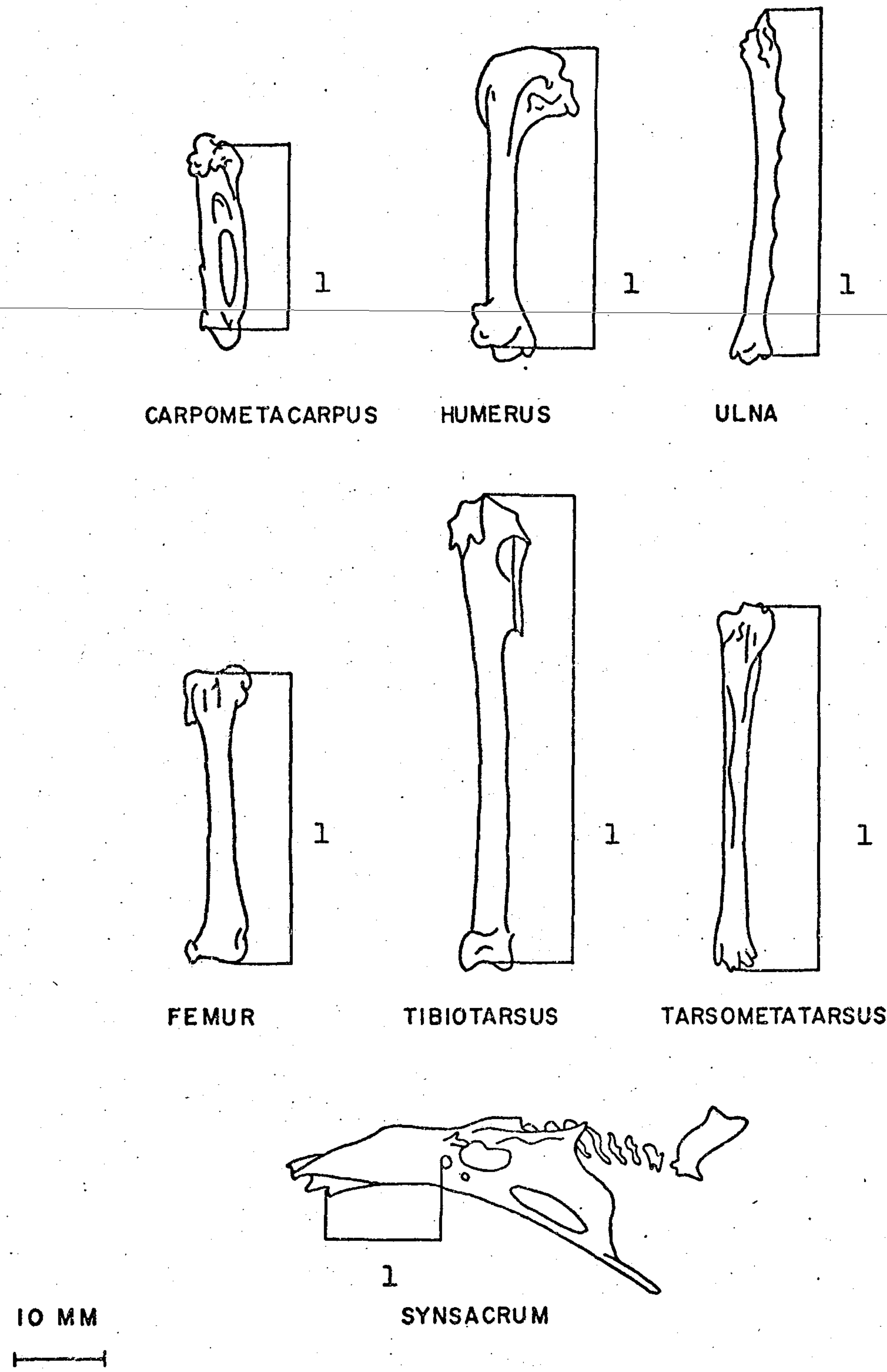
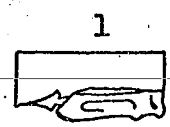
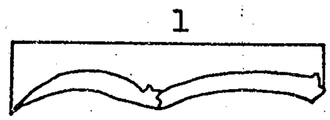

1
1
1
CARPOMETACARPUS
HUMERUS
ULNA
1
1
1
FEMUR
TIBIOTARSUS
TARSOMETATARSUS
1
SYNSACRUM
10 MM

Figure 2

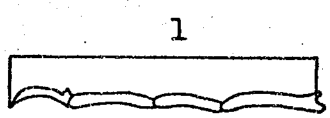
Lengths (1) of the Digits



DIGIT II - MANUS



HALLUX



DIGIT III - PES

10 MM

Figure 3

Intramembral Ratios: Wing

A- ulna/humerus
B- hand/humerus
median- horizontal line
range- vertical line
95% confidence interval- box

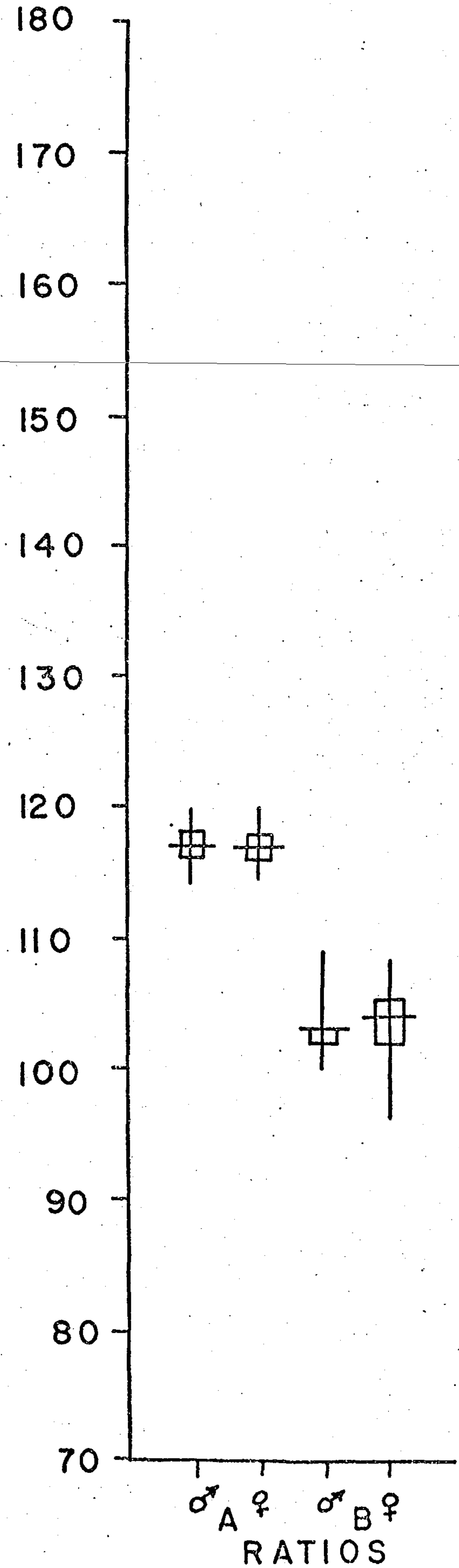
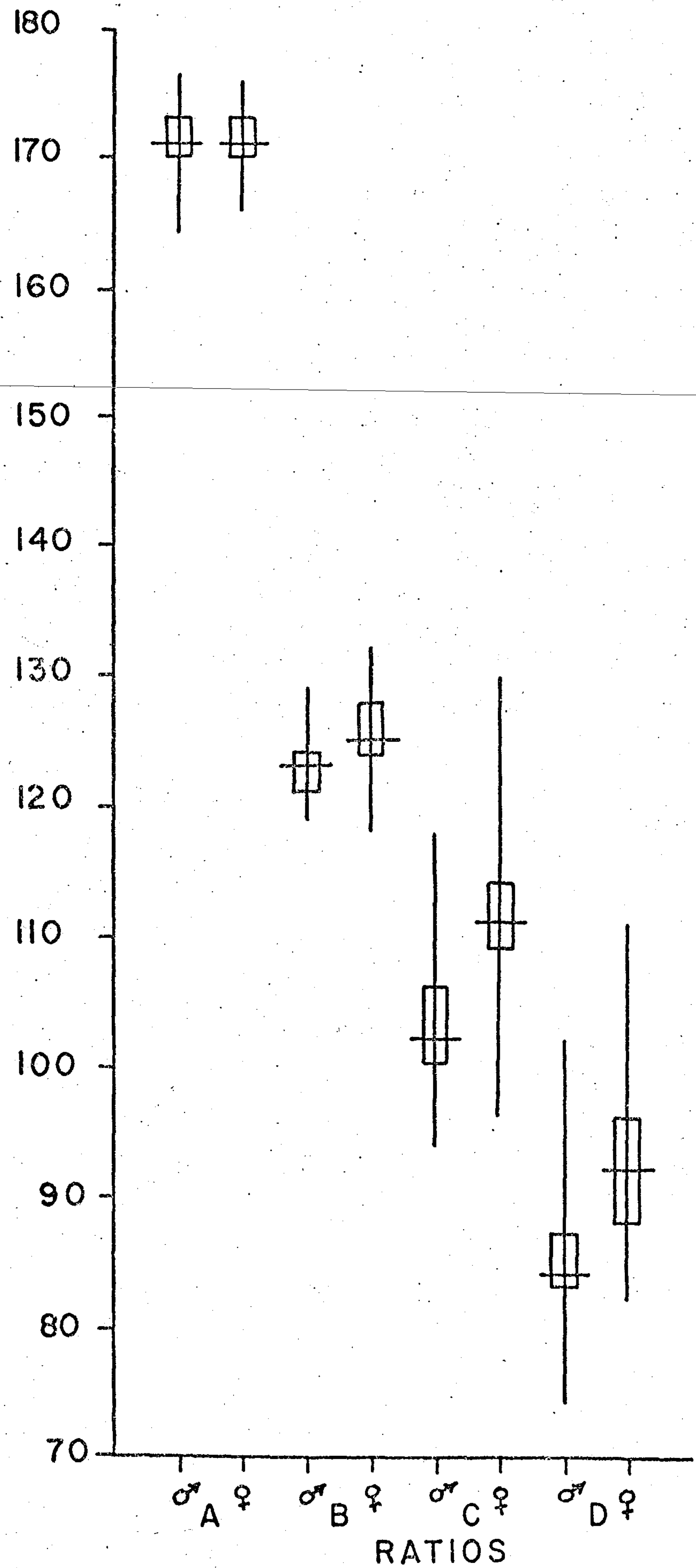

180
170
160
150
140
130
120
110
100
90
80
70
♂ A ♀
♂ B ♀
RATIOS

Figure 4

Intramembral Ratios: Leg

A- tibiotarsus/femur
B- tarsometatarsus/femur
C- middle toe/femur
D- hallux/femur


180
170
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150
140
130
120
110
100
90
80
70
♂ A ♀
♂ B ♀
♂ C ♀
♂ D ♀
RATIOS

Figure 5

Intermembral Ratios

A- wing/leg
B- humerus/femur
C- ulna/tibiotarsus
D- carpometacarpus/tarsometatarsus
E- hand/middle toe
F- hand/hallux

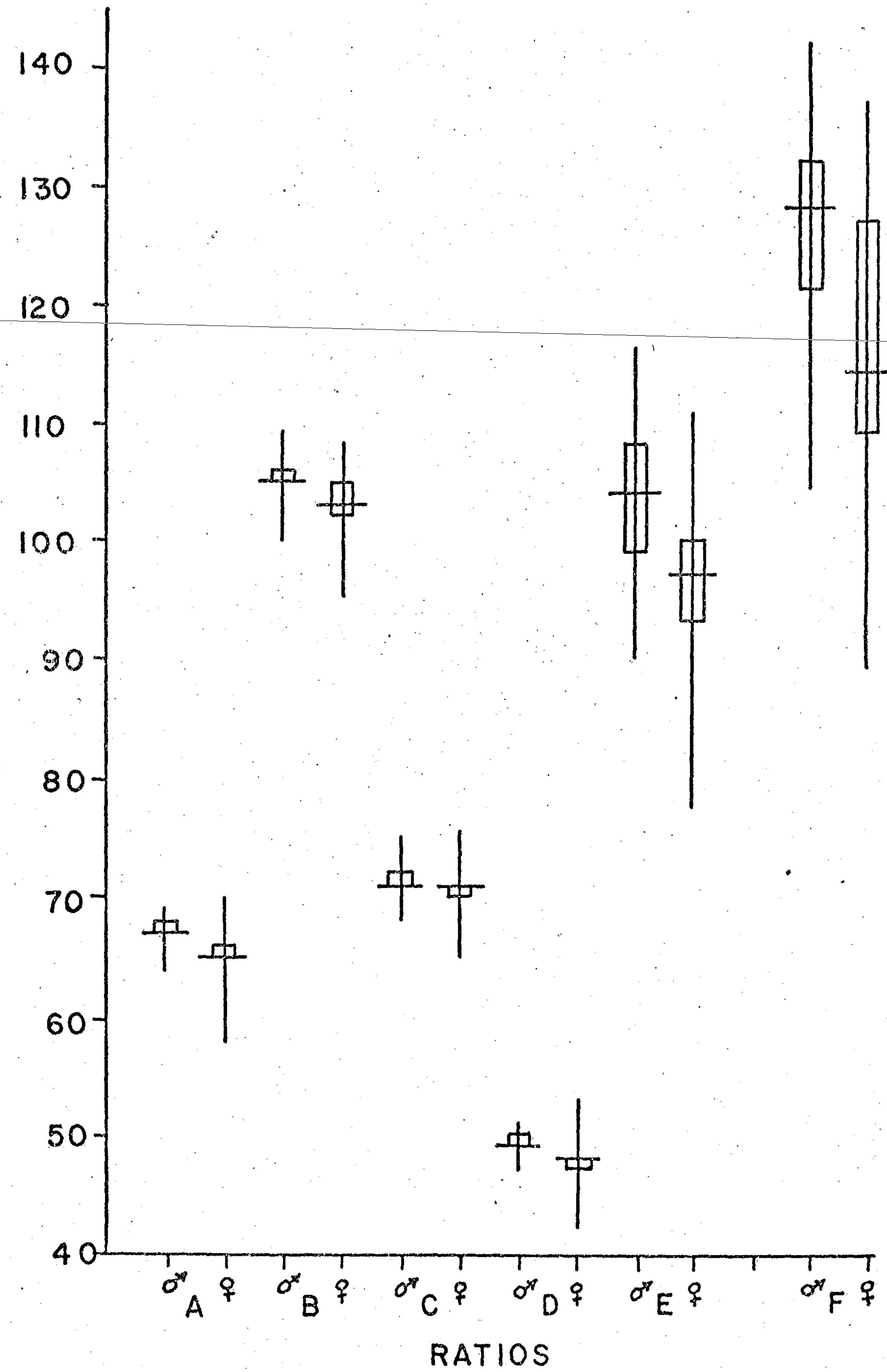
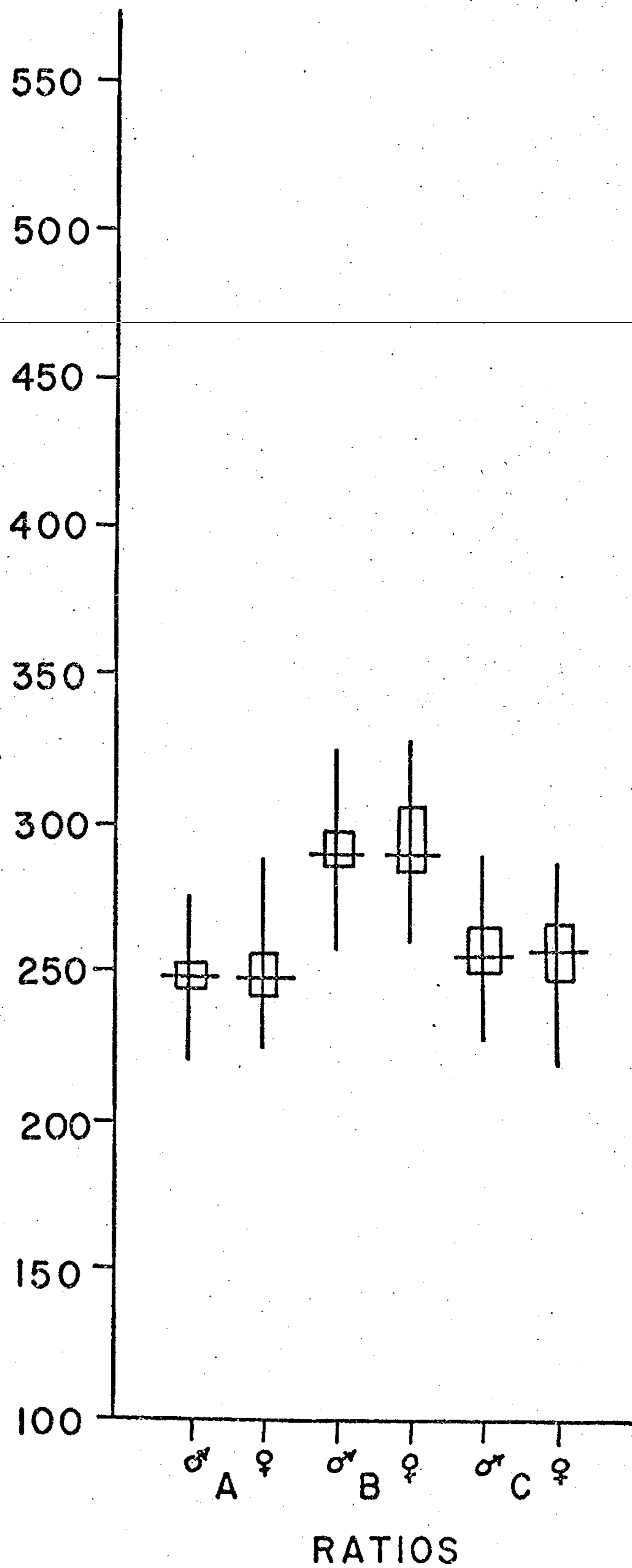

140
130
120
110
100
90
80
70
60
50
40
♂ A ♀
♂ B ♀
♂ C ♀
♂ D ♀
♂ E ♀
♂ F ♀
RATIOS

Figure 6

Limb/Synsacrum Ratios: Wing

A- humerus/synsacrum
B- ulna/synsacrum
C- hand/synsacrum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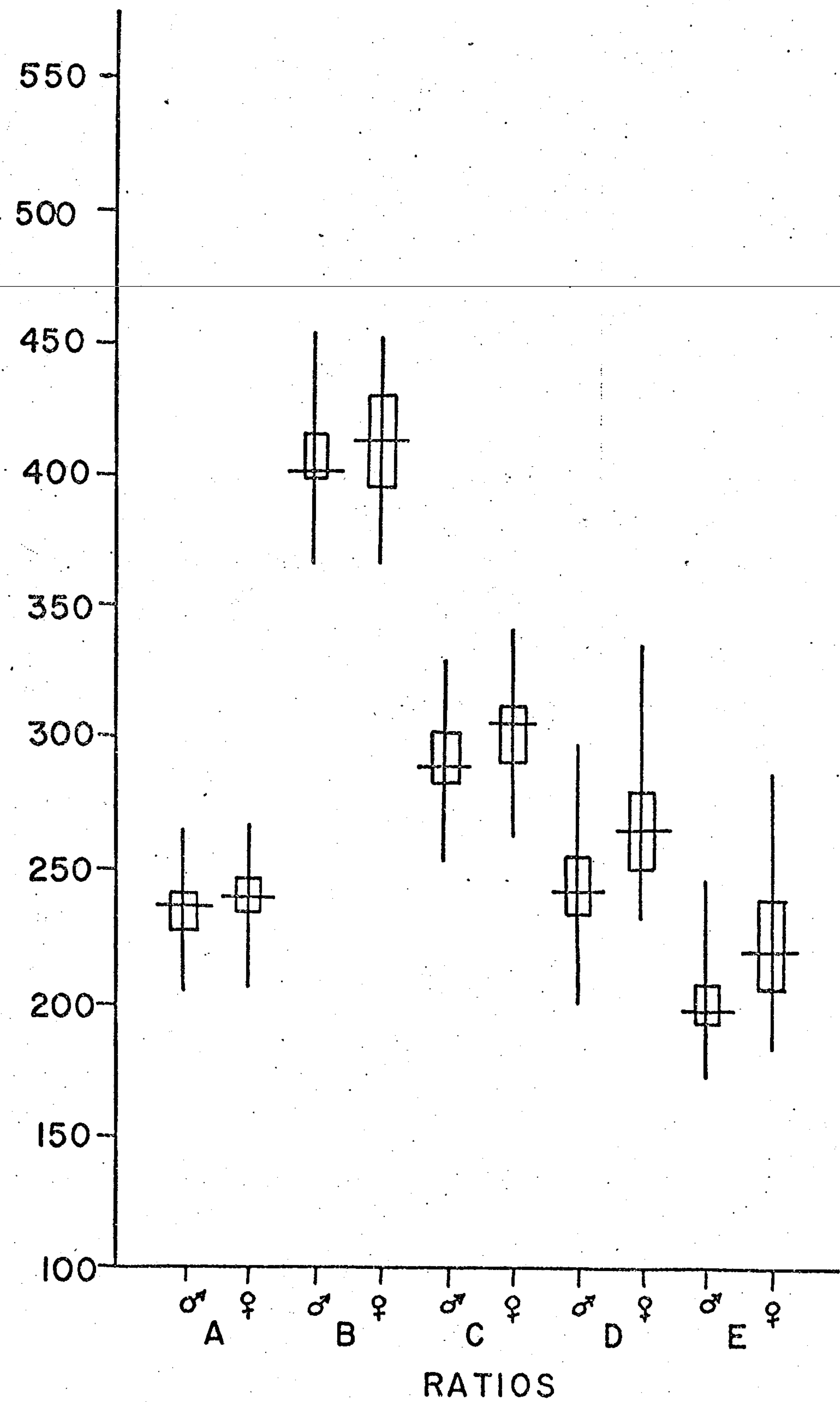
♂ A ♀
♂ B ♀
♂ C ♀
RATIOS

Figure 7

Limb/Synsacrum Ratios: Leg

A- femur/synsacrum
B- tibiotarsus/synsacrum
C- tarsometatarsus/synsacrum
D- middle toe/synsacrum
E- hallux/synsacrum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RATIOS

Chapter 5

MYOLOGY

In this portion of the study the musculature of the pelvic appendage of *Sturnella n. neglecta* was examined. Since the muscles of the pelvic appendage of *Sturnella n. neglecta* have not been described previously I have described them very extensively.

No variation was found to exist between the sexes as concerns the origin, insertion, and general appearance of each of the muscles of the pelvic appendage. The muscles of the male were used as a model for the illustrations. Only one leg of each specimen was dissected because shot typically damaged the bird to the extent that only one leg was in a condition suitable for dissection.

Studies of the muscles of the pelvic appendage of birds have appeared in American ornithological literature since the late nineteenth century. Most of the early studies were general and descriptive in nature. Frequently broad conclusions were drawn from a study of only a few representatives of a family or an order. Few measurements of skeletal elements or muscles were published and detailed comparative studies of skeletal and myological features of closely related forms were rare. Hudson (1937) gives an excellent review of the early major works pertaining to the myology of the leg. The more recent American works on the muscles of the pelvic appendage of birds have emphasized the functional aspect of anatomy.

Since the appearance of Hudson's paper, the following additional papers on the myology of the leg have appeared in America; Miller (1937); Hudson (1948); Engels (1938b, 1940); Richardson (1942); Storer (1945); Fisher (1946); Berger (1952, 1953, 1968); Wilcox (1952); Hudson, Lanzillotti, and Edwards (1959); Hudson, Parker, Berge, and Lanzillotti (1966); Fleming (1966); Owre (1967); and Gaunt (1969). Most of these papers deal with one genus or family of birds. The only work combining the findings of previous avian anatomists in one large survey of avian myology is George and Berger's Avian Myology, 1966.

In order to interpret any differences or similarities between the muscles of the pelvic appendage of the male and female Western Meadowlark, ratios of the weight of each muscle expressed in terms of percentage of the total weight of the leg muscles were constructed. Since the main purpose of this paper was to determine the possible extent of differences between the sexes in the pelvic appendage it was felt that a measurement of the average weight of each muscle was sufficient, even though the weight of a muscle is only proportional to the work of which the muscle is capable, and not an indication of the actual force of this muscle in nature.

Table 6 illustrates the muscle weights and ratios of the two sexes. When the ratios of the weight of each muscle to the total muscle weight are analysed by the Mann-Whitney U test the z-value obtained (-0.503; 26 df) indicates that there is no significant difference between the sexes when all the ratios are compared with one another. A close examination of the table does reveal a few small differences between ratios which may be of importance when the habits of the bird are considered. The following list illustrates these differences (only those greater than 3% are listed):

Muscle	Percent Difference Between Ratios of Sexes: Larger in Male	Larger in Female
M. iliotibialis		4%
M. sartorius		6
M. femorotibialis medius and externus		5
M. semitendinosus and accesorius semitendinosi		8
M. ischiofemoralis		6
M. flexor perforatus digiti III		12
M. flexor perforatus digiti IV		28
M. semimembranosus	8	

Muscle	Percent Difference Between Ratios of Sexes: Larger in Male	Larger in Female
M. femorotibialis internus	7	
M. tibialis anterior	6	
M. extensor digitorum longus	8	
M. flexor hallucis longus	25	
M. flexor digitorum longus	10	

DESCRIPTIONS OF MUSCLES

Musculus Sartorius

M. sartorius arises from the posterior portion of an aponeurosis shared with M. rhomboideus profundus attached to the neural spine of the last dorsal vertebra and the anterior edge of the median dorsal ridge of the synsacrum; and by fleshy fibers from the anterior iliac process and the lateral edge of the ilium posterior to the anterior iliac process. The flat belly passes down the anterolateral and anteromedial surfaces of the thigh, over the patellar ligament at the knee, and inserts by fleshy and tendinous fibers on the anterior edge of the tibiotarsus at the proximal base of the inner cnemial crest.

M. sartorius is a two-joint muscle which acts to extend both the thigh and the crus in an anterior and upward direction.

Table 6

Muscle Force Values, Ratios, and Percent Differences

Muscle	Male F (gm)	Male ind. musc. wt. / tot. musc. wt.	Female F (gm)	Female ind. musc. wt. / tot. musc. wt.	% diff. bet. Ratios of Sexes
M. iliotibialis	0.2132	10.7	0.1772	11.2	4
M. sartorius	.0609	3.0	.0506	3.2	6
M. femorotibialis medius and externus	.1965	9.8	.1624	10.3	5
M. iliotrochantericus posterior	.0689	3.4	.0541	3.4	0
M. iliotrochantericus anterior	.0082	.4	.0060	.4	0
M. iliotrochantericus medius	.0014	.1	.0011	.1	0
M. biceps femoris	.0676	3.4	.0533	3.4	0
M. semitendinosus and accesorius semitendinosi	.1403	7.0	.1200	7.6	8
M. piriformis	.0434	2.2	.0355	2.2	0
M. ischiofemoralis	.0324	1.6	.0273	1.7	6

Table 6 (continued)

Muscle	Male F (gm)	Male ind. musc. wt. / tot. musc. wt.	Female F (gm)	Female ind. musc. wt. / tot. musc. wt.	% diff. bet. Ratios of Sexes
M. semimembranosus	.0264	1.3	.0185	1.2	8
M. femorotibialis internus	.0288	1.4	.0213	1.3	7
M. adductor longus et brevis	.1086	5.4	.0858	5.4	0
M. gastrocnemius	.3871	19.4	.3108	19.7	1
M. peroneus longus	.1414	7.1	.1146	7.2	1
M. flexor perforans et perforatus digiti II	.0050	.2	.0040	.2	0
M. flexor perforans et perforatus digiti III	.0461	2.3	.0366	2.3	0
M. tibialis anterior	.1003	5.0	.0752	4.7	6
M. peroneus brevis	.0144	.7	.0112	.7	0
M. plantaris	.0041	.2	.0030	.2	0
M. extensor digitorum longus	.0265	1.3	.0194	1.2	8

Table 6 (continued)

Muscle	Male F (gm)	Male ind. musc. wt. / tot. musc. wt.	Female F (gm)	Female ind. musc. wt. / tot. musc. wt.	% diff. bet. Ratios of Sexes
M. flexor perforatus digiti III	.0166	.8	.0141	.9	12
M. flexor perforatus digiti IV	.0288	1.4	.0279	1.8	28
M. flexor perforatus digiti II	.0138	.7	.0118	.7	0
M. flexor hallucis longus	.1459	7.3	.0918	5.8	25
M. flexor digitorum longus	0.0668	3.3	0.0472	3.0	10
Total weight	1.9934		1.5807		

M. Iliotibialis

M. iliotibialis is a large, flat muscle covering most of the lateral surface of the thigh. The anterior and medial portions of M. iliotibialis arise from an aponeurosis attached to the median dorsal ridge, the anterior iliac crest, and the posterior iliac crest. The posterior portion of M. iliotibialis arises by fleshy fibers from the posterior one-third of the posterior iliac crest. The posterior border of the proximal one-third of the muscle is fused with M. semitendinosus.

The anterior and posterior portions of M. iliotibialis are fleshy while the central portion of the muscle is aponeurotic in the distal three-fourths of the thigh. The aponeurotic portion is fused to the underlying M. femorotibialis externus. M. iliotibialis ends on an aponeurosis which forms the most superficial layer of the patellar ligament. The aponeurosis then inserts on the rotular crest of the tibiotarsus.

M. iliotibialis is a two-joint muscle which acts to extend the crus and abduct the entire limb. Since the major part of the muscle is posterior to the femur there is also a tendency to extend the femur.

M. Femorotibialis Externus

M. femorotibialis externus arises from the lateral and posterolateral surface of the shaft of the femur, beginning about 2 mm from the proximal end of the bone and extending distad for almost the whole length of the bone.

The fleshy fibers of the proximal head begin distal to the area of insertion of M. ischiofemoralis and posterior to the areas of insertion of Mm. iliotrochantericus anterior and iliotrochantericus medius. Distal to the area where M. iliotrochantericus anterior passes between the proximal portions of Mm. femorotibialis and medius the anteromedial border of M. femorotibialis externus is fused with M. femorotibialis medius. Next to the knee the belly of M. femorotibialis externus gives rise to an aponeurosis which forms the lateral part of the patellar ligament and inserts on the rotular crest of the tibiotarsus.

The distal head lies deep to the proximal head and arises by fleshy fibers from the posterolateral surface of the distal half of the shaft of the femur. The distal head ends on an aponeurosis which forms the deep layer of the most lateral part of the patellar ligament. The aponeurosis inserts on the rotular crest of the tibiotarsus.

M. femorotibialis externus acts to extend the crus.

M. Femorotibialis Medius

M. femorotibialis medius arises by fleshy fibers from the trochanteric ridge and the anterior surface of the shaft of the femur. The fleshy fibers of M. femorotibialis medius insert on the proximal end of the patella. The total distal end of the muscle gives rise to aponeurotic fibers which aid in the formation of the patellar ligament and insert on the rotular crest of the head of the tibiotarsus and the proximal tip of the inner cnemial crest.

M. femorotibialis medius acts to extend the crus.

M. Iliotrochantericus Posterior

M. iliotrochantericus posterior arises by fleshy fibers from the entire iliac fossa and from the anterior iliac crest to a point dorsal to the acetabulum. The bulky belly ends on a flat tendon which inserts on a curved ridge on the lateral surface of the femur just distal to the trochanter.

M. iliotrochantericus posterior acts to rotate the lateral surface of the femur mediad and cephalad. This action would tend to adduct the lower leg.

M. Iliotrochantericus Anterior

M. iliotrochantericus anterior arises by fleshy fibers from the tip of the anterior iliac process and from the lateral edge of the ilium. The flat belly passes posteriorly and laterally to insert by tendinous fibers between Mm. femorotibialis externus and femorotibialis medius on the posterolateral surface of the shaft of the femur about 5 mm from the proximal end of the bone.

M. iliotrochantericus anterior acts to rotate the lateral surface of the femur mediad and cephalad. This action would tend to adduct the lower leg.

M. Iliotrochantericus Medius

M. iliotrochantericus medius is a small muscle (1 mm by 5 mm) which originates from the lateral edge of the ilium posterior to the origin of M. iliotrochantericus anterior. The belly of M. iliotrochantericus medius tapers to an aponeurosis which inserts on the anterolateral surface of the shaft of the femur just proximal to the area of insertion of M. iliotrochantericus anterior.

M. iliotrochantericus medius acts to rotate the lateral surface of the femur mediad and cephalad. This action would tend to adduct the lower leg.

M. Iliacus

M. iliacus is a tiny band of muscle fibers about 7 mm long and 0.5 mm wide. The muscle arises by fleshy fibers from the ventral edge of the ilium immediately posterior to the origin of M. iliotrochantericus medius. M. iliacus passes posteriorly and inserts by fleshy fibers on the posteromedial surface of the femur about 1 mm distad to the neck of the femur.

Since this muscle is so small any action that it has would be weak. M. iliacus acts to rotate the posterior surface of the femur cephalad and laterad, adducting it at the same time.

M. Biceps Femoris

M. biceps femoris arises by tendinous and fleshy fibers from the ventral surface of the posterior iliac crest in its anterior section. The belly of M. biceps femoris passes distally down the thigh, tapers to a small tendon 1 mm wide, passes through the biceps loop, and inserts on the posterior surface of the shaft of the fibula about 9 mm from the proximal end of the bone.

The biceps loop is composed of three arms: two femoral and one fibular. The proximal femoral arm arises from the anterolateral surface of the femur about 8 mm from the distal end of the bone. The distal femoral arm arises from the anteroproximal surface of the external femoral condyle. The fibular arm passes distad from the bottom of the biceps loop and attaches to the shaft of the fibula about 1 mm from the proximal end of the bone.

M. biceps femoris acts to flex the crus. It may also tend to rotate the lower leg laterally.

Mm. Semitendinosus and Accesorius Semitendinosi

M. semitendinosus arises partly by tendinous fibers from the ventrolateral surface of the posterior iliac crest in its caudal 2 mm and partly by an aponeurosis which extends medially posterior to the ilium and superficial to the dorsal muscles of the tail to insert primarily on the transverse processes of the first three free caudal vertebrae. The large belly passes distally and ends on a ligamentous raphe shared with the accesorius semitendinosi part of the muscle complex.

M. accesorius semitendinosi arises by fleshy fibers from the ligamentous raphe shared with M. semitendinosus. M. accesorius semitendinosi inserts on the posterolateral surface of the shaft of the femur, beginning just proximal to the proximal arm of the biceps loop and extending medially into the popliteal fossa and to the lateral surface of the internal femoral condyle.

Part of the ligamentous raphe shared by the two muscles fans out into a flat aponeurosis which fuses with the lateral surface of the aponeurosis of insertion of M. semimembranosus and inserts on the tibiotarsus with it; and, part of the raphe fuses with the lateral surface of the belly of M. gastrocnemius pars media.

M. semitendinosus acts to flex the crus and adduct the lower limb. M. accesorius semitendinosi aids M. semitendinosus in the flexion of the crus. Mm. semitendinosus and accesorius semitendinosi may aid in the extension of the tarsometatarsus through their attachment by ligamentous raphe on the belly of M. gastrocnemius pars media.

M. Piriformis

M. piriformis pars caudofemoralis arises by tendinous fibers from the ventrolateral corner of the base of the pygostyle. The fleshy belly (approximately 22 mm long) extends anteriorly and tapers to a thin aponeurosis

(2mm wide) which inserts on the posterior surface of the shaft of the femur, beginning approximately 9 mm from the proximal end of the bone. The belly of M. piriformis pars caudofemoralis passes superficial to M. ischiofemoralis.

M. piriformis has two possible actions. The muscle may depress the tail and draw it laterally; or, the muscle may pull the femur posteriorly.

M. Ischiofemoralis

M. ischiofemoralis arises by fleshy fibers from the lateral surface of the ischium and from the ventral surface of the posterior iliac crest. M. ischiofemoralis passes anteriorly and inserts by tendinous fibers from the superficial surface of the belly of the muscle on a ridge on the lateral surface of the femur, beginning 2 mm from the proximal end of the bone.

M. ischiofemoralis acts as a strong lateral rotator of the femur. The muscle may also act to move the femur posteriorly; but, this movement is not very effective due to the shortness of the lever arm of the muscle.

M. Semimembranosus

M. semimembranosus arises by fleshy fibers from the ventrolateral surface of the caudal half of the ischium about 2 mm dorsal to the ischiopubic fenestra. The belly of M. semimembranosus forms the most caudal of the muscles on the medial surface of the thigh. The belly ends on a 4 mm wide aponeurosis which inserts on the posteromedial surface of the tibiotarsus, beginning about 5 mm from the proximal end of the bone. Part of the aponeurosis of the raphe of Mm. semitendinosus and accesorius semitendinosi is fused to the lateral surface of the aponeurosis of insertion of M. semimembranosus.

M. semimembranosus acts as a strong flexor of the crus and adductor of the lower limb.

M. Femorotibialis Internus

M. femorotibialis internus is composed of two independent bellies.

1) The proximal belly arises by fleshy fibers from the proximomedial surface of the shaft of the femur about 5 mm posterior to the trochanter. The proximal belly ends on an aponeurosis which inserts on the anteromedial corner of the head of the tibiotarsus.

2) The deep distal belly arises by aponeurotic and fleshy fibers from the medial surface of the femur just proximal to the internal condyle. The belly ends on an aponeurosis which inserts on the tibiotarsus posterior and adjacent to the insertion of the tendon of the proximal belly.

M. femorotibialis internus acts to extend the crus and rotate it in a medial direction.

M. Adductor Longus et Brevis

M. adductor longus et brevis consists of two independent bellies in the Western Meadowlark.

1) Pars anterior arises by tendinous and fleshy fibers from the ventrolateral surface of the ischium along the dorsal border of the ischiopubic fenestra, beginning at the caudal border of the obturator foramen. The flat belly inserts by fleshy fibers on the posterior surface of the femur in its distal three-fourths.

2) Pars posterior arises by a thin aponeurosis from the dorsal margin of the ischiopubic fenestra primarily posterior to the origin of pars anterior, but the posterior portion of the tendinous fibers of origin of pars posterior lie dorsal and superficial to the origin of pars anterior. The flat belly of pars posterior inserts by tendinous and fleshy fibers on the posteromedial surface of the distal end of the femur and the posteroproximal end of the internal femoral condyle, where the insertion is fused with the origin of M. gastrocnemius pars media.

M. adductor longus et brevis acts to pull the femur posteriorly. The muscle may also act as a weak adductor of the femur.

M. Obturator Externus

M. obturator externus is composed of two independent bellies in the Western Meadowlark.

1) The dorsal belly arises by fleshy fibers from the posterodorsal border of the obturator foramen of the ischium. The tiny belly (approximately 4 mm long and 0.5 mm wide) of the muscle inserts by an aponeurosis partly on the tendon of insertion of M. obturator internus and partly on the head of the femur anterior to that tendon.

2) The ventral belly arises by fleshy fibers from the ventral border of the obturator foramen. The small belly (about 5 mm long and 1 mm wide) inserts primarily by fleshy fibers on a ridge on the lateral surface of the femur distal to the tendon of insertion of M. obturator internus; some of the fibers insert on the obturator internus tendon.

M. obturator externus acts to rotate the lateral surface of the femur posteriorly and medially.

M. Obturator Internus

M. obturator internus arises by fleshy fibers from the medial surface of the ischium, the ischiopubic membrane, and the pubis. Two tendons form on the deep surface of the anterior part of the muscle. The two tendons fuse at the obturator foramen. This single tendon passes through the obturator foramen and inserts on the posteroproximal end of the femur about 1 mm from the proximal articular surface of the bone.

M. obturator internus acts to rotate the lateral surface of the femur posteriorly and medially.

M. Gastrocnemius

M. gastrocnemius has three heads in the Western Meadowlark.

1) Pars externa has a belly extending approximately two-thirds the length of the crus. Pars externa arises by a tendon from a tubercle on the posterolateral surface of the femur just proximal to the external condyle. The tendon of origin is fused with the superficial surface of the distal femoral arm of the biceps loop. The belly of pars externa passes distad and ends on an aponeurosis which forms the most lateral portion of the Tendo Achillis.

2) Pars media (18 mm long and 6 mm wide at the widest point) arises by tendinous fibers from a tubercle of the posteroproximal surface of the internal femoral condyle. The origin is shared with the insertion of M. adductor longus et brevis pars posterior. The lateral surface of the belly has part of the raphe of Mm. semitendinosus and accesorius semitendinosi fused to it. The fleshy belly of pars media extends approximately one-third of the length of the crus and ends on an aponeurosis which forms the central portion of the Tendo Achillis.

The tendon of insertion of M. semimembranosus passes between the origins of pars media and pars interna.

3) Pars interna has a bipartite configuration in the Western Meadowlark.

The anterior section is the most superficial muscle of the anteromedial surface of the proximal end of the crus. The muscle arises by fleshy fibers from the medial surface of the inner cnemial crest and the head of the tibiotarsus. The posterior section arises partly by fleshy fibers from the surface of the head of the tibiotarsus medial to the inner cnemial crest, and partly by tendinous fibers from the proximal portion of the spine of the inner cnemial crest. The fleshy bellies of the anterior and posterior sections exist independently for two-thirds of their length before they fuse and end on an aponeurosis which forms the most medial portion of the Tendo Achillis.

The Tendo Achillis passes distad over the posterior surface of the tibial cartilage where part of it inserts on the posterior surface of the hypotarsus and part of it continues distad to insert on the posterolateral ridge of the tarsometatarsus. Extensions of the Tendo Achillis fuse with the deep fascia on the back of the tarsometatarsus and form a sheath superficial to the tendons of the flexor muscles of the toes.

M. gastrocnemius acts to extend the tarsometatarsus and flex the tibiotarsus upon the femur.

M. Peroneus Longus

The belly of M. peroneus longus arises by fleshy fibers from the anterior edge of the inner cnemial crest, the rotular crest, and the outer cnemial crest of the head of the tibiotarsus. The origin is intimately related with the origin of M. tibialis anterior. The fleshy belly extends almost three-quarters the length of the crus and may be fused in its proximal portion to the underlying M. tibialis anterior. The belly of M. peroneus longus tapers to a tendon 1 mm wide, which bifurcates about 6 mm from the distal end of the tibiotarsus. The larger branch continues distad and inserts on the proximolateral corner of the tibial cartilage. The smaller, longer branch passes distad over the external condyle of the tibiotarsus and into a foramen in the sheath of the Tendo Achillis approximately 4 mm from the proximal end of the bone. After passing through the foramen the tendon inserts on the tendon of M. flexor perforatus digiti III about 7 mm inferior to the proximal end of the hypotarsus.

M. peroneus longus acts to flex digit III because of its insertion on the tendon of M. flexor perforatus digiti III. At the same time M. peroneus longus acts to extend and abduct the tarsometatarsus due to the insertion of part of the tendon on the lateral corner of the tibial cartilage.

M. Flexor Perforans et Perforatus Digiti II

M. flexor perforans et perforatus digiti II is a small spindle-shaped muscle with a belly approximately 12 mm long and 3 mm in maximum width. M. flexor perforans et perforatus digiti II arises partly by fleshy fibers from the posteroproximal face of the lateral femoral condyle just distal to the origin of M. gastrocnemius pars externa, and partly by fleshy fibers from the aponeurosis of origin of Mm. flexor perforatus digiti II and flexor hallucis longus. Fleshy fibers also arise on the anterior and deep surfaces of M. flexor perforans et perforatus digiti II from a raphe shared by Mm. flexor perforans et perforatus digiti III, flexor perforatus digiti IV, and flexor hallucis longus.

The belly of M. flexor perforans et perforatus digiti II ends on a flat aponeurosis which tapers to a small tendon. The tendon passes distad through the posterior surface of the tibial cartilage, through the middle bony tendinal canal of the hypotarsus, and then down the posterior surface of the tarsometatarsus where it passes deep to the tendon of M. flexor perforatus digiti III and then ensheathes the tendon of M. flexor digitorum longus. The tendon of M. flexor perforans et perforatus digiti II splits to permit the passage of the tendon of M. flexor digitorum longus near the middle of the proximal phalanx of digit II and then inserts on the proximal plantar surface of the second phalanx of the digit.

M. flexor perforans et perforatus digiti II acts to extend the tarsus and flex digit II.

M. Flexor Perforans et Perforatus Digiti III

M. flexor perforans et perforatus digiti III has two heads in the Western Meadowlark.

1) The anterior head arises by fleshy fibers from the lateral surface of the outer cnemial crest of the tibiotarsus.

2) The posterior head arises by an aponeurosis from the lateral femoral condyle just distal to the origin of M. flexor perforans et perforatus digiti II.

The belly of M. flexor perforans et perforatus digiti III tapers to a tendon which passes down the posterior surface of the crus, through a fibrous canal in the medial half of the tibial cartilage, and then through the middle bony tendinal canal of the hypotarsus. The tendon continues down the posterior surface of the tarsometatarsus, through the lateral surface of a fibrocartilaginous pulley at the base of digit III, and onto the plantar surface of that digit. The tendon then expands to form a sheath for the tendon of M. flexor digitorum longus near the middle of the proximal phalanx of digit III. The tendon of M. flexor perforans et perforatus digiti III then splits to permit the longus tendon to pass through, and inserts on the sides of the proximal base of the third phalanx of digit III.

M. flexor perforans et perforatus digiti III acts to extend the tarsometatarsus and flex digit III.

M. Tibialis Anterior

M. tibialis anterior has two heads in the Western

Meadowlark.

1) The tibial head of M. tibialis anterior arises by fleshy fibers from the proximolateral surface of the inner cnemial crest, from the rotular crest, and from a large area on the medial surface of the outer cnemial crest of the tibiotarsus.

2) The femoral head arises by a short tendon from a pit on the apex of the external femoral condyle. The fleshy belly passes distad in the interval between the fibular head and the head of the tibiotarsus, and then along the anterior surface of the tibiotarsus deep to the tibial head. The two heads fuse about half way down the crus just proximal to the formation of the tendon of insertion.

The single, large tendon of insertion passes distad along the anterior surface of the crus, through the ligamentum transversum, but superficial to the tendon of M. extensor digitorum longus, and inserts on the anterior surface of the tarsometatarsus about 3 mm from the proximal end of the bone.

M. tibialis anterior acts as a strong flexor of the tarsometatarsus.

M. Peroneus Brevis

M. peroneus brevis has a small, spindle-shaped belly (about 28 mm long) that arises by fleshy fibers from the anterior surface of the shaft of the fibula. The belly tapers to a tendon which passes down the anterior surface of the tibiotarsus and through a ligament on the anterolateral surface of the tibiotarsus at the level of the ligamentum transversum. The tendon then passes deep to the tendon of M. peroneus longus and inserts on a tubercle on the lateral surface of the proximal end of the tarsometatarsus.

M. peroneus brevis acts as a weak abductor and flexor of the tarsometatarsus.

M. Plantaris

M. plantaris arises by fleshy fibers from the posteromedial surface of the head of the tibiotarsus. The belly of the muscle is approximately 12 mm long and 2 mm wide. The belly tapers to a tendon which passes down the medial surface of the crus to insert on the proximomedial corner of the tibial cartilage.

M. plantaris acts as a weak extensor of the tarsometatarsus and a mover of the tibial cartilage in a proximal direction.

M. Extensor Digitorum Longus

M. extensor digitorum longus arises by fleshy fibers from most of the lateral surface of the inner cnemial crest, from the medial base of the outer cnemial crest, and from the anterior surface of the head and the proximal end of the shaft of the tibiotarsus. The long belly (about 33 mm) passes distad on the anterior surface of the tibiotarsus and tapers to a large tendon which passes under the ligamentum transversum deep to the tendon of M. tibialis anterior and then through a bony canal just proximal to the condyles of the tibiotarsus. The tendon next passes through a second canal on the proximal end of the tarsometatarsus before continuing distad on the anterior surface of the tarsometatarsus.

The tendon of M. extensor digitorum longus trifurcates near the distal end of the tarsometatarsus. Small branch tendons pass along the dorsal surfaces of digits II, III, and IV held close to the bones by dense fascial sheaths. The primary insertion of the tendons of digit II and IV is on the dorsal surface of the base of the ungual phalanx, but small branches of each main tendon insert on the bases of all but the proximal phalanx of each digit. The tendon to digit III passes along the dorsal surface of the proximal phalanx of digit III and bifurcates near the mid-section of the phalanx. The branch tendons insert on the dorsal section of the base of the ungual phalanx and also send slips to the bases of the second and third phalanges of the digit.

M. extensor digitorum longus acts as the major extensor of digits II, III, and IV. M. extensor digitorum longus also acts to flex the tarsometatarsus.

M. Flexor Perforatus Digiti III

M. flexor perforatus digiti III arises in the inter-condyloid region of the femur from the most medial portion of the common tendinous and fleshy origin shared with Mm. flexor perforatus digiti II and flexor hallucis longus. The posteroproximal border of three-fourths of the belly of M. flexor perforatus digiti III may be fused with the anteroproximal border of the belly of M. flexor perforatus digiti IV. The belly of M. flexor perforatus digiti III ends on a flat tendon which passes through the tibial cartilage and a lateral superficial tendinal canal on the posteroproximal end of the hypotarsus.

The tendon passes distad along the posterior surface of the tarsometatarsus through a fibrocartilaginous pulley at the base of digit III where it splits opposite the base of the proximal phalanx and is thus perforated by the tendons of Mm. flexor perforans et perforatus digiti III and flexor digitorum longus. The two branches of the tendon of M. flexor perforatus digiti III insert on the plantar joint pad between the first and second phalanges of digit III.

M. flexor perforatus digiti III acts to extend the tarsometatarsus and flex digit III.

M. Flexor Perforatus Digiti IV

M. flexor perforatus digiti IV arises by tendinous and fleshy fibers from the intercondyloid region of the femur. This origin is shared by Mm. flexor perforatus digiti III and flexor hallucis longus. M. flexor perforatus digiti IV is the most posterior of the three muscles sharing the common origin. The anteroproximal border of M. flexor perforatus digiti IV is inextricably fused with the posteroproximal border of M. flexor perforatus digiti III. The belly of M. flexor perforatus digiti IV passes caudad three-fourths of the length of the crus and ends on a flat tendon which passes through the tibial cartilage and a lateral superficial bony canal on the posteroproximal end of the hypotarsus. In its course through the tibial cartilage and the bony canal in the hypotarsus as well as throughout most of its descent along the posterolateral surface of the tarsometatarsus, the tendon of M. flexor perforatus digiti IV lies superficial to the tendon of M. flexor perforatus digiti III.

The tendon of M. flexor perforatus digiti IV passes through a fibrocartilaginous pulley at the base of digit IV, forms a sheath around the tendon of M. flexor digitorum longus, gives rise to a branch which inserts on the fibrous joint pad between the first and second phalanges of digit IV, and then splits so that it is perforated by the tendon of M. flexor digitorum longus. The branches of the tendon of M. flexor perforatus digiti IV insert on the plantar joint pad between the second and third phalanges of digit IV.

M. flexor perforatus digiti IV acts to extend the tarsometatarsus and flex digit IV.

M. Flexor Hallucis Longus

M. flexor hallucis longus arises by two separate heads in the Western Meadowlark.

1) The medial head arises in the intercondyloid region of the femur from the common tendinous and fleshy origin shared with Mm. flexor perforatus digiti III and flexor perforatus digiti IV.

2) The intermediate head arises by tendinous fibers from the posterolateral surface of the femur, proximal to the external condyle. The short tendon of the intermediate head gives rise to a fleshy belly which passes distad medial to the biceps loop and the tendon of M. biceps femoris.

In the Red-winged Blackbird this muscle arises by three separate heads. In the Western Meadowlark the lateral head of M. flexor hallucis longus is not present, but it appears as though the belly of what was once the lateral head has fused with the intermediate head of the muscle.

The medial and intermediate heads of M. flexor hallucis longus fuse behind the knee and pass distad along the posterior three-fourths of the crus. The fleshy belly tapers to a tendon which passes through a fibrous canal in the lateral half of the tibial cartilage and then through the deepest tendinal canal in the lateral half of the hypotarsus. The tendon of M. flexor hallucis longus passes distad along the posterior surface of the tarsometatarsus, curves around the lateral surface of metatarsal I and reaches the plantar surface of the hallux. The tendon passes distad along the plantar surface of the proximal phalanx, held close to the bone by a fibrous sheath, and inserts on the base of the ungual phalanx.

M. flexor hallucis longus acts to extend the tarsometatarsus and flex the hallux.

M. Flexor Perforatus Digiti II

M. flexor perforatus digiti II arises by a tendon shared with the lateral head of M. flexor hallucis longus from the posterodistal surface of the external femoral condyle. Fleshy fibers arise on the deep surface of the belly of M. flexor perforatus digiti II from a raphe shared with M. flexor hallucis longus. The belly of M. flexor perforatus digiti II tapers to a tendon which passes through a fibrous canal on the lateral border of the tibial cartilage, takes a diagonal course from lateral to medial through the intertarsal space, and emerges through the medial tendinal canal of the hypotarsus. The tendon continues distad along the medial surface of the tarsometatarsus and through a fibrous canal on the lateral surface of metatarsal I. The tendon inserts on the medial corner of the base of the proximal phalanx of digit II.

M. flexor perforatus digiti II acts to extend the tarsometatarsus and flex digit II.

M. Flexor Digitorum Longus

M. flexor digitorum longus arises by two heads in the Western Meadowlark. One head arises by fleshy fibers from the posterior surface of the fibula along its total length; and, the other head arises by fleshy fibers from the posterior surface of the tibiotarsus along the anterior three-fourths of its length. The two heads fuse about 3 mm from the proximal end of the tibiotarsus. After the belly of M. flexor digitorum longus extends distad along the posterior surface of the crus for three-fourths of its length it tapers to a tendon which passes through the deep layer of the medial half of the tibial cartilage and then through the deepest tendinal canal in the medial half of the hypotarsus. The tendon then passes distad along the posterior surface of the tarsometatarsus deep to the tendon of M. flexor hallucis longus. At the level of metatarsal I the tendon of M. flexor digitorum longus trifurcates.

The tendon to digit II passes through fibrous tissue at the base of the proximal phalanx of digit II and along the plantar surface of the digit to insert on the base of the distal phalanx. A viniculum from the deep surface of the tendon inserts on the fibrous plantar joint pad at the distal end of phalanx II of the digit.

The tendon to digit III passes between the two limbs of the tendon of insertion of M. flexor perforatus digiti III near the base of the proximal phalanx, perforates the tendon of M. flexor perforans et perforatus digiti III near the distal end of phalanx II, and inserts on the base of the ungual phalanx. A small viniculum from the deep surface of the tendon inserts on the fibrous pad at the distal end of phalanx III.

The tendon to digit IV is ensheathed by the tendon of M. flexor perforatus digiti IV at the level of phalanx I of digit IV. The tendon then perforates the tendon of M. flexor perforatus digiti IV near the distal end of phalanx I, passes along the plantar surface of digit IV, and inserts on the base of the ungual phalanx. A viniculum inserts on the fibrous pad between the distal and next to distal phalanges of digit IV.

M. flexor digitorum longus extends the tarsometatarsus and flexes digits II, III, and IV.

M. Extensor Hallucis Longus

M. extensor hallucis longus is a minute muscle about 18 mm long and 0.5 mm wide. The muscle arises by fleshy fibers from the anteromedial surface of the proximal end of the tarsometatarsus. The flat belly ends on a tendon which passes through a fascial sheath on metatarsal I to the dorsal surface of the hallux. The tendon passes along the dorsal surface of the hallux and inserts on a ligament which extends from the distal end of the proximal phalanx to the base of the terminal phalanx of the hallux.

M. extensor hallucis longus acts as a weak extensor of the hallux.

M. Flexor Hallucis Brevis

M. flexor hallucis brevis has a belly approximately 4 mm long and 1 mm in maximum width at its origin. M. flexor hallucis brevis originates from the anteromedial corner of the base of the hypotarsus and tapers to a small tendon which passes distad along the posterior portion of the tarsometatarsus medial to the tendons of all the deep flexor muscles. At the level of metatarsal I the tendon of M. flexor hallucis brevis passes along the lateral surface of metatarsal I, and inserts on a fibrous pad which is attached to the base of the plantar surface of the proximal phalanx of the hallux.

M. flexor hallucis brevis acts as a weak flexor of the hallux.

DRAWINGS OF MUSCLES

Abbreviations used in Figures

Acc. semit.- Musculus accesorius semitendinosi

Add. long.- M. adductor longus

Ant.- anterior

Apo.- aponeurosis

Bic. fem.- M. biceps femoris

Bic. loop- Biceps loop

Ext.- externus

Ext. dig. l.- M. extensor digitorum longus

Ext. hal. l.- M. extensor hallucis longus

Fem. tib. ext.- M. femorotibialis externus

Fem. tib. int.- M. femorotibialis internus

Fem. tib. med.- M. femorotibialis medius

F. dig. l.- M. flexor digitorum longus

F. hal. brev.- M. flexor hallucis brevis

F. hal. l.- M. flexor hallucis longus

F. p. et p. d. II- M. flexor perforans et perforatus digiti II

F. p. et p. d. III- M. flexor perforans et perforatus digiti III

Flex. per. d. II- M. flexor perforatus digiti II

Flex. per. d. III- M. flexor perforatus digiti III

Flex. per. d. IV- M. flexor perforatus digiti IV

Gas.- M. gastrocnemius

Iliacus- M. iliacus

Il. troc. ant.- M. iliotrochantericus anterior

Il. troc. med.- M. iliotrochantericus medius

Il. troc. post.- M. iliotrochantericus posterior

Il. tib.- M. iliotibialis

Int.- internus

Isch. fem.- M. ischiofemoralis

Lig. trans.- ligamentum transversum

Med.- medius

Obt. ext.- M. obturator externus

Obt. int.- M. obturator internus

P. ext.- pars externa

P. int.- pars interna

P. med.- pars media

Per. brev.- M. peroneus brevis

Per. long.- M. peroneus longus

Pirif. p. caudo.- M. piriformis pars caudofemoralis

Plantaris- M. plantaris

Post.- posterior

Sar.- M. sartorius

Semimemb.- M. semimembranosus

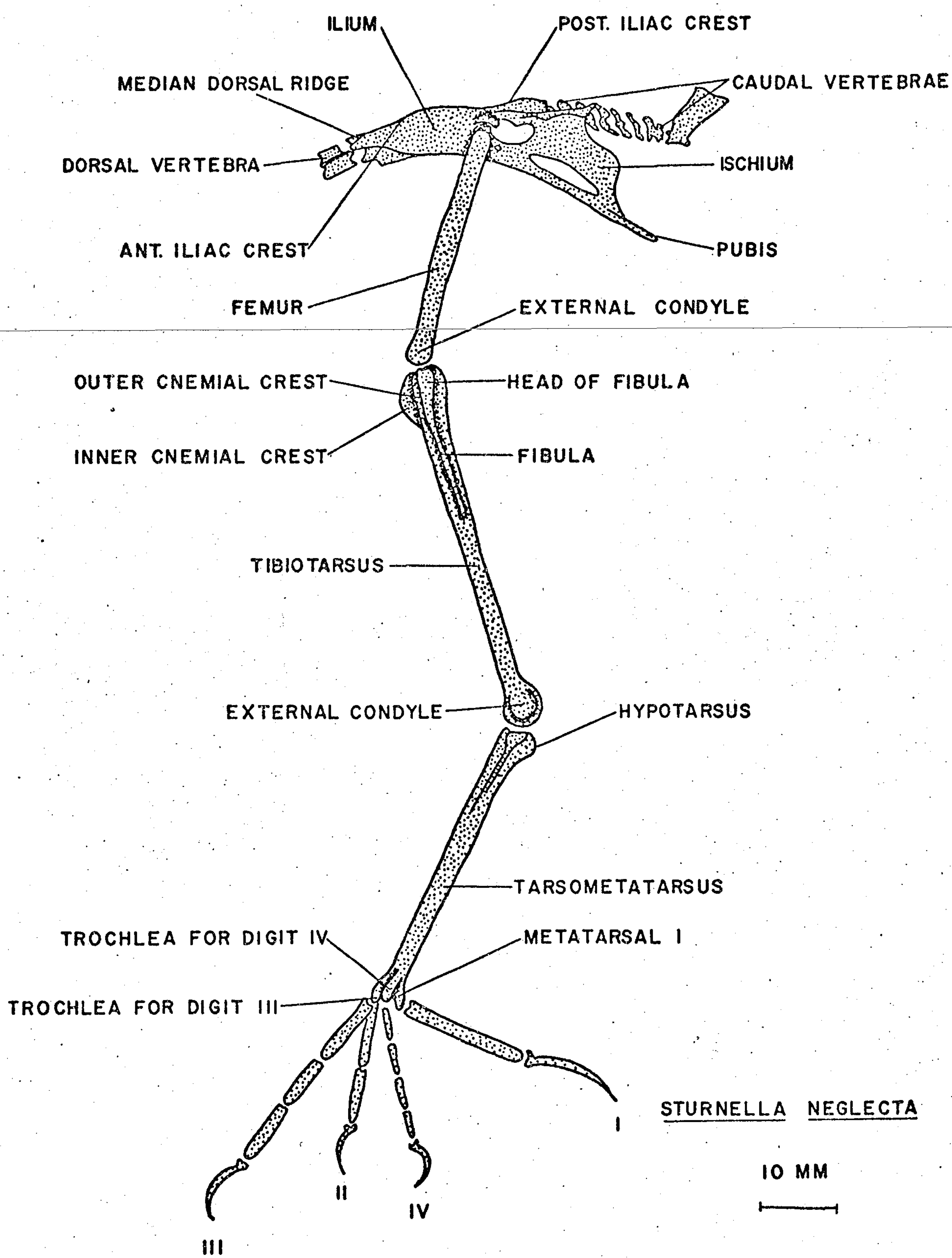
Semit.- M. semitendinosus

Tib. ant.- M. tibialis anterior

Tib. cart.- tibial cartilage

Figure 8

Lateral View of the Pelvis, Caudal Vertebrae
and Left Leg



STURNELLA NEGLECTA

Figure 9

Medial View of the Pelvis, Caudal Vertebrae
and Left Leg

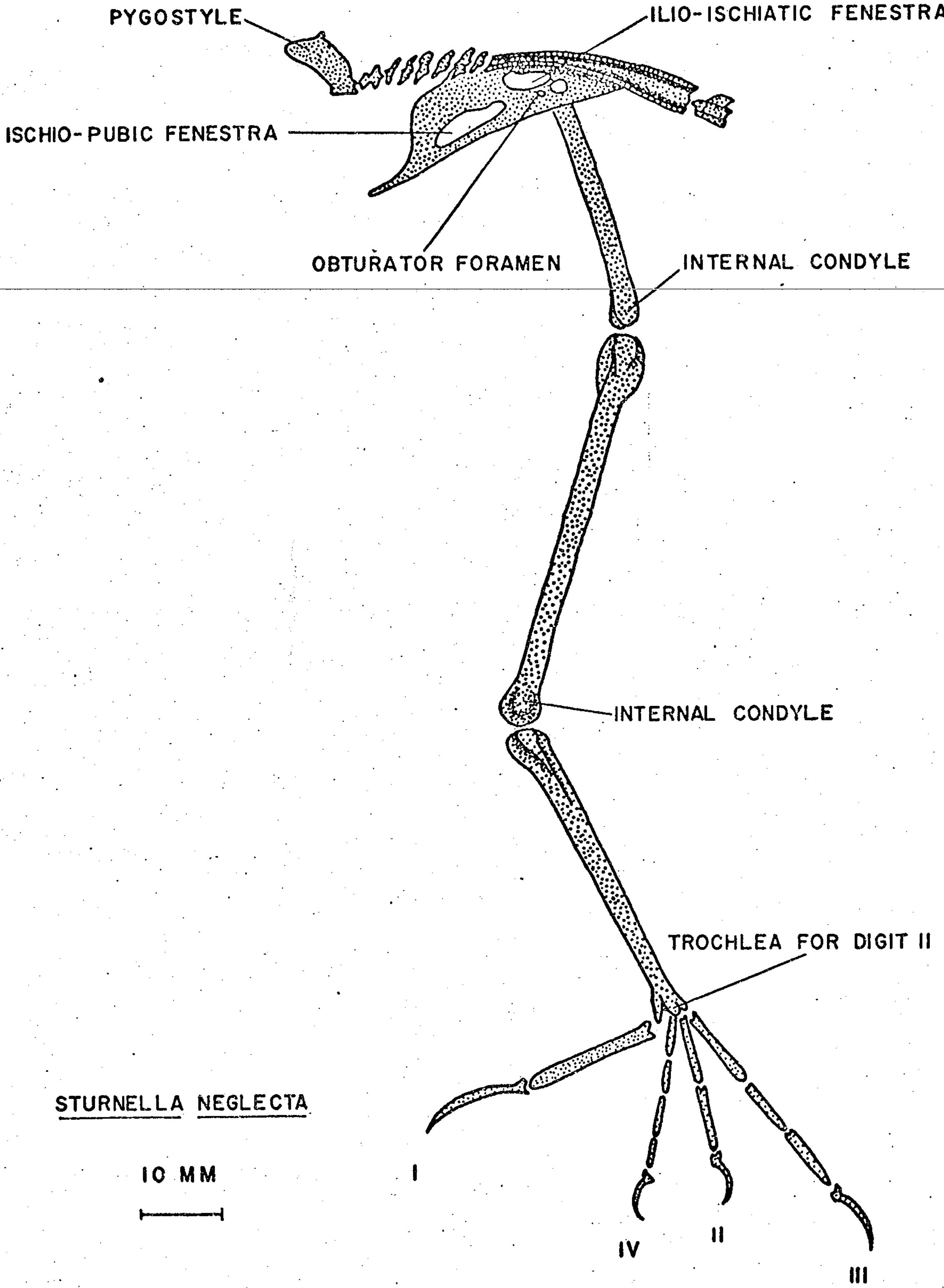
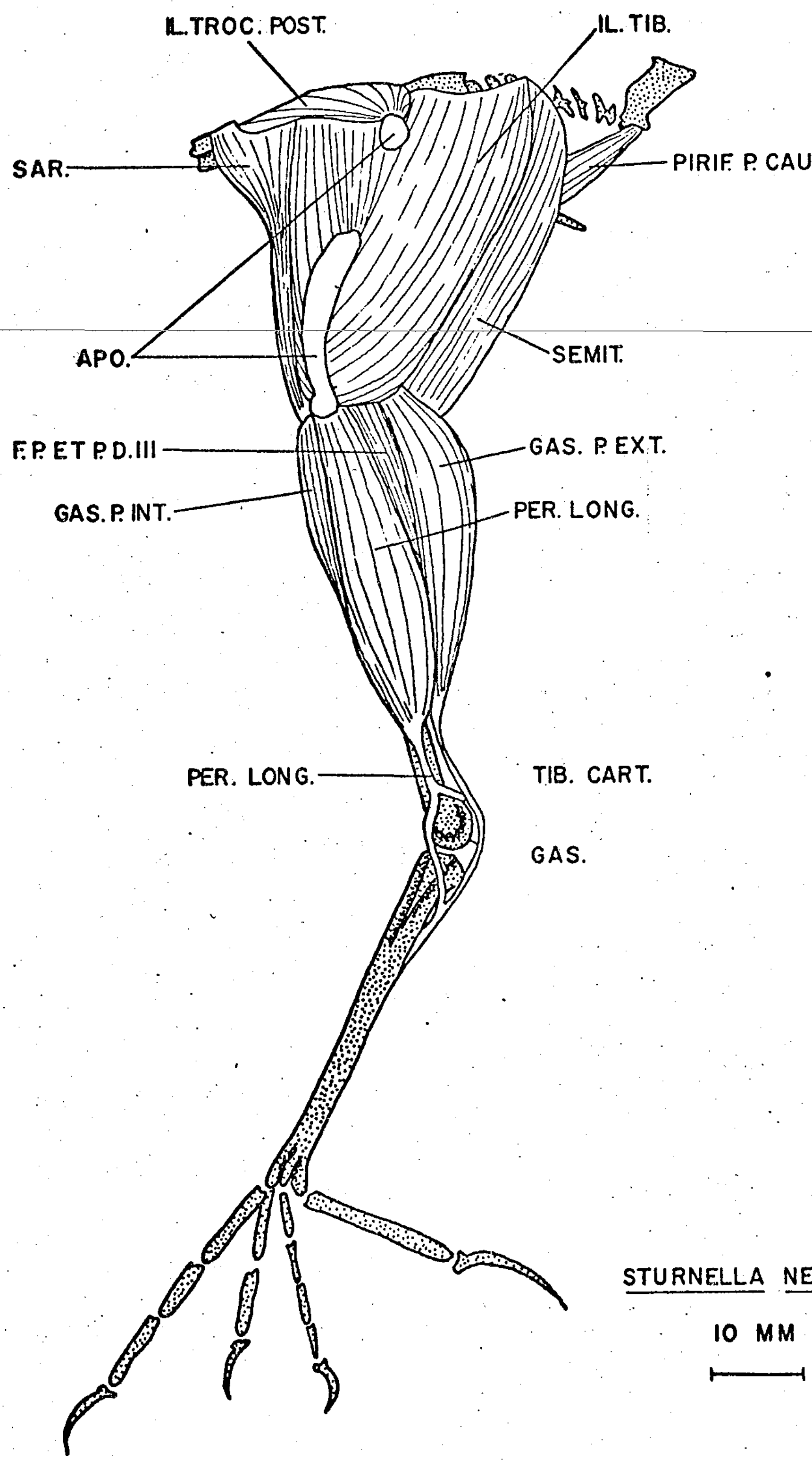

PYGOSTYLE
ILIO-ISCHIATIC FENESTRA
ISCHIO-PUBIC FENESTRA
OBTURATOR FORAMEN
INTERNAL CONDYLE
INTERNAL CONDYLE
TROCHLEA FOR DIGIT II
STURNELLA NEGLECTA
10 MM
I
IV
II
III

Figure 10

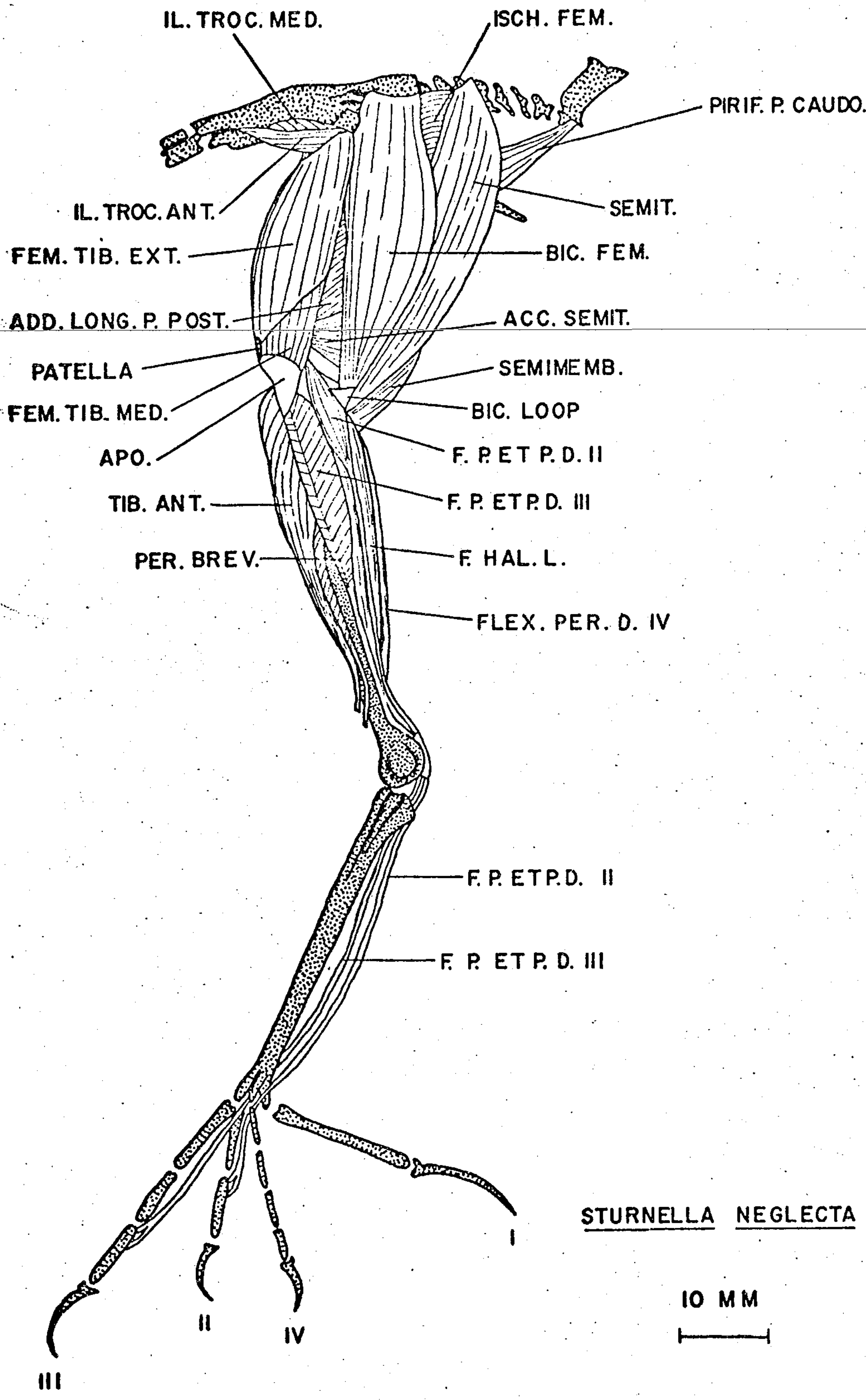
Lateral View of the Superficial Muscles
of the Left Leg



STURNELLA NEGLECTA

Figure 11

Lateral View of the Left Leg Showing a Second Layer of Muscles. The Following Superficial Muscles Have Been Wholly Removed: Sar.; Il. tib.; Il. troc. post.; Gas.; Per. long.



STURNELLA NEGLECTA

Figure 12

Lateral View of the Left Leg Showing a Third Layer of Muscles. In Addition to Those Listed for Figure 11, the Following Muscles Have Been Wholly or Partly Removed: F. p. et p. d. II; F. p. et p. d. III; Semit.; Tib. ant.; Fem. tib. med.; Fem. tib. ext.; Il. troc. ant.; Il. troc. med.; Bic. fem.

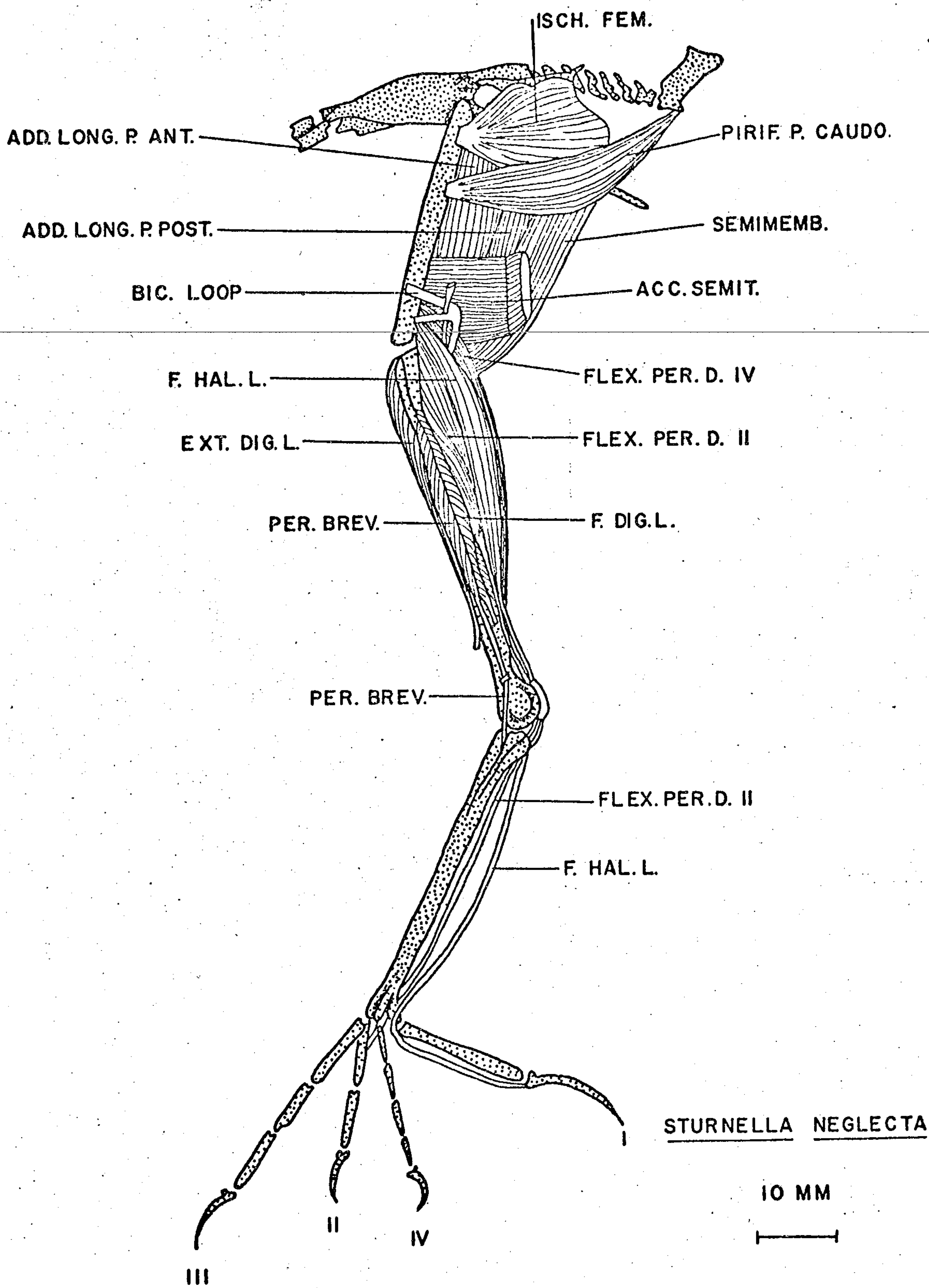
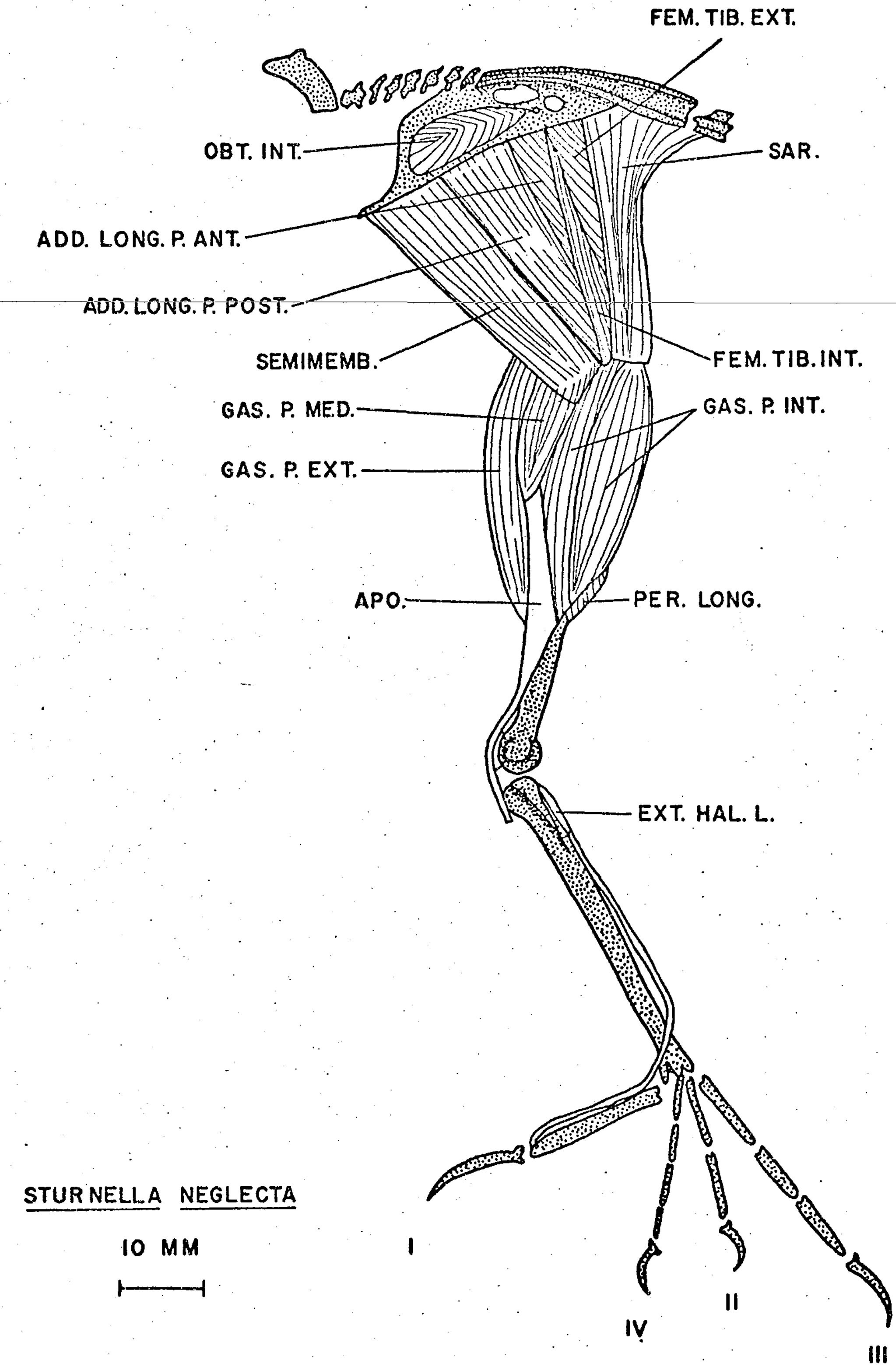

ISCH. FEM.
ADD. LONG. P. ANT.
PIRIF. P. CAUDO.
ADD. LONG. P. POST.
SEMIMEMB.
BIC. LOOP
ACC. SEMIT.
F. HAL. L.
FLEX. PER. D. IV
EXT. DIG. L.
FLEX. PER. D. II
PER. BREV.
F. DIG. L.
PER. BREV.
FLEX. PER. D. II
F. HAL. L.
I
II
III
IV
STURNELLA NEGLECTA
10 MM

Figure 13

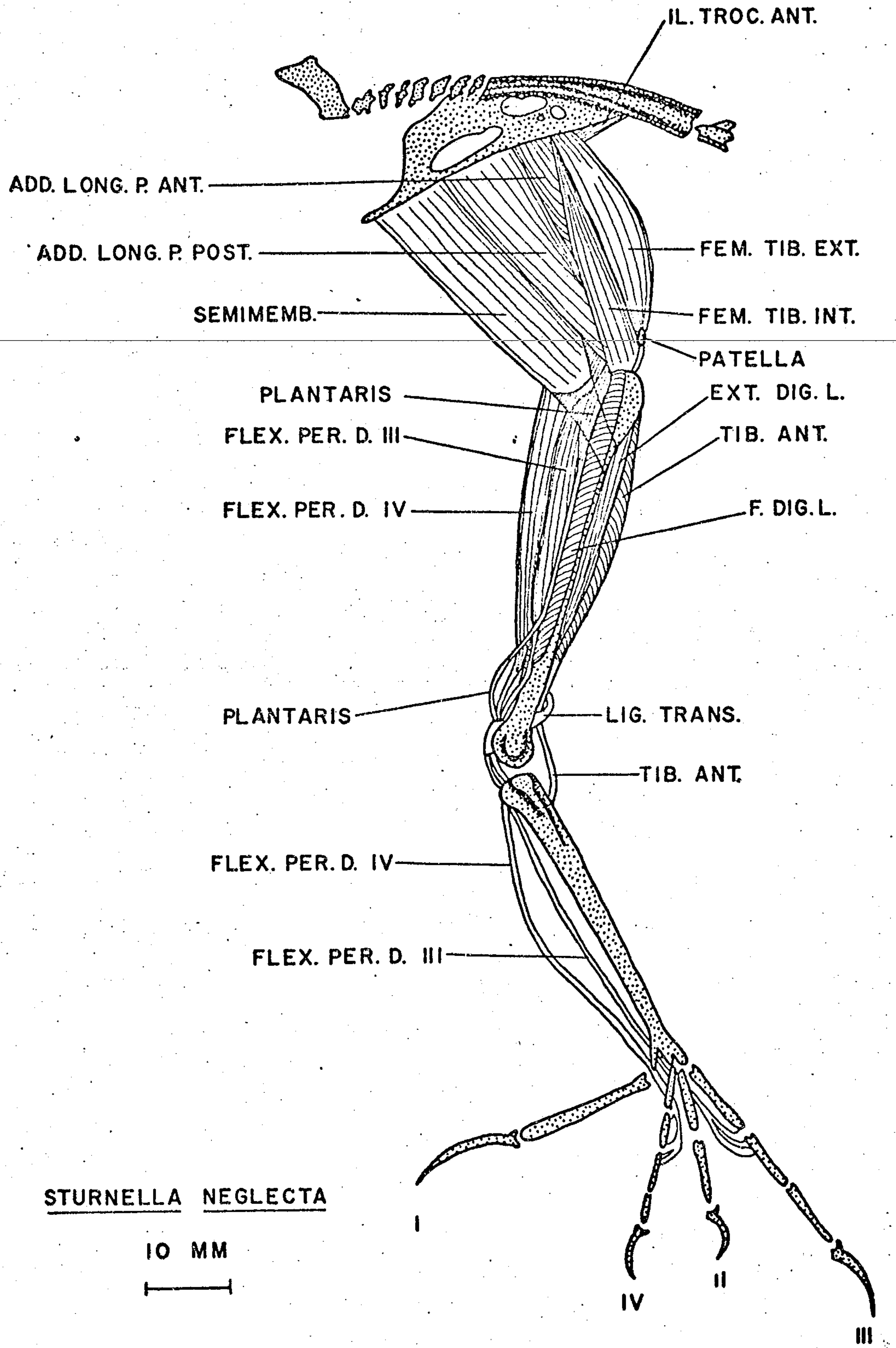
Medial View of the Superficial Muscles of the Left Leg



STURNELLA NEGLECTA

Figure 14

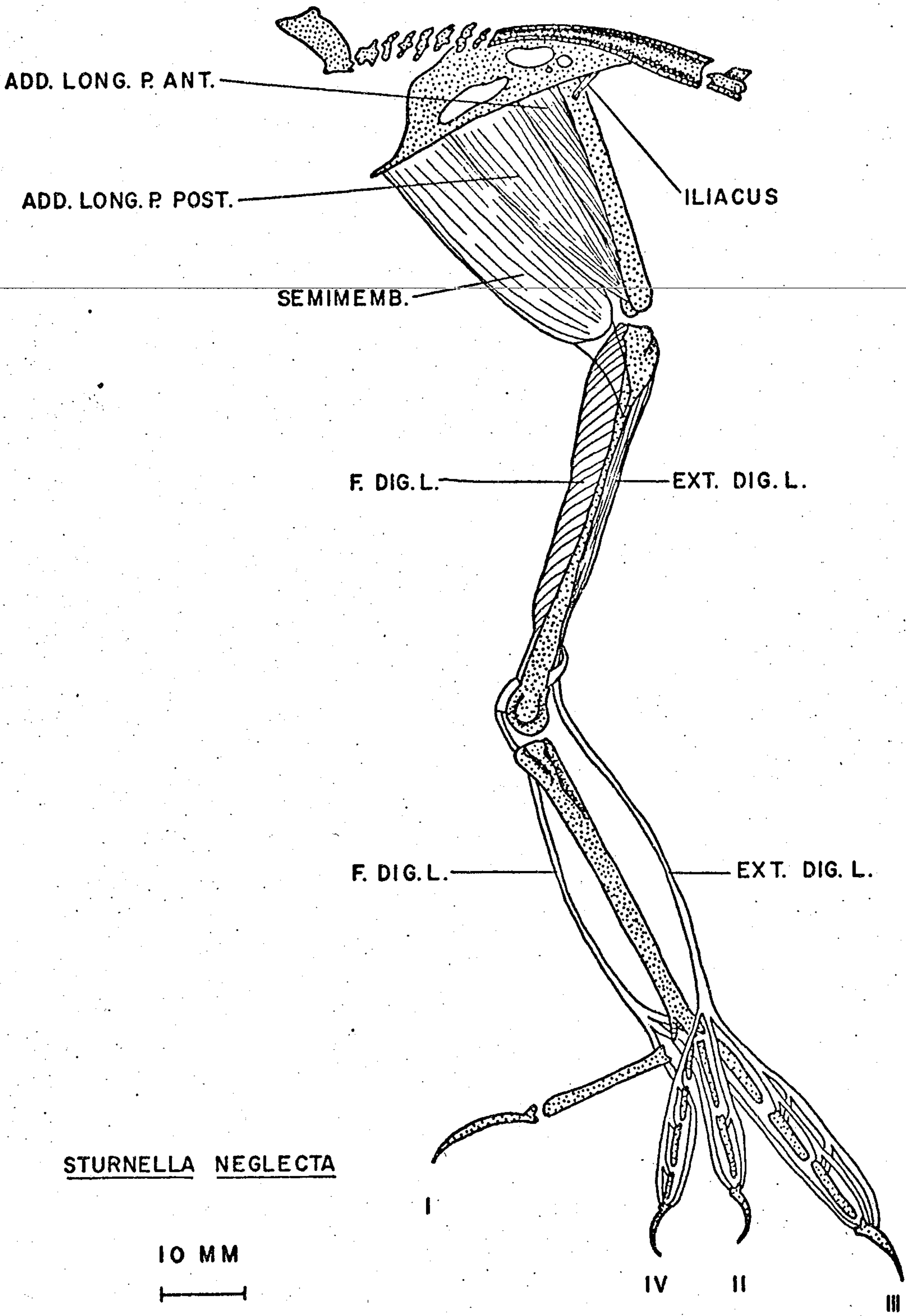
Medial View of the Left Leg Showing a Second Layer of Muscles. The Following Superficial Muscles Have Been Wholly Removed: Obt. int.; Gas.; Sar.; Per. long.; Ext. hal. l.



STURNELLA NEGLECTA

Figure 15

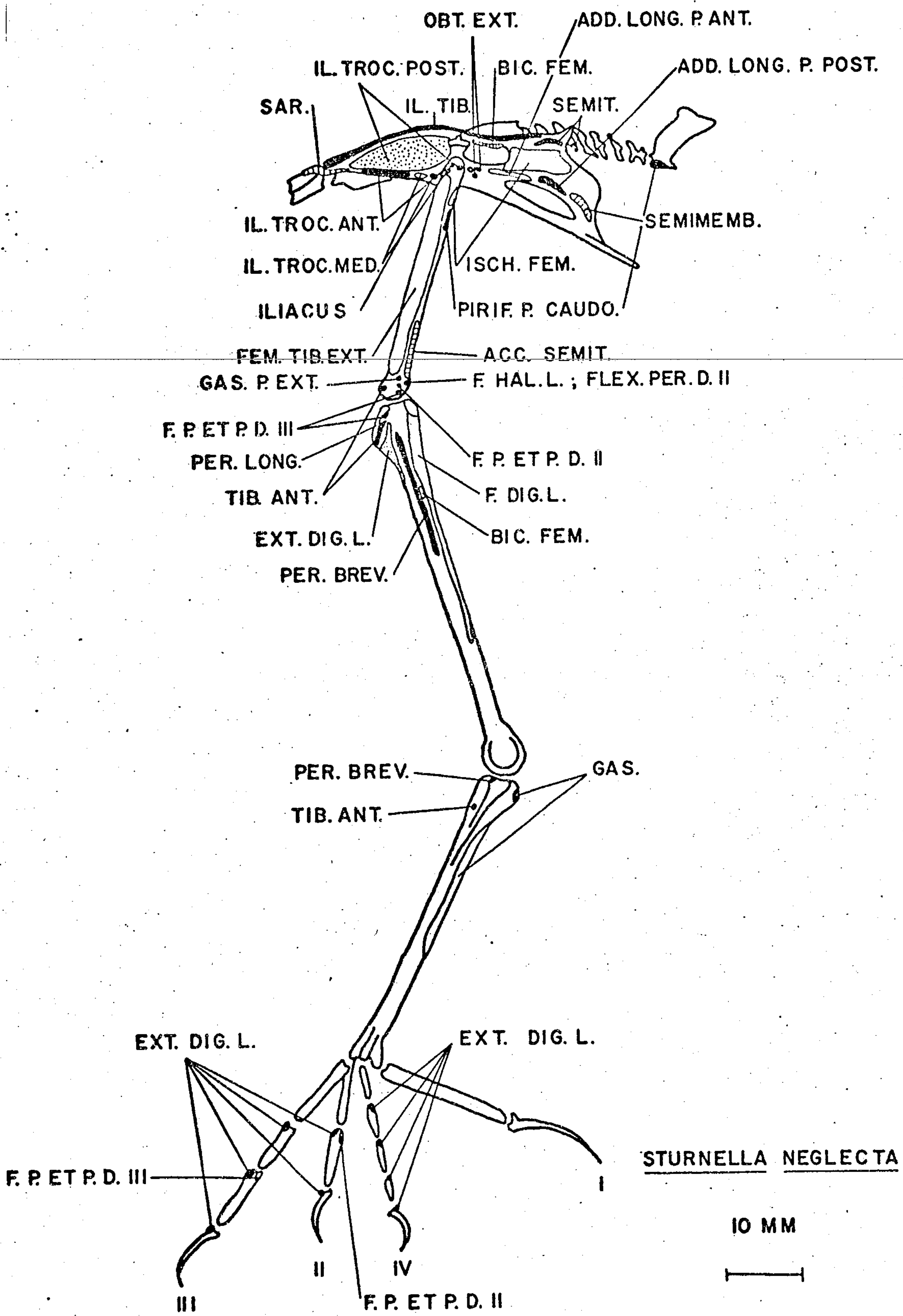
Medial View of the Left Leg Showing a Third Layer of Muscles. In Addition to Those Listed for Figure 14, the Following Muscles Have Been Wholly or Partly Removed: Fem. tib. int.; Plantaris; Flex. per. d. II; Flex. per. d. III; Flex. per. d. IV; F. hal. l.; Pirif. p. caudo.; Isch. fem.; Acc. semit.; Per. brev.



STURNELLA NEGLECTA

Figure 16

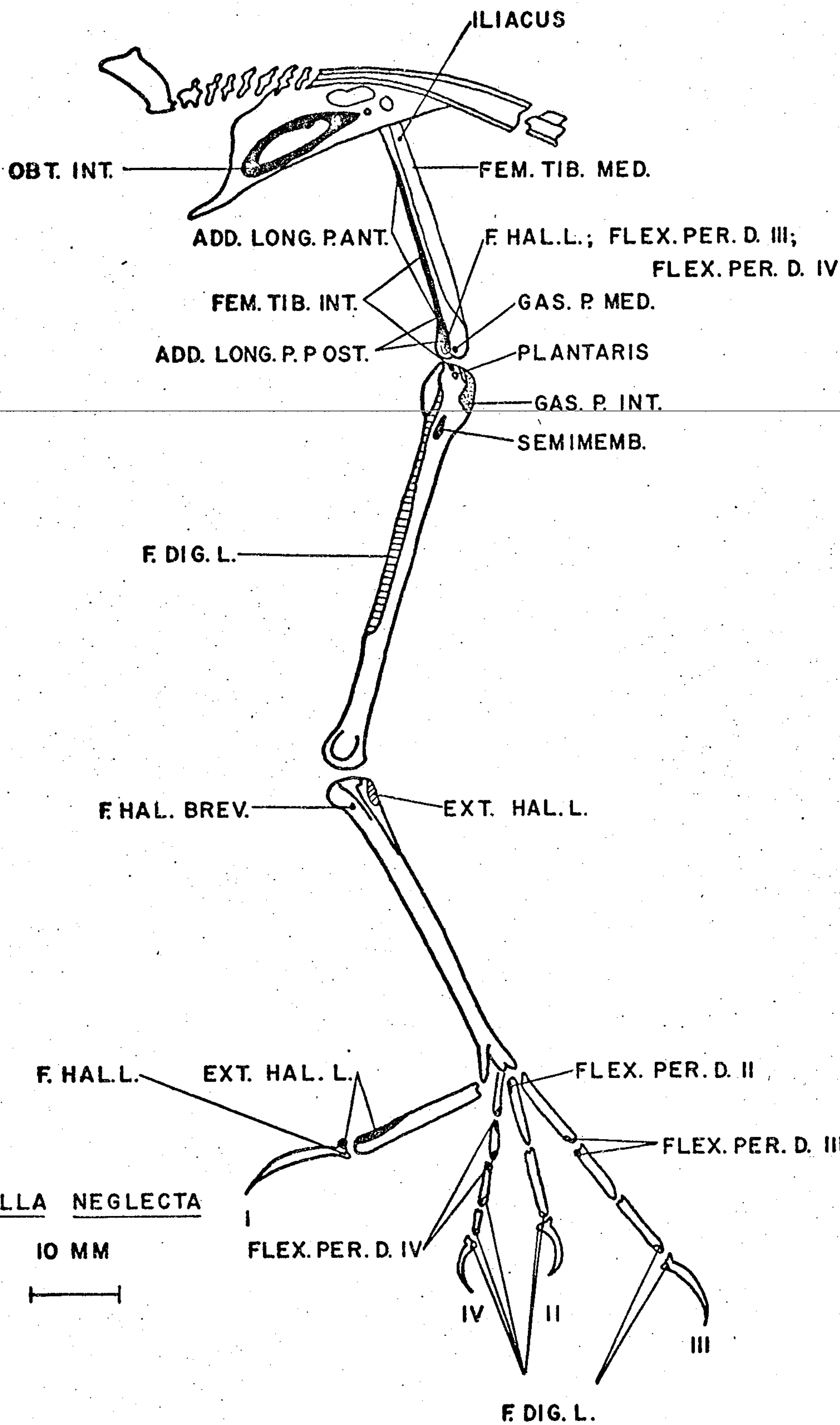
Lateral View of the Left Leg Showing Areas of Muscle Attachment



STURNELLA NEGLECTA

Figure 17

Medial View of the Left Leg Showing Areas of Muscle Attachment



STURNELLA NEGLECTA

10 MM

Figure 18

Figure 1. Anterior View of Left Femur Showing Areas of Muscle Attachment. Figure 2. Anterior View of Left Tibiotarsus Showing Areas of Muscle Attachment. Figure 3. Anterior View of Left Tarsometatarsus and Digits Showing Areas of Muscle Attachment. Digits I and IV Rotated to Show Extensor Surface

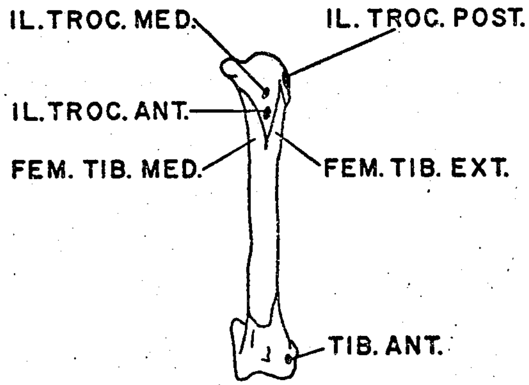


FIG. 1

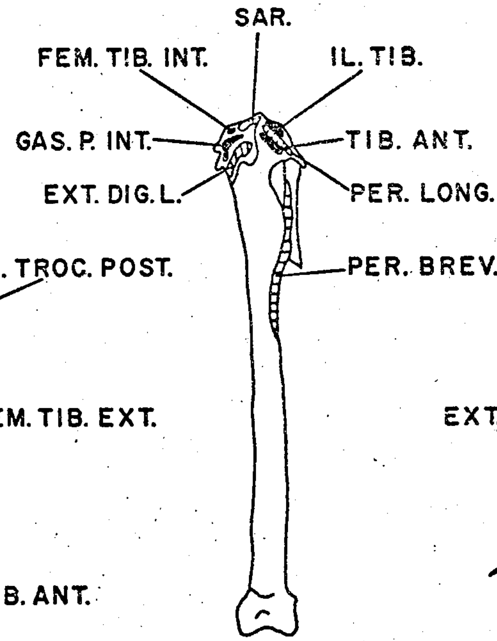


FIG. 2

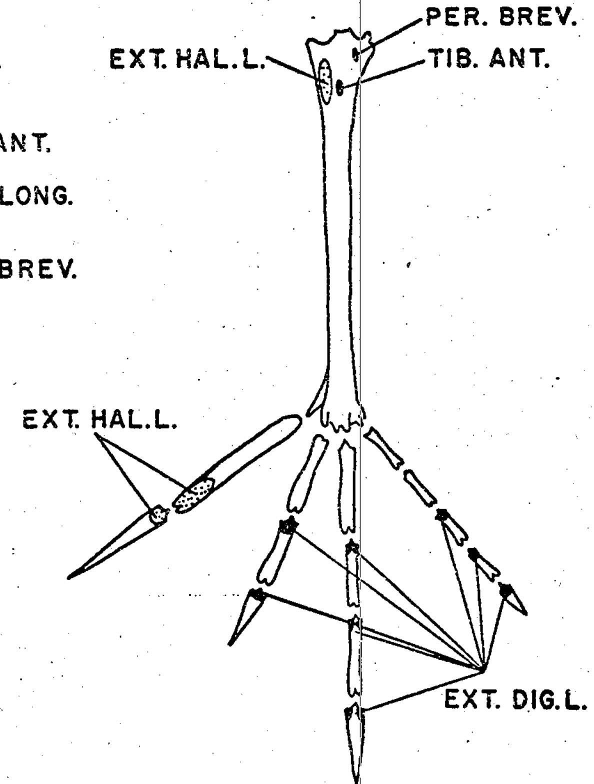


FIG. 3

STURNELLA NEGLECTA

10 MM

Figure 19

Figure 1. Posterior View of Left Femur Showing Areas of Muscle Attachment. Figure 2. Posterior View of Left Tibiotarsus Showing Areas of Muscle Attachment. Figure 3. Posterior View of Left Tarsometatarsus and Digits Showing Areas of Muscle Attachment. Digits I and IV Have Been Rotated to Show Palmar Surface

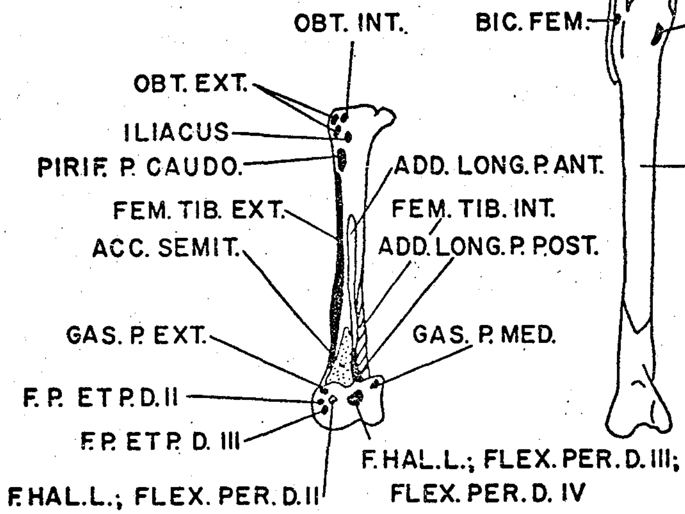


FIG. 1

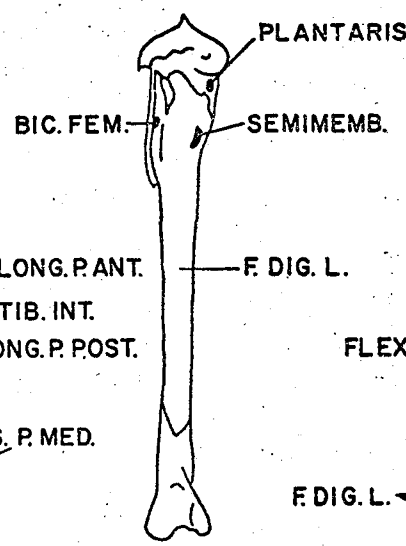


FIG. 2

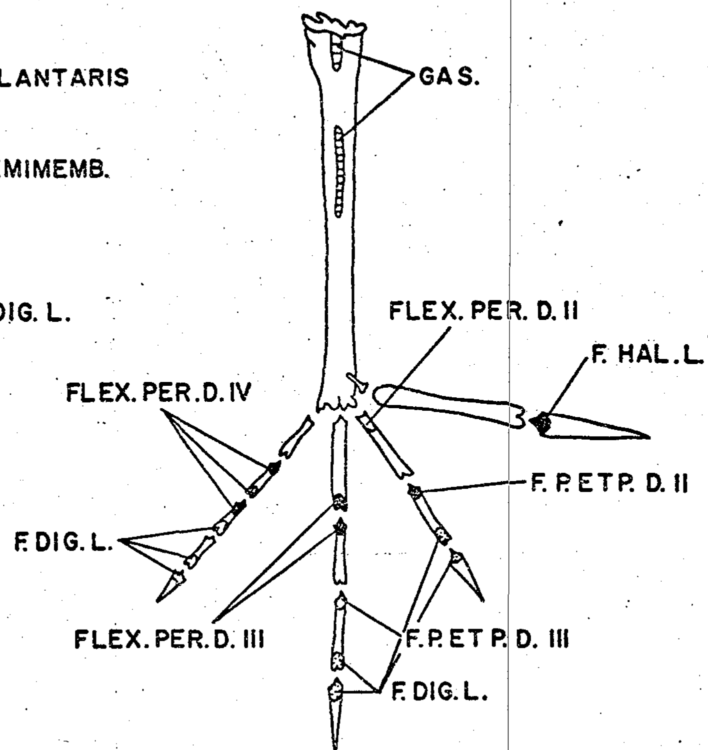


FIG. 3

STURNELLA NEGLECTA

10 MM

Chapter 6

DISCUSSION

In his study on the pelvic appendage in three genera of Cuculidae, Berger (1952) states that it is a well established principle of comparative anatomy that in closely related forms cursorial animals possess longer appendages than non-cursorial animals. Berger (1952) and Engels (1938a) found this to be true in their comparisons of the Road-runner (*Geococcyx*) and the Black-billed and Yellow-billed Cuckoos (*Coccyzus*). In those birds which have been studied the longer appendages of cursorial forms seem to be the result of adaptive changes in the distal elements of the appendage (Miller, 1937; Engels, 1938a; Richardson, 1942; Berger, 1952).

The z-values obtained for the intramembral ratios of *Sturnella n. neglecta* indicate that there is no significant difference between the ratios of the sexes in the ratios of the ulna and hand to the humerus, and the ratio of the tibiotarsus to the femur. The z-values do indicate a highly significant difference between the sexes when the ratios of the tarsometatarsus, middle toe, and hallux to the femur are considered. If the length of the femur was relatively the same in both sexes these results would indicate a lengthening of the distal elements (i.e. tarsometatarsus, middle toe, and hallux) of the leg of the female. But, these intramembral ratios indicate nothing about the relative length of the femur in one sex or the other. It is necessary to use a non-appendage element as a standard of comparison to gain insight into the relative length of specific limb segments in the male or the female.

It has been presumed by previous investigators in the field of avian anatomy (Böker, 1927; Engels, 1940; Richardson, 1942; Berger, 1952) that the trunk of birds is more stable in evolution than the paired appendages. If one accepts this presumption as valid an examination of limb/synsacrum ratios ought to reveal information about the relative length of individual bones among the various representatives of a genus or family. The z-values for the limb/synsacrum ratios of Sturnella n. neglecta reveal no significant difference between the sexes for the ratios of the humerus, ulna, hand, femur and tibiotarsus to the synsacrum, but they do reveal a significant to highly significant difference between the sexes for the ratios of the tarsometatarsus, middle toe, hallux, and total leg length to the synsacrum. The distal elements of the leg and the total leg seem to be relatively longer in the female than the male.

This relatively longer leg and distal elements of the leg of the female is also indicated by the results of the intermembral ratios. In each ratio (except the ulna/tibiotarsus ratio) there is a highly significant difference between the sexes, with the male having larger median ratio values than the female. These results would imply longer legs and distal leg elements in the female and thus a reduction in the size of the female over the male ratio values.

If the leg and distal elements of the leg are relatively longer in the female one would expect that the muscles and tendons of the female leg would only be relatively longer than the male unless differences in the habits of the sexes necessitated a change in the form or relative development of the muscles. The z-values for the comparison of the myological ratios of the sexes of the Western Meadowlark indicates no significant difference between the sexes when all the ratios are compared with one another. However, there are some small differences (listed in the chapter on myology) which do seem to indicate a different trend of muscular development in each sex.

In the female the muscles concerned with extending and flexing the thigh and crus (i.e. Mm. iliotibialis, sartorius, femorotibialis medius and externus, ischiofemoralis, semitendinosus and accesorius semitendinosi), and with flexing digits III and IV (i.e. Mm. flexor perforatus digiti III, flexor perforatus digiti IV) are better developed than in the male. The flexors and extensors of the thigh and crus are muscles which would seem to be useful in walking by their flexing of the digits to propel the bird in a forward direction, and useful in supporting the bird while it is extracting food or objects from the ground.

In the male the muscles concerned with extending and flexing the crus (i.e. Mm. femorotibialis internus, semimembranosus), flexing the tarsometatarsus (M. tibialis anterior), and flexing and extending the digits (Mm. extensor digitorum longus, flexor hallucis longus, flexor digitorum longus) are better developed than in the female. The flexors and extensors of the crus, tarsometatarsus, and digits are muscles which would seem to be useful in perching.

The osteological and myological differences between the sexes would seem to indicate that the female is slightly better cursorially adapted than the male who is better perching adapted than the female. When these differences are viewed in terms of what is known of the natural history of the species it seems as though the differences would arise primarily as a result of sexual selection during the breeding season.

The male Western Meadowlark establishes, maintains, and defends a breeding territory for up to four weeks before the arrival of the females. He advertises his occupation of an area by singing songs from fence posts, tall weeds, small trees, or other relatively high areas.

He maintains the territory until the final brood is fledged. After the males have established territories the females arrive and exhibit a strong homing behavior directed toward the territory of the previous season rather than toward a particular mate. The males may have more than one mate in their territories. After the breeding season is over Western Meadowlarks form loose foraging flocks of from 10 to 75 individuals until the next breeding season.

This type of breeding behavior would seem to select for male birds that can successfully establish and maintain a breeding territory. A successful male would be one that could advertise the boundaries of his territory and defend them from encroachment by other males. A successful bird would necessarily have leg muscles which would allow him to utilize the perches necessary for the maintenance of his territory. Western Meadowlark breeding behavior would select for females that had the stamina to survive the fall and winter months. The females that survived would be those that could find enough food to eat. Since these birds forage along the ground those females that could walk along the ground more rapidly and extract food from on or below the surface of the ground more successfully would be the ones that would survive to breed the next year.

In summary, the male and female Western Meadowlark possess small differences in their bone lengths and muscle weights which seem to be related to the breeding habits of the birds. The female is better cursorially adapted than the male by her possession of a relatively longer tarsometatarsus, middle toe, and hallux, and by a better development of leg muscles useful in walking. The male is better adapted to utilize perches than the female by his better development of leg muscles useful in perching. These sexual differences between the pelvic appendage of *Sturnella n. neglecta* would seem to be the result of sexual selection during the breeding season.

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