A STUDY OF CANINE AND EQUINE SKELETAL MUSCLE

H. M. Gunn
M.V.B.,(Hons), M.R.C.V.S.

A thesis presented for the Degree
of Doctor of Philosophy in the
University of Edinburgh
1975

Volume II Tables, Figures, Appendices
and Published Work.

Table 1 Total number of samples of 13 body components obtained by dissection of 75 dogs and 63 horses.

	M.Semi-tendin-osus	Femur	Femoral Muscle group	Distal hind-limb Muscle group	Proximal fore-limb Muscle group	Distal muscle	Fore-limb group M. Longissimus	Humerus	Total hind-limb bones	Total fore-limb bones	Heart	Total muscle	Total bone
Young Greyhounds (Weights ·38 to 23·5 kg)	11	11	11	11	11	11	11	11	11	11	11	11	11
Adult Greyhounds (Weights 19 to 37 kg)	33	13	13	8	7	7	7	7	7	7	7	7	7
Young other dogs (Weights ·46 to 9·90 kg)	18	16	16	4	4	4	4	4	4	4	4	4	4
Adult other dogs (Weights 7·7 to 46·5 kg)	13	9	5	5	5	5	5	5	5	5	5	5	5
Young Thoroughbreds (Weights ·691 to 433 kg)	23	16	16	8	7	7	7	7	7	7	8	7	7
Adult Thoroughbreds (Weights 445 to 509 kg)	7	4	3	-	-	-	-	-	-	-	-	-	-
Young other horses (Weights 2·15 to 207 kg)	12	7	8	4	4	4	3	4	4	4	4	3	3
Adult other horses (Weights 154 to 547 kg)	21	11	9	6	3	3	3	3	3	3	3	3	3

Fig. 1.

Femurs of Greyhounds and other dogs, indicating their sizes over the range of liveweight studied.

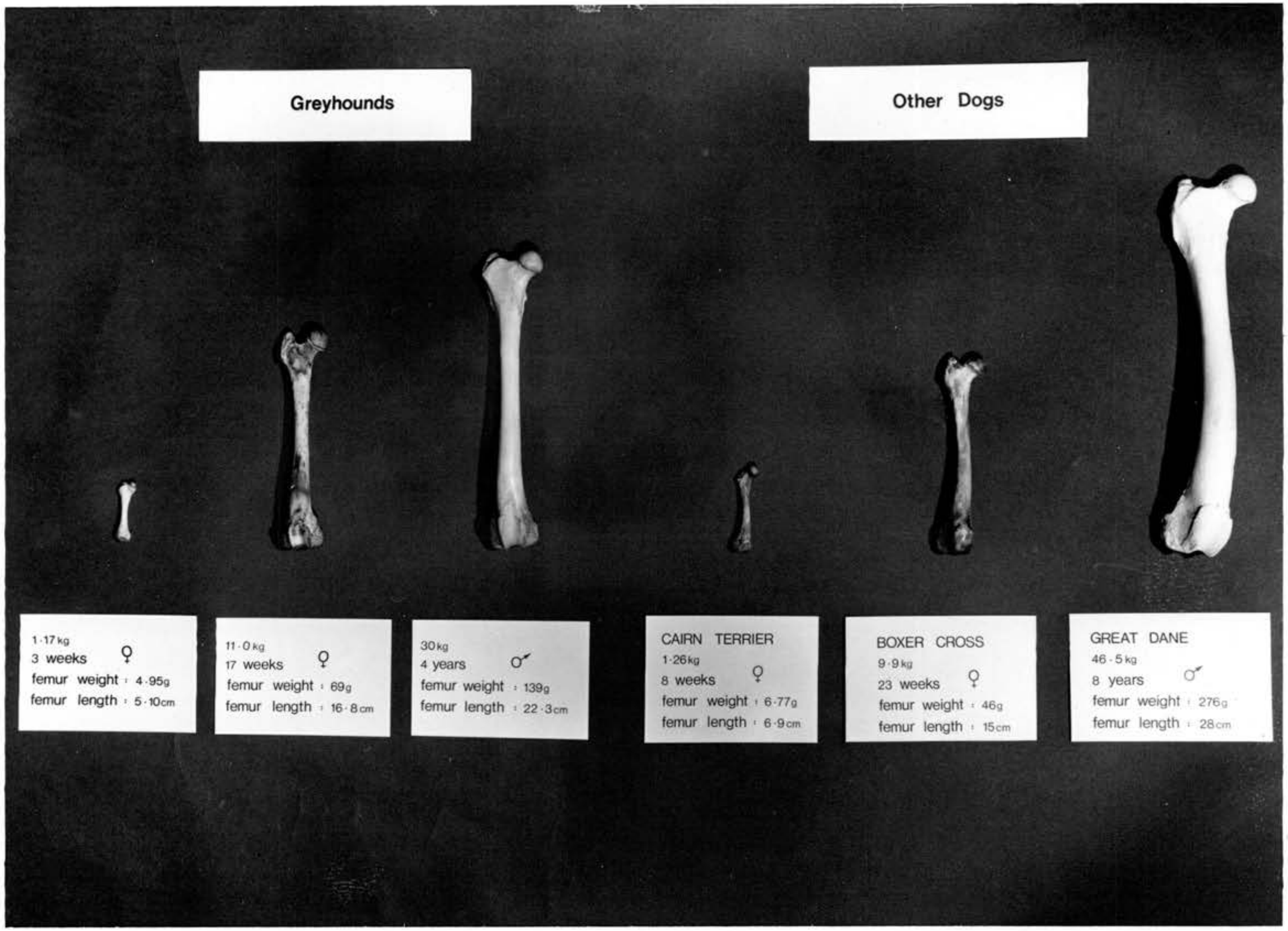

Greyhounds
Other Dogs
1·17kg 3 weeks ♀ femur weight : 4·95g femur length : 5·10cm
11·0kg 17 weeks ♀ femur weight : 69g femur length : 16·8cm
30kg 4 years ♂ femur weight : 139g femur length : 22·3cm
CAIRN TERRIER 1·26kg 8 weeks ♀ femur weight : 6·77g femur length : 6·9cm
BOXER CROSS 9·9kg 23 weeks ♀ femur weight : 46g femur length : 15cm
GREAT DANE 46·5kg 8 years ♂ femur weight : 276g femur length : 28cm

Fig. 2.

Femurs of Thoroughbreds and other horses, indicating their sizes over the range of liveweight studied.

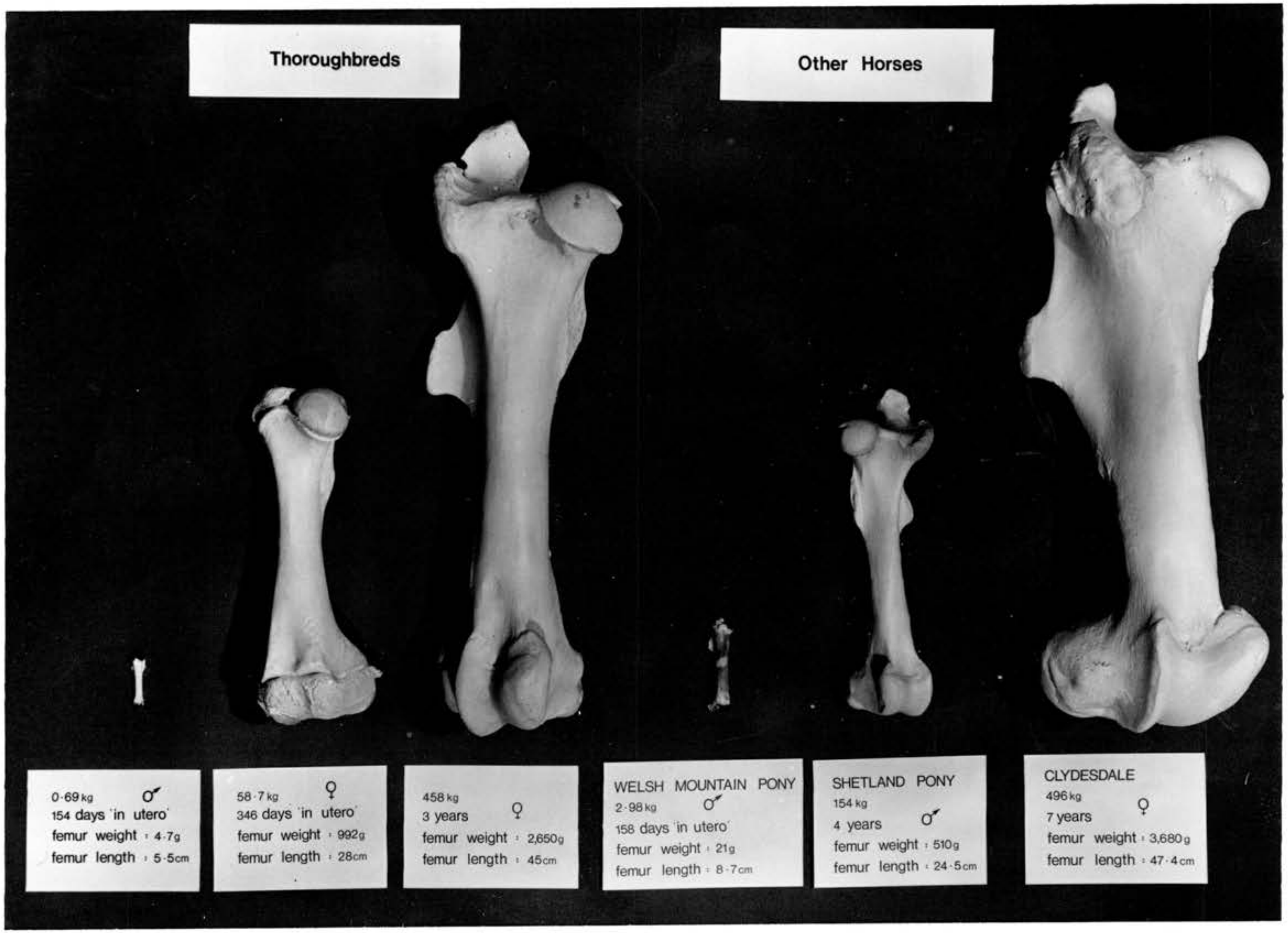

Thoroughbreds
Other Horses
0·69 kg ♂
154 days 'in utero'
femur weight : 4·7 g
femur length : 5·5 cm
58·7 kg ♀
346 days 'in utero'
femur weight : 992 g
femur length : 28 cm
458 kg
3 years ♀
femur weight : 2,650 g
femur length : 45 cm
WELSH MOUNTAIN PONY
2·98 kg ♂
158 days 'in utero'
femur weight : 21 g
femur length : 8·7 cm
SHETLAND PONY
154 kg
4 years ♂
femur weight : 510 g
femur length : 24·5 cm
CLYDESDALE
496 kg
7 years ♀
femur weight : 3,680 g
femur length : 47·4 cm

Table 2 Lengths of the femur, tibia and fibula, humerus, radius and ulna of dogs and horses in cm.

Type of animal	Live-weight	Sex	Femur	Tibia & Fibula	Humerus	Radius & Ulna
Young Greyhounds	377	♀	4·1	3·6	4·1	4·6
	927	♀	5·5	5·2	5·7	6·1
	1,056	♀	5·5	5·0	5·6	6·0
	1,174	♀	5·1	5·1	5·3	5·7
	1,423	♂	7·6	7·2	7·4	8·3
	2,280	♂	8·3	7·9	8·1	9·3
	5,712	♀	12·6	13·0	12·1	14·1
	11,000	♀	16·8	17·2	15·3	18·5
	15,250	♀	18·8	20·3	17·4	21·4
	19,750	♂	20·9	22·2	19·1	23·4
	23,500	♀	21·6	22·2	20·0	23·9
Adult Greyhounds	25,000	♀	21·8	22·2	19·7	24·1
D*	25,300	♂	21·8	22·5	-	-
	28,000	♂	23·6	23·9	-	-
D*	28,500	♀	21·0	24·2	21·2	25·4
D*	30,000	♂	23·5	24·3	22·5	25·9
Young other dogs						
Cairn Terrier	1,256	♀	6·9	6·8	6·6	7·3
Boxer X	6,585	♀	11·8	11·9	11·3	13·0
Boxer X	8,500	♂	13·1	14·2	13·1	15·9
Boxer X	9,900	♀	15·0	15·5	13·6	16·6
Adult other dogs						
Collie X	10,400	♀	14·2	14·8	15·5	13·5
Afghan	25,100	♀	25·6	27·0	28·0	23·2
Afghan	31,900	♂	25·7	26·0	27·0	24·0
Great Dane	46,500	♂	28·1	29·9	30·9	26·5

D* Detrained Greyhounds

Type of animal	Live-weight	Sex	Femur	Tibia & Fibula	Humerus	Radius & Ulna
Young Thoroughbreds	691	♂	5·5	5·3	4·2	6·3
	13,429	♀	17·6	18·1	14·1	20·2
	19,000	♀	20·0	21·3	-	-
	23,872	♂	22·6	23·8	16·8	26·0
	29,000	♂	22·9	24·2	-	-
	30,965	♀	22·4	23·5	-	-
	33,500	♂	24·0	25·9	-	-
	40,500	♀	27·0	27·7	21·1	31·2
	42,962	♀	26·4	27·3	20·59	31·2
	58,664	♀	28·4	29·1	22·1	33·8
	432,727	♂	47·6	43·4	36·2	50·2
Adult Thoroughbreds	-	-	-	-	-	-
Young other horses						
Welsh Mt.	2,977	♂	8·7	7·9	6·8	9·1
Welsh Mt.	109,091	♂	30·7	28·7	22·5	32·9
Welsh Mt.	114,546	♀	29·7	28·3	22·6	32·5
Welsh Mt.	118,182	♂	30·8	29·0	-	-
Welsh Mt.	153,727	♂	31·2	28·4	20·0	32·6
Adult other horses						
Welsh Mt.	178,182	♂	36·1	31·6	27·4	37·1
Shetland	203,636	♂	35·2	30·9	26·3	36·1
Shetland	280,000	♂	31·4	27·5	-	-
TB X **	369,091	♂	47·1	42·5	-	-
TB X **	432,727	♂	42·5	37·4	31·9	42·6
Connemara X	445,455	♀	41·9	37·0	-	-
Clydesdale	496,364	♀	47·4	36·4	36·5	49·8
TB X **	521,818	♂	44·5	39·3	-	-
TB X **	534,545	♀	43·5	38·5	-	-

TB X ** Thoroughbred Crosses

Table 3 Allometric equations comparing the growth of the combined lengths of the propodial and epipodial skeleton of the limbs of dogs and horses relative to liveweight. The weight ranges for computations being: birth to 30 kg for Greyhounds, birth to 47 kg for other dogs, 13·4 to 433 kg for Thoroughbreds and 109 to 535 kg liveweight for other horses.

Type of animal	Number of observations	Growth ratio b*	Se b	log a	r**	Significance of difference of b from ·333
Hindlimb						
Greyhounds	16	0·434	0·012	-0·253	0·9944	P< 0·001
Other dogs	8	0·428	0·028	-0·292	0·9872	P< 0·05
Thoroughbreds	10	0·259	0·016	0·516	0·9847	P< 0·005
Other horses	13	0·247	0·030	0·516	0·9259	P< 0·02
Forelimb						
Greyhounds	14	0·408	0·013	-0·138	0·9942	P< 0·001
Other dogs	8	0·415	0·024	-0·169	0·9901	P< 0·02
Thoroughbreds	6	0·256	0·022	0·513	0·9850	P< 0·025
Other horses	7	0·281	0·046	0·314	0·9397	N.S.

* Regression coefficient b, standard error Se b.

** Correlation coefficient r.

Table 4 Values of the combined propodial and epipodial skeletal lengths in cm calculated from the allometric equations of Table 3 for dogs of 0·5 kg and 30 kg liveweight.

		0·5 kg		30 kg	
		Mean	95% limits	Mean	95% limits
Greyhounds	Hindlimb	8·29	7·66 - 8·97	49·0	46·3 - 51·9
	Forelimb	9·20	8·51 - 9·94	48·9	45·9 - 52·1
Other dogs	Hindlimb	8·56	6·82 - 10·74	49·3	44·6 - 54·4
	Forelimb	8·93	7·36 - 10·8	48·9	44·9 - 53·2

Table 5 Values of the combined propodial and epipodial skeletal segments in cm for horses calculated from the allometric equations on Table 3 for Thoroughbreds from 13·4 kg to 433 kg and other horses from 109 to 535 kg liveweight.

		50 kg		500 kg	
		Mean	95% limits	Mean	95% limits
Thoroughbreds	Hindlimb	54·2	52·3 - 56·0	98·4*	88·9 - 108·7
	Forelimb	52·0	48·6 - 55·6	91·6	79·9 - 109·8
Other horses	Hindlimb	47·2	42·10 - 53·0	83·3*	78·4 - 88·5
	Forelimb	42·8	35·8 - 51·1	81·6	72·2 - 92·3

* Values significantly different ($P < 0·05$) between each type of horse.

Table 6 Allometric equations comparing the growth in length of propodial with epipodial skeletal segments in dogs (Greyhounds: birth to 30 kg, other dogs: birth to 46·5 kg liveweight) and horses (Thoroughbreds: 0·7 kg to 430 kg, other horses: 3·0 kg to 500 kg liveweight).

Comparison	Type of animal	Number of observ-ations	Growth ratio b*	Se b	log a	r**	Significance*** of difference in b.
Femur v Tibia and Fibula							
	Greyhounds	16	0·920^{+}	0·014	0·087	0·9984	NS
	Other dogs	8	0·966	0·022	0·027	0·9982	
	Thoroughbreds	11	0·992	0·031	0·001	0·9956	NS
	Other horses	14	1·031	0·035	0·005	0·9932	
Humerus v Radius and Ulna							
	Greyhounds	14	0·932^{+}	0·011	0·012	0·9992	NS
	Other dogs	8	0·971	0·029	-0·031	0·9974	
	Thoroughbreds	7	1·015	0·025	-0·193	0·9985	NS
	Other horses	8	0·984	0·053	-0·125	0·9974	

* Regression coefficient b, standard error Se b. ** Correlation coefficient r.

\+ Values of b followed by this superscript are significantly different ($P < 0·05$) from 1.

*** Significance of difference in b between breeds, tested by the test quotient t; NS = not significant.

Fig. 3.

Growth changes in the combined lengths of the propodial and epipodial skeleton of dogs.

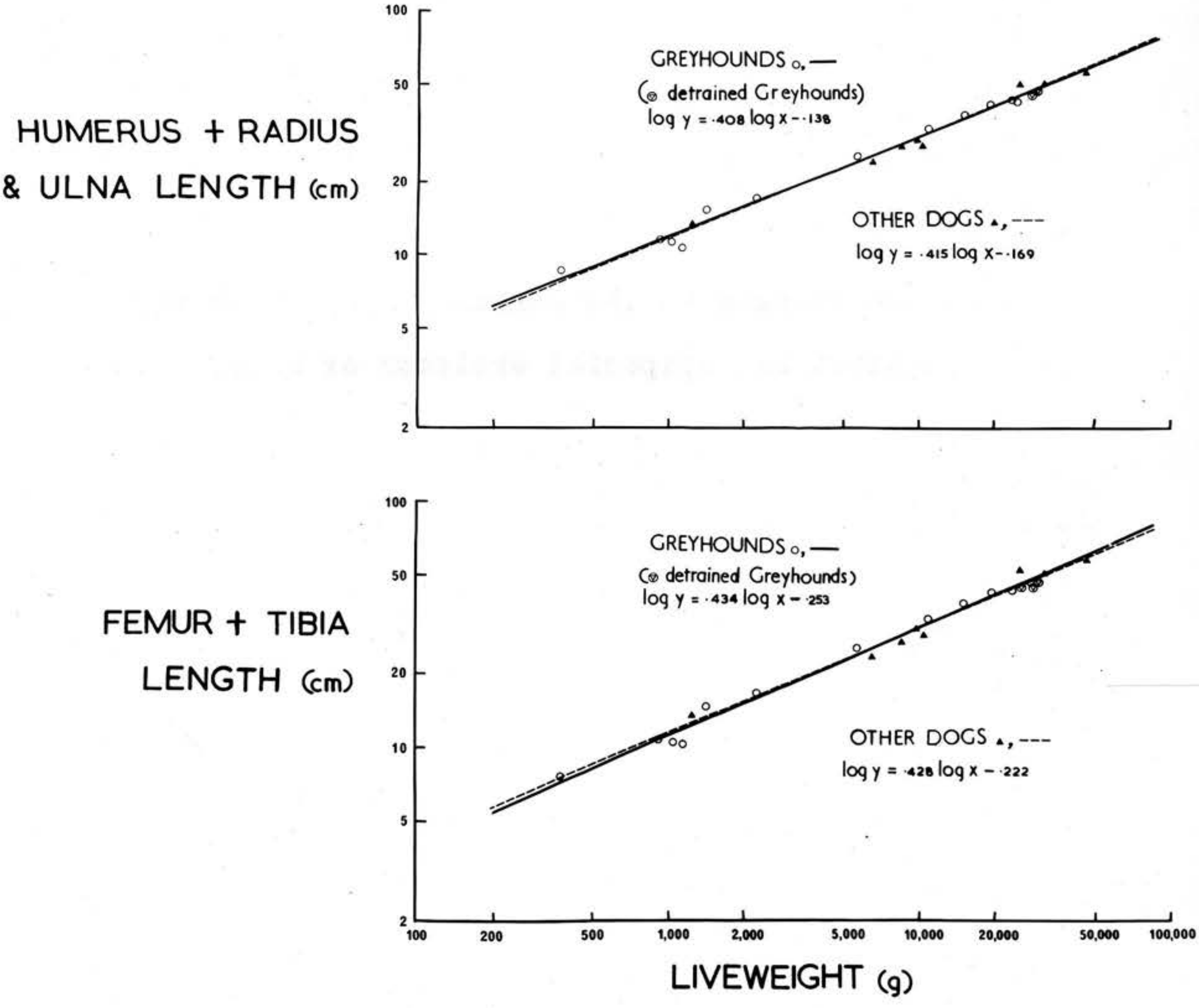

HUMERUS + RADIUS & ULNA LENGTH (cm)
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = ·408 log x – ·138
OTHER DOGS ▲, ---
log y = ·415 log x – ·169
100
50
20
10
5
2
FEMUR + TIBIA LENGTH (cm)
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = ·434 log x – ·253
OTHER DOGS ▲, ---
log y = ·428 log x – ·222
100
50
20
10
5
2
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
LIVEWEIGHT (g)

Fig. 4.

Growth changes in the combined lengths of the propodial and epipodial skeleton in Thoroughbreds from 13·4 kg to 433 kg and other horses from 109 kg to 545 kg liveweight.

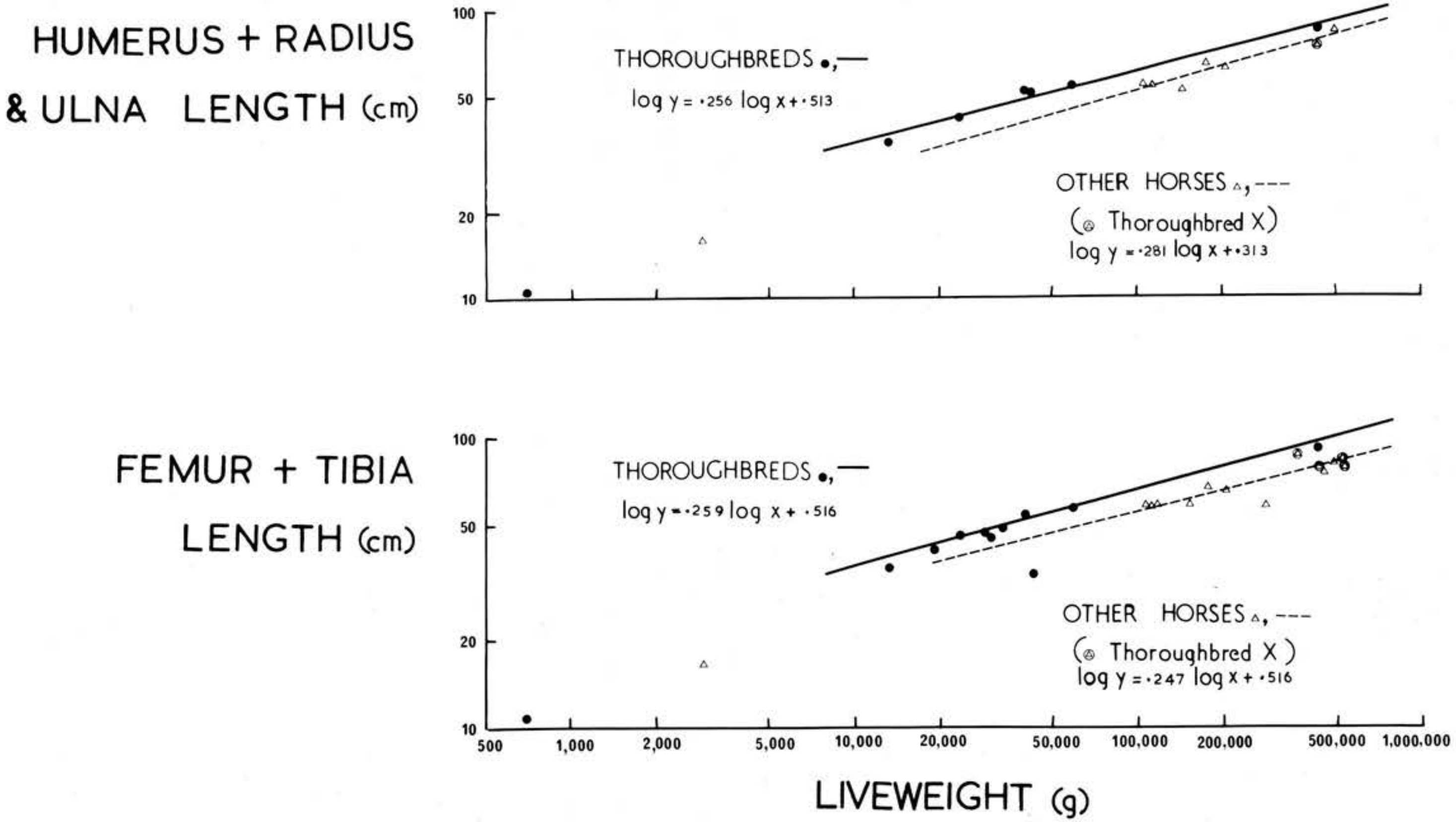

HUMERUS + RADIUS
& ULNA LENGTH (cm)
100
50
20
10
THOROUGHBREDS ●, —
log y = ·256 log x + ·513
OTHER HORSES △, ---
(⊗ Thoroughbred X)
log y = ·281 log x + ·313
FEMUR + TIBIA
LENGTH (cm)
100
50
20
10
THOROUGHBREDS ●, —
log y = ·259 log x + ·516
OTHER HORSES △, ---
(⊗ Thoroughbred X)
log y = ·247 log x + ·516
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
200,000
500,000
1,000,000
LIVEWEIGHT (g)

Fig. 5.

Allometric equations comparing the increase in length of the humerus relative to that of the radius and ulna; and femur relative to that of the tibia in dogs and horses.

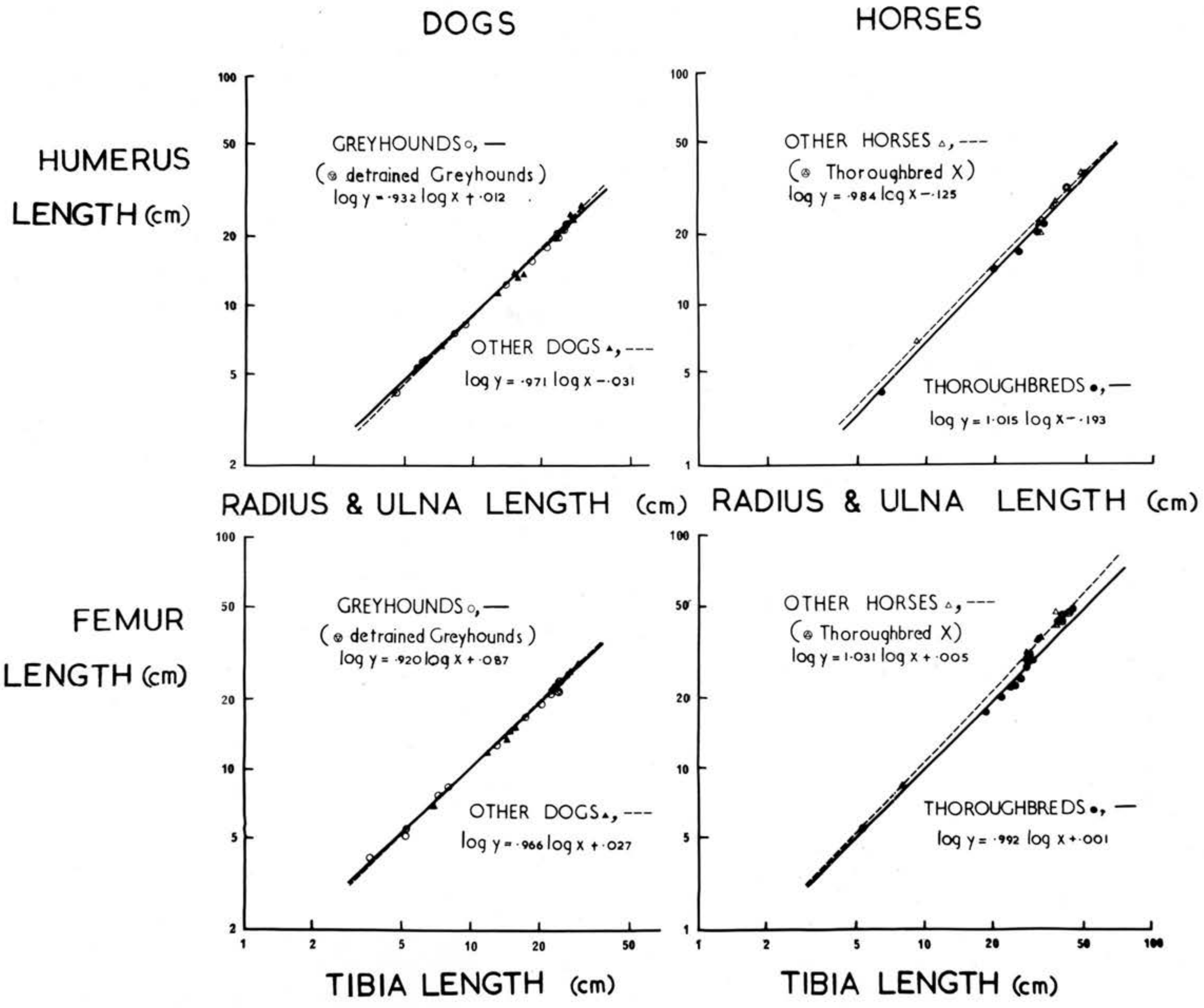

DOGS
HORSES
HUMERUS LENGTH (cm)
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = ·932 log x + ·012
OTHER DOGS ▲, ---
log y = ·971 log x – ·031
OTHER HORSES △, ---
(⊗ Thoroughbred X)
log y = ·984 log x – ·125
THOROUGHBREDS ●, —
log y = 1·015 log x – ·193
RADIUS & ULNA LENGTH (cm)
RADIUS & ULNA LENGTH (cm)
FEMUR LENGTH (cm)
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = ·920 log x + ·087
OTHER DOGS ▲, ---
log y = ·966 log x + ·027
OTHER HORSES △, ---
(⊗ Thoroughbred X)
log y = 1·031 log x + ·005
THOROUGHBREDS ●, —
log y = ·992 log x + ·001
TIBIA LENGTH (cm)
TIBIA LENGTH (cm)
100
50
20
10
5
2
1

Table 7 The weights and volumes of the femur, tibia and fibula, humerus and radius and ulna of dogs and horses.

Type of Animal	Live-weight (g)	Femur		Tibia & Fibula		Humerus		Radius & Ulna	
		Weight (g)	Volume (cm^2)	Weight (g)	Volume (cm^2)	Weight (g)	Volume (cm^2)	Weight (g)	Volume (cm^2)
Young Greyhounds	377	1·98	1·8	1·3	1·1	2·72	2·3	2·01	1·8
	927	5·71	4·5	3·9	3·0	7·3	5	6·1	4·5
	1,056	5·70	4·8	3·9	3·1	7·7	6	6·3	4·9
	1,174	4·95	3·4	4·0	2·8	6·41	4·0	5·4	3·2
	1,423	12·07	10	7·9	7·0	13·4	10·5	11·2	9
	2,280	16·92	14	12·8	10·1	19	13	16	12
	5,712	44	36	34	26	41	33	40	30
	11,000	69	56	54	31	64	47	62	44
	15,250	85	62	74	52	76	50	75	52
	19,750	107	75	94	65	102	74	100	72
	25,500	90	63	75	50	86	57	69	43
Adult Greyhounds	24,150	103	70	-	-	101	68	-	-
	25,000	121	82	114	65	113	70	95	60
	25,200	137	100	110	80	135	90	-	-
	25,300	126	90	105	80	116	90	-	-
	28,000	137	100	119	80	-	-	-	-
	28,500	141	110	117	85	126	95	105	70
	29,750	172	110	-	-	162	113	-	-
	30,000	149	80	126	110	142	100	125	83
	37,000	165	120	-	-	-	-	-	-
Young other dogs	1,256	6·8	5·5	4·9	4	6·4	5	5·5	4·5
	6,585	33	24	25	19	34	25	30	22
	8,500	40	30	35	27	40	30	35	26
	9,900	46	33	41	28	44	29	40	26
Adult other dogs	10,400	40	31	35	25	39	30	35	22
	25,100	137	91	116	77	129	94	112	68
	31,900	146	104	118	79	148	102	123	78
	33,000	119	82	-	-	125	87	-	-
	46,500	276	236	276	198	278	256	243	162
Young Thoroughbreds	691	4·7	10	3·0	3·0	3·7	3·0	3·0	3·0
	13,429	178	160	120	90	100·6	80	92	72
	19,000	280	240	200	200	-	-	-	-
	23,872	407	320	280	230	211	182	240	180
	29,000	465	410	330	280	-	-	-	-
	30,965	487	410	340	280	-	-	-	-
	33,500	503	490	350	380	-	-	-	-
	40,500	730	560	470	410	410	355	410	370
	42,962	685	590	460	480	410	384	440	430
	58,664	992	740	580	530	595	471	482	470
	432,727	2,880	2,290	1,790	1,450	1,844	1,650	1,660	1,270
Adult Thoroughbreds	-	-	-	-	-	-	-	-	-
Young other horses	2,977	21	20	14	11	12·5	9	8	12
	22,000	400	380	-	-	-	-	-	-
	109,091	736	710	470	420	490	470	400	410
	114,546	618	490	410	400	394	340	320	350
	118,182	782	670	510	520	-	-	-	-
	153,727	815	670	550	500	400	560	470	410
	178,182	1,042	890	-	-	-	-	-	-
Adult other horses	178,182	1,132	990	750	660	-	-	660	550
	203,636	1,127	980	680	480	790	570	620	400
	229,091	945	840	-	-	-	-	-	-
	280,000	925	730	560	440	-	-	-	-
	369,091	3,135	2,750	1,930	1,790	-	-	-	-
	432,727	2,032	1,620	1,220	920	1,380	1,130	1,080	790
	445,455	1,955	1,530	1,160	930	-	-	-	-
	496,364	3,680	2,880	2,170	1,690	2,300	1,940	2,090	1,710
	521,818	2,576	2,970	1,530	1,090	-	-	-	-
	534,545	2,360	1,810	1,320	990	-	-	-	-

Table 8 Logarithmic regression equations comparing the increase in weight with increase in volume of the femur, tibia and fibula, humerus and radius and ulna of dogs and horses.

Bone	Type of animal	Number of observ- ations	Growth ratio b*	Se b	log a	r**
Femur						
	Greyhounds	20	1·048 +	0·017	0·058	0·9977
	Other dogs	9	1·011	0·027	0·112	0·9975
	Thoroughbreds	11	1·200 +C	0·039	-·482	0·9953
	Other horses	17	1·016 C	0·023	0·018	0·9961
Tibia and Fibula						
	Greyhounds	17	1·033	0·020	0·092	0·9973
	Other dogs	8	1·046 +	0·018	0·071	0·9991
	Thoroughbreds	11	1·013	0·025	0·015	0·9973
	Other horses	14	1·000	0·028	0·081	0·9955
Humerus						
	Greyhounds	18	1·017	0·017	0·122	0·9979
	Other dogs	9	0·982	0·031	0·158	0·9965
	Thoroughbreds	7	0·984	0·012	0·106	0·9996
	Other horses	7	0·973	0·027	0·165	0·9982
Radius and ulna						
	Greyhounds	14	1·040	0·021	0·096	0·9976
	Other dogs	8	1·067	0·027	0·065	0·9980
	Thoroughbreds	7	1·021	0·027	0·013	0·9982
	Other horses	8	0·962	0·035	0·192	0·9961

* Regression coefficient b, standard error Se b.

\+ Values of b followed by this superscript are significantly different ($P <$ 0·05) from 1.

C Values of b followed by this superscript are significantly different ($P <$ 0·001) from one another.

** Correlation coefficient r.

Table 9 Regression equations comparing the growth of the proximal hindlimb muscles plus the femur with the distal hindlimb muscles plus the other bones of the hindlimb in Greyhounds from birth to 30 kg, other dogs from birth to 46·5 kg; Thoroughbreds from 13·4 kg to 430 kg and other horses from 3·0 kg to 530 kg liveweight.

Type of animal	Number of observ-ations	Growth ratio b*	Se b	log a	r**	Significance of differenc in b***
Greyhounds	18	1·205 +	0·024	0·061	0·9968	NS
Other dogs	9	1·103	0·059	0·239	0·9901	
Thoroughbreds	6	1·195	0·167	-0·304	0·9630	NS
Other horses	7	1·074	0·036	0·352	0·9966	

* Regression coefficient b, standard error Se b.

** Correlation coefficient.

*** Significance of the difference in b between breeds tested by the test quotient t.

NS Not significant.

\+ Growth ratio significantly greater ($P < \cdot 05$) than 1.

Fig. 6.

Changes in weight of the proximal hindlimb muscle plus the femur with increasing weight of the distal hindlimb muscle plus the other bones in dogs.

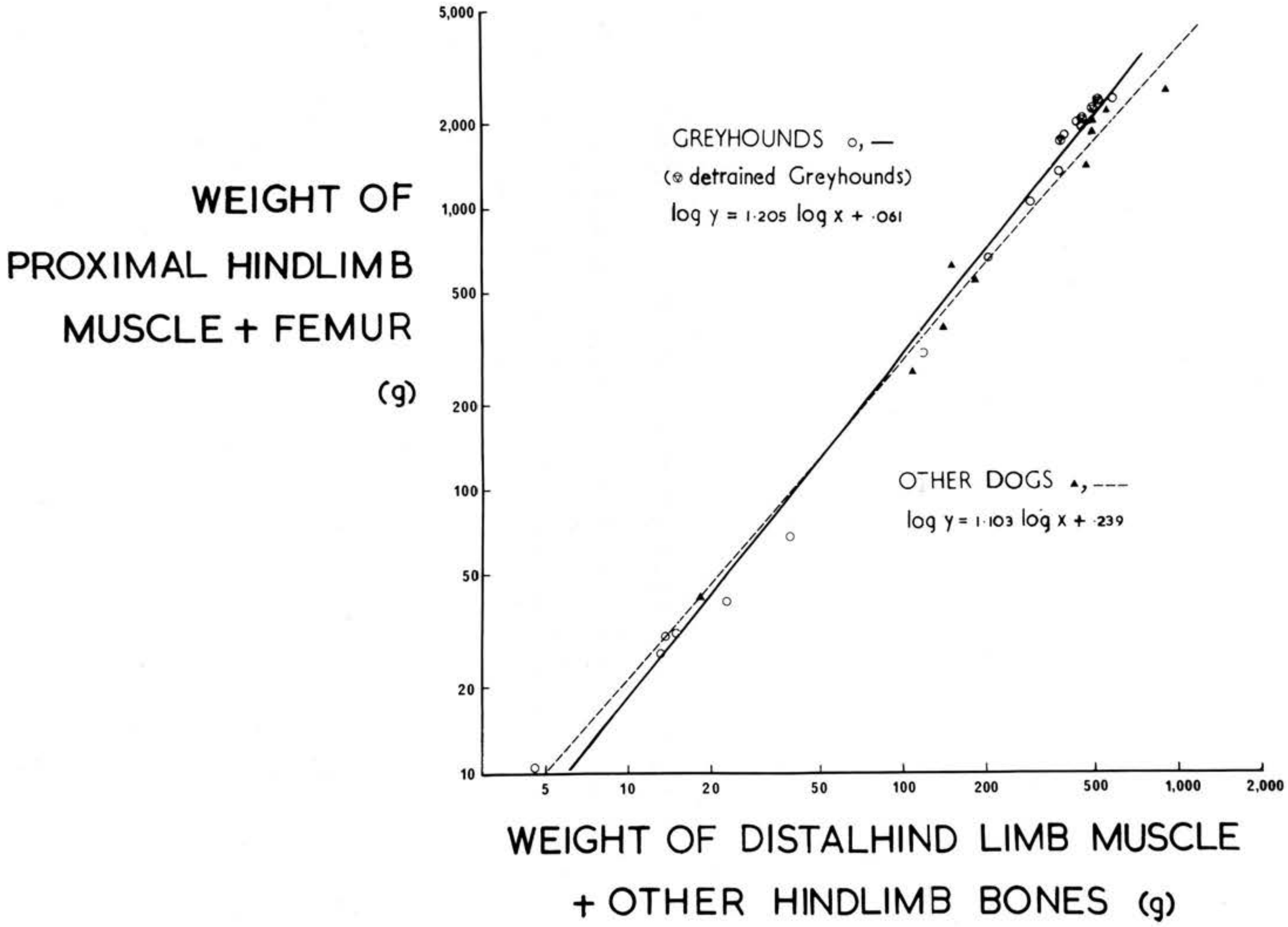

WEIGHT OF PROXIMAL HINDLIMB MUSCLE + FEMUR (g)
5,000
2,000
1,000
500
200
100
50
20
10
5
10
20
50
100
200
500
1,000
2,000
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = 1·205 log x + ·061
OTHER DOGS ▲, ---
log y = 1·103 log x + ·239
WEIGHT OF DISTALHIND LIMB MUSCLE + OTHER HINDLIMB BONES (g)

Fig. 7.

Changes in weight of the proximal hindlimb muscle plus the femur with increasing weight of the distal hindlimb muscle plus the other bones in Thoroughbreds from 13·4 kg to 430 kg and other horses from 3·0 kg to 530 kg liveweight.

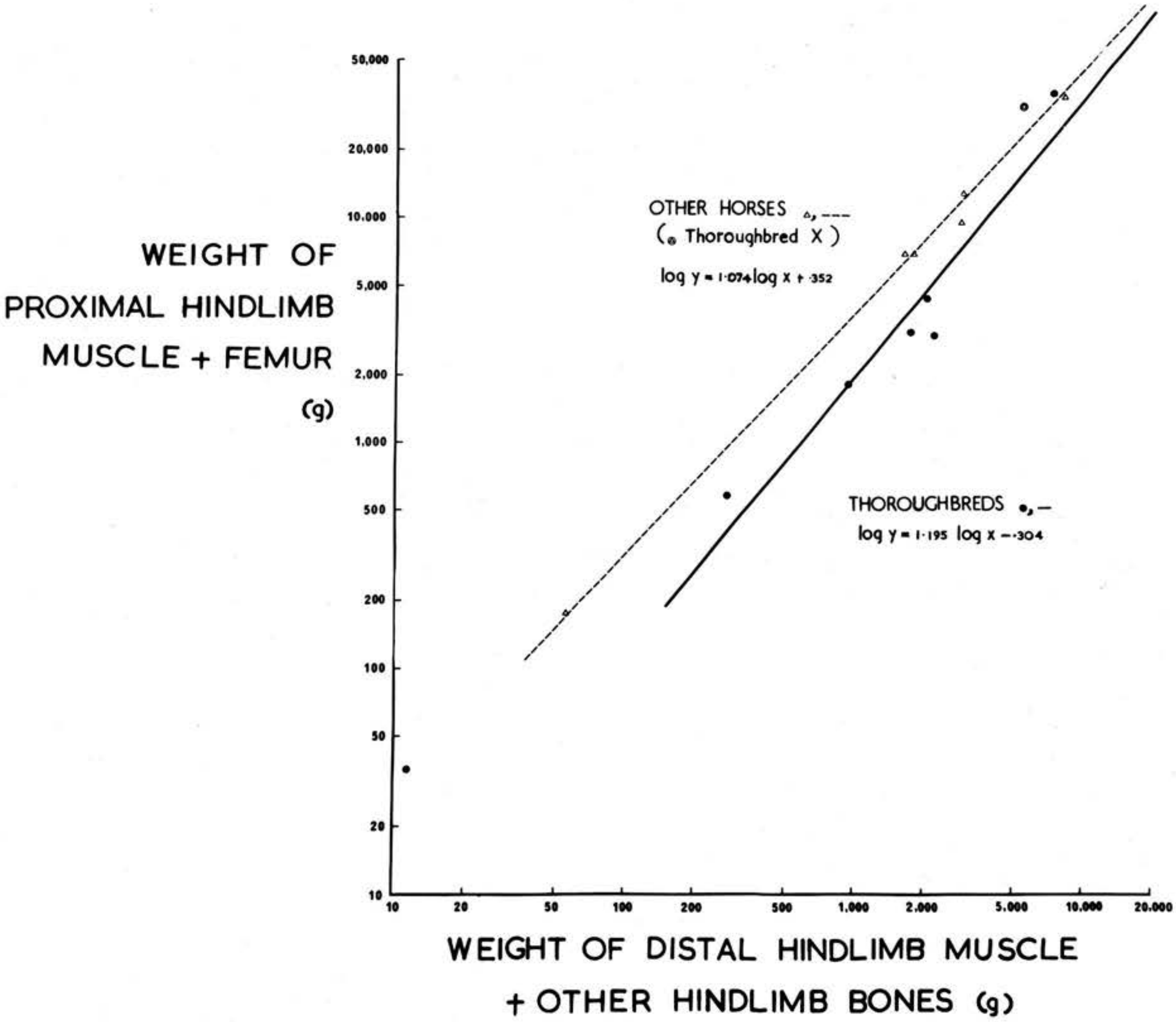

WEIGHT OF PROXIMAL HINDLIMB MUSCLE + FEMUR (g)
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
50
20
10
10
20
50
100
200
500
1,000
2,000
5,000
10,000
20,000
OTHER HORSES △, ---
(⊙ Thoroughbred X)
log y = 1·074 log x + ·352
THOROUGHBREDS ●, —
log y = 1·195 log x – ·304
WEIGHT OF DISTAL HINDLIMB MUSCLE + OTHER HINDLIMB BONES (g)

Table 10 The weights and percentage of liveweight of total muscle, total bone and total fat in 18 Greyhounds and 9 other dogs.

GREYHOUNDS

Liveweight (g)	Age status	Sex	Total muscle weight (g)	Total bone weight (g)	Total fat weight (g)
377	Young	♀	97·4 (25·8)*	60·8 (16·1)*	·24 (·06)*
927	Young	♀	260·4 (28·1)*	148·6 (16·0)*	2·19 (·24)*
1,056	Young	♀	327·5 (31·0)*	156·2 (14·8)*	8·53 (·81)*
1,174	Young	♀	296·3 (25·2)*	156·0 (13·3)*	15·6 (1·3)*
1,423	Young	♂	300·4 (21·1)*	266·3 (18·7)*	0 (0)*
2,280	Young	♂	606·7 (26·6)*	436·4 (19·1)*	19·8 (·86)*
5,712	Young	♀	2,080 (36·4)*	958 (16·8)*	9·0 (·16)*
11,000	Young	♀	4,338 (39·4)*	1,561 (14·2)*	24·0 (·22)*
15,250	Young	♀	7,206 (47·3)*	1,920 (12·6)*	97·0 (·64)*
19,750	Young	♂	9,563 (48·4)*	2,531 (12·8)*	19·0 (·10)*
23,500	Young	♀	12,455 (53·0)*	2,272 (10·3)*	196 (·83)*
24,150	Adult D*	♀	13,297 (55·1)*	2,550 (10·6)*	210 (·87)*
25,000	Adult	♀	14,088 (56·4)*	2,819 (11·3)*	0 (0)*
25,200	Adult	♂	14,692 (58·3)*	3,306 (13·1)*	0 (0)*
25,300	Adult D*	♂	14,422 (57·0)*	3,123 (12·3)*	65 (·26)*
28,500	Adult D*	♀	15,742 (55·2)*	3,259 (11·4)*	185 (·65)*
29,750	Adult	♀	17,983 (60·4)*	4,310 (14·5)*	0 (0)*
30,000	Adult D*	♂	17,213 (57·4)*	3,684 (12·3)*	70 (·23)*
Mean percentage of all adults			57·1	12·2	0·28
		SD	1·85	1·30	0·35
Mean percentage of detrained (D*) adults			56·2	11·7	0·50
		SD	1·20	0·82	0·31
Mean percentage of trained adults			58·4	12·9	0
		SD	2·00	1·6	0

OTHER DOGS

Liveweight (g)	Breed	Age status	Sex	Total muscle weight (g)	Total bone weight (g)	Total fat weight (g)
1,256	Cairn Terrier	Young	♀	327·5 (26·1)*	151·9 (12·1)*	48 (3·82)*
6,585	Boxer X	Young	♀	2,120 (32·2)*	823 (12·5)*	158 (2·40)*
8,500	Boxer X	Young	♂	3,024 (35·6)*	979 (11·5)*	223 (2·62)*
9,900	Boxer X	Young	♀	4,183 (42·3)*	1,120 (11·3)*	72 (·73)*
10,400	Collie X	Adult	♀	4,453 (42·8)*	1,031 (9·9)*	116 (1·12)*
25,100	Afghan	Adult	♀	12,639 (50·4)*	3,276 (13·1)*	407 (1·62)*
31,900	Afghan	Adult	♂	14,509 (45·5)*	3,698 (11·6)*	111 (·35)*
33,000	Labrador	Adult	♀	11,250 (34·1)*	3,470 (10·5)*	183 (·56)*
46,500	Great Dane	Adult	♂	20,875 (44·9)*	7,396 (15·9)*	478 (1·03)*
Mean percentage of all adults				43·5	12·2	0·94
			SD	6·0	2·4	0·50

* Percentage of liveweight.

Table 11 The weights and percentage of liveweight of total muscle, total bone and total fat in 7 Thoroughbreds and 6 other horses.

THOROUGHBREDS						OTHER HORSES						
Liveweight (g)	Age status	Sex	Total muscle weight (g)	Total bone weight (g)	Total fat weight (g)	Liveweight (g)	Breed	Age status	Sex	Total muscle weight (g)	Total bone weight (g)	Total fat weight (g)
691	Young	♂	274·6 (39·7)*	111·7 (16·2)*	0 (0)*	2,977	Welsh Mt.	Young	♂	1,272 (42·7)*	384 (12·9)*	7·23 (0·24)*
13,429	Young	♀	2,806 (20·9)*	3,004 (22·4)*	0 (0)*	109,091	Welsh Mt.	Young	♂	37,803 (34·7)*	13,286 (12·2)*	1,984 (1·82)*
23,872	Young	♂	8,809 (36·9)*	5,847 (24·5)*	16 (0·07)*	114,546	Welsh Mt.	Young	♀	39,051 (34·1)*	11,373 (9·9)*	630 (0·55)*
40,500	Young	♀	16,257 (40·1)*	11,497 (28·4)*	0 (0)*							
42,962	Young	♀	16,789 (39·1)*	10,876 (25·3)*	0 (0)*	203,636	Shetland	Adult	♂	85,054 (41·8)*	27,402 (13·5)*	5,169 (2·5)*
58,664	Young	♀	23,679 (40·4)*	15,295 (26·1)*	0 (0)*	432,727	Thoroughbred X	Adult	♂	170,880 (39·5)*	34,564 (8·0)*	1,902 (0·44)*
432,727	Young	♂	191,883 (44·3)*	53,855 (12·4)*	4,306 (1·00)*	496,364	Clydesdale	Adult	♀	223,997 (45·1)*	70,420 (14·2)*	873 (0·18)*
						Mean percentage of all adults				42·1	11·9	1·04
									SD	2·8	3·4	1·27

* Percentage of liveweight.

Table 12 Logarithmic regression equations comparing the growth of total muscle and total bone with liveweight and total muscle plus bone weight in Greyhounds from birth to 30 kg liveweight, other dogs from birth to 46·5 kg; Thoroughbreds from 13·4 kg to 430 kg and other horses from 109 kg to 500 kg liveweight.

			Independent variable = liveweight				Independent variable = muscle plus bone weight			
Dependent variable	Type of animal	Number of observ- ations	Growth ratio b*	Se b	log a	r**	Growth ratio b*	Se b	log a	r**
Total muscle										
	Greyhounds	18	1·222 c	0·019	-1·248	0·9980	1·077 cd	0·009	-0·410	0·9994
	Other dogs	9	1·143 c	0·046	-1·002	0·9945	1·029 d	0·013	-0·228	0·9994
	Thoroughbreds	6	1·161	0·082	-1·198	0·9901	1·119 cd	0·017	-0·748	0·9995
	Other horses	5	1·143	0·052	-1·177	0·9970	1·024 d	0·029	-0·235	0·9988
Total bone										
	Greyhounds	18	0·911 cd	0·022	-0,521	0·9950	0·800 cd	0·021	0·111	0·9945
	Other dogs	9	1·029 d	0·045	-1·042	0·9930	0·921 d	0·042	-0·326	0·9927
	Thoroughbreds	6	0·804	0·080	0·271	0·9810	0·780 c	0·034	0·562	0·9963
	Other horses	5	0·985	0·191	-0·866	0·9470	0·909	0·111	-0·189	0·9784

* Regression coefficient b, standard error Se b.

c Values of b followed by this superscript are significantly different ($P < 0·05$) from 1.

d Values of b followed by this superscript are significantly different ($P < 0·05$) from one another.

** Correlation coefficient r.

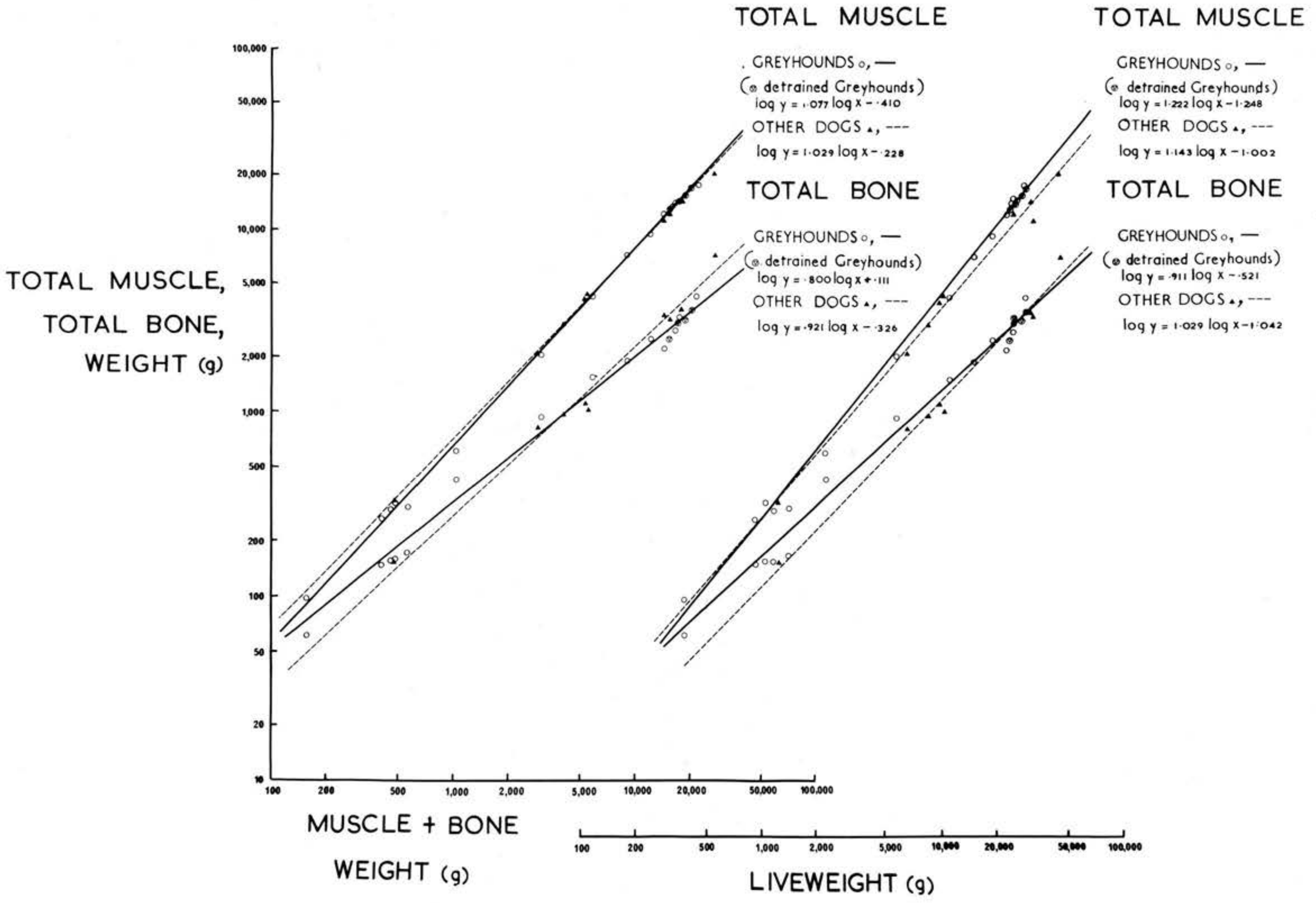

TOTAL MUSCLE
GREYHOUNDS ○, —
(⊚ detrained Greyhounds)
log y = 1·077 log x − ·410
OTHER DOGS ▲, ---
log y = 1·029 log x − ·228
TOTAL BONE
GREYHOUNDS ○, —
(⊚ detrained Greyhounds)
log y = ·800 log x + ·111
OTHER DOGS ▲, ---
log y = ·921 log x − ·326
TOTAL MUSCLE
GREYHOUNDS ○, —
(⊚ detrained Greyhounds)
log y = 1·222 log x − 1·248
OTHER DOGS ▲, ---
log y = 1·143 log x − 1·002
TOTAL BONE
GREYHOUNDS ○, —
(⊚ detrained Greyhounds)
log y = ·911 log x − ·521
OTHER DOGS ▲, ---
log y = 1·029 log x − 1·042
TOTAL MUSCLE, TOTAL BONE, WEIGHT (g)
100,000
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
50
20
10
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
MUSCLE + BONE WEIGHT (g)
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
LIVEWEIGHT (g)

Fig. 9.

Allometric equations comparing the growth of total muscle and total bone relative to liveweight and total muscle plus bone weight between Thoroughbreds from 13·4 kg to 430 kg and other horses from 109 kg to 500 kg liveweight.

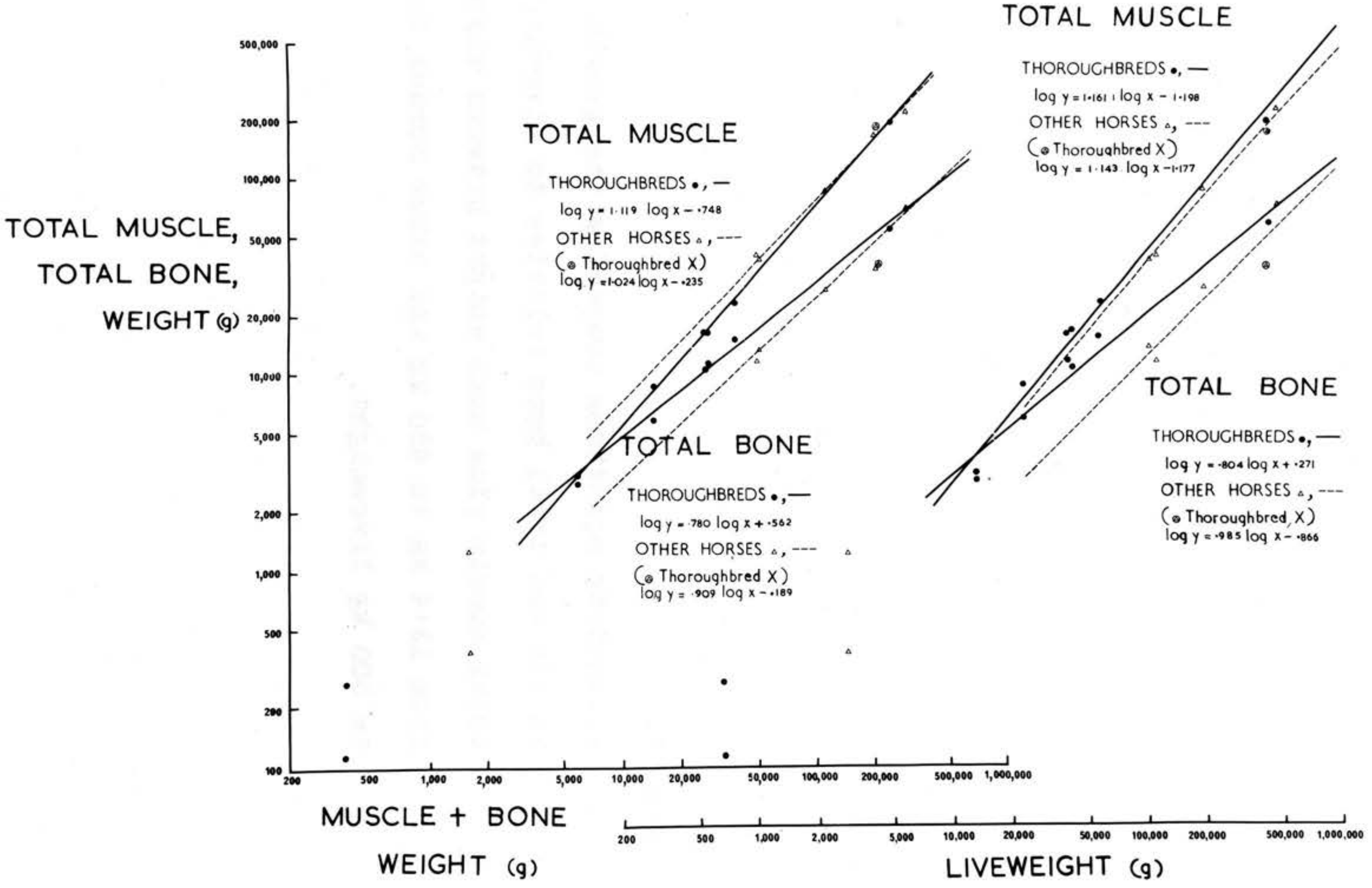

TOTAL MUSCLE,
TOTAL BONE,
WEIGHT (g)
500,000
200,000
100,000
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
TOTAL MUSCLE
THOROUGHBREDS ●, —
log y = 1·119 log x − ·748
OTHER HORSES △, ---
(⊛ Thoroughbred X)
log y = 1·024 log x − ·235
TOTAL BONE
THOROUGHBREDS ●, —
log y = ·780 log x + ·562
OTHER HORSES △, ---
(⊛ Thoroughbred X)
log y = ·909 log x − ·189
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
200,000
500,000
1,000,000
MUSCLE + BONE
WEIGHT (g)
TOTAL MUSCLE
THOROUGHBREDS ●, —
log y = 1·161 log x − 1·198
OTHER HORSES △, ---
(⊛ Thoroughbred X)
log y = 1·143 log x − 1·177
TOTAL BONE
THOROUGHBREDS ●, —
log y = ·804 log x + ·271
OTHER HORSES △, ---
(⊛ Thoroughbred X)
log y = ·985 log x − ·866
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
200,000
500,000
1,000,000
LIVEWEIGHT (g)

Table 13 Weights of muscle groups and their percentage of liveweight and total muscle weight in adult dogs.
Muscles are grouped according to the articulations over which they act and their weights refer to one side of the animal only.

Type of Dog	Live-weight (g)	Total muscle weight (g)	Sex	Distal forelimb			Brachial			Pectoral Girdle			Longissimus			Femoral			Distal hindlimb		
				Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle
Greyhound (D)	24,150	13,297	♀	173	0·73	1·30	855	3·5	6·43	1,190	4·9	8·95	685	2·8	5·15	1,661	6·9	12·5	223	0·92	1·67
Greyhound	25,000	14,088	♀	157	0·63	1·11	850	3·4	6·03	1,285	5·1	9·12	813	3·3	5·77	1,832	7·3	13·0	249	1·00	1·77
Greyhound	25,200	14,692	♂	194	0·77	1·32	956	3·8	6·51	1,125	4·5	7·66	973	3·9	6·62	1,901	7·5	12·9	244	0·97	1·66
Greyhound (D)	25,300	14,422	♂	173	0·68	1·20	900	3·6	6·24	1,266	5·0	8·78	719	2·8	4·99	1,953	7·7	13·5	244	0·96	1·69
Greyhound	27,200	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	2,041	7·5	-	-	-	-
Greyhound	27,500	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	2,321	8·4	-	-	-	-
Greyhound	28,000	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	2,530	9·0	-	260	0·93	-
Greyhound (D)	28,500	15,742	♀	201	0·71	1·28	1,041	3·7	6·61	1,295	4·5	8·23	815	2·9	5·18	2,148	7·5	13·7	270	0·95	1·72
Greyhound	29,750	17,983	♀	230	0·77	1·28	1,120	3·8	6·23	1,522	5·1	8·46	1,422	4·8	7·91	2,267	7·6	12·7	310	1·00	1·72
Greyhound (D)	30,000	17,213	♂	203	0·68	1·18	1,132	3·8	6·58	1,605	5·4	9·32	863	2·9	5·01	2,287	7·6	13·3	279	0·93	1·62
Greyhound	30,000	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	2,135	7·1	-	-	-	-
Greyhound	33,608	-	♀	-	-	-	-	-	-	-	-	-	-	-	-	2,475	7·4	-	-	-	-
Greyhound	37,000	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	2,724	7·4	-	-	-	-
	Mean %				0·71	1·24+		3·69+	6·38		4·93+	8·65		3·34+	5·80		7·61+	13·08		0·96	1·69+
	SD				0·05	0·08		0·16	0·21		0·33	0·57		0·75	1·10		0·54	0·48		0·03	0·05
	Mean			190·1	0·71	1·24	958·5	3·5	6·25	1,327	4·94	8·65	898·6	3·35	5·85	2,175	7·62	13·1	259·9	0·96	1·69
Collie X	10,400	4,453	♀	68	0·65	1·53	240	2·3	5·39	354	3·4	7·95	205	2·0	4·60	594	5·7	13·2	85	0·82	1·91
Afghan	25,100	12,639	♀	220	0·88	1·74	947	3·8	7·49	947	3·8	7·49	685	2·7	5·42	1,743	6·9	13·8	270	1·10	2·14
Afghan	31,900	14,509	♂	199	0·62	1·37	1,021	3·2	7·04	1,065	3·3	7·34	820	2·6	5·65	1,924	6·0	13·3	278	0·87	1·92
Labrador	33,000	11,250	♀	229	0·69	2·04	804	2·4	7·15	861	2·6	7·65	458	1·4	4·07	1,312	4·0	11·7	261	0·79	2·32
Great Dane	46,500	20,875	♂	393	0·85	1·88	1,438	3·1	6·88	2,155	4·6	10·3	910	2·0	4·36	2,339	5·0	11·2	434	0·93	2·08
	Mean %				0·74	1·71+		2·96+	6·79		3·54+	8·15		2·13+	4·82		5·52+	12·64		0·90	2·07+
	SD				0·12	0·27		0·62	0·81		0·73	1·23		0·53	0·68		1·09	1·12		0·12	0·17
	Mean			221·8	0·75	1·74	890	3·03	6·98	1,076	3·6	8·44	616	2·10	4·83	1,582	5·38	12·4	265·6	0·90	2·08

D - Detrained Greyhounds

\+ Values bearing this superscript are significantly different ($P < 0{\cdot}02$) between the two types of dog.

Table 14 Weights of muscle groups and their percentage of liveweight and total muscle weight in adult horses*. Muscles are grouped according to the articulations over which they act and their weights refer to one side of the animal only.

Type of animal	Live-weight (g)	Total muscle weight (g)	Sex	Distal forelimb			Brachial			Pectoral Girdle			Longissimus			Femoral			Distal hindlimb		
				Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle	Weight (g)	Percentage of Live-weight	Percentage of Total muscle
Thoroughbred	432,727	191,883	♂	2,378	0·55	1·24	9,945	2·29	5·18	13,080	3·0	6·82	5,400	1·2	2·8	34,392	7·9	17·9	3,772	0·87	1·97
Thoroughbred	470,909	-	♀	-	-	-	-	-	-	-	-	-	-	-	-	39,978	8·4	-	-	-	-
Thoroughbred	470,909	-	♀	-	-	-	-	-	-	-	-	-	-	-	-	33,388	7·1	-	-	-	-
Thoroughbred	483,636	-	♀	-	-	-	-	-	-	-	-	-	-	-	-	41,645	8·6	-	-	-	-
	Mean %				0·55	1·24		2·29	5·18		3·0	6·82		1·2	2·80		8·0^{+}	17·9		0·87	1·97
	SD	-			-	-		-	-		-	-		-	-		0.81	-		-	-
	Mean	-		-	-	-	-	-	-	-	-	-	-	-	-	38,337	8·1	-	-	-	-
Shetland Pony	153,727	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	7,305	4·8	-	-	-	-
Shetland Pony	203,636	85,054	♂	1,165	0·57	1·37	4,790	2·4	5·63	6,561	3·2	7·71	2,024	0·99	2·3	12,236	6·0	14·4	1,604	0·79	1·89
Shetland Pony	280,000	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	14,320	5·1	-	-	-	-
Thoroughbred X	369,091	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	28,594	7·7	-	3,311	0·90	-
Thoroughbred X	432,727	170,880	♂	2,058	0·48	1·20	8,504	2·0	4·98	12,645	2·9	7·40	4,133	0·96	2·42	30,473	7·0	17·8	2,975	0·69	1·74
Connemara X	445,455	-	♀	-	-	-	-	-	-	-	-	-	-	-	-	26,742	6·0	-	-	-	-
Clydesdale	496,364	223,997	♀	6,922	1·4	3·09	11,490	2·3	5·13	16,540	3·3	7·38	5,482	1·1	2·45	33,068	6·3	14·8	3,857	0·78	1·72
Thoroughbred X	521,818	-	♂	-	-	-	-	-	-	-	-	-	-	-	-	37,218	7·1	-	3,611	0·69	-
Thoroughbred X	534,545	-	♀	-	-	-	-	-	-	-	-	-	-	-	-	41,253	7·7	-	3,608	0·68	-
	Mean %				0·82	1·89		2·23	5·25		3·13	7·50		1·02	2·42		6·41^{+}	15·67		0·76	1·78
	SD				0·51	1·05		0·21	·34		0·21	·19		0·07	0·04		1·05	1·86		0·09	0·09
	Mean			3,381	0·89	2·11	8,261	2·19	5·16	11,915	3·16	7·44	3,879	1·03	2·42	25,690	6·65	15·8	3,161	0.74	1·76

* The values for all the muscle groups of Thoroughbreds, except the femoral group, are those for the largest (young) Thoroughbred in which these values were assessed.

\+ Values bearing this superscript are significantly different ($P < 0{\cdot}05$) between the two types of horse.

Table 15 Logarithmic regression equations comparing the growth of six muscle groups relative to liveweight in Greyhounds from birth to 37 kg, other dogs from birth to 47 kg; Thoroughbreds from 0·7 kg to 480 kg, and other horses from 3·0 to 530 kg liveweight.

Muscle Group	Type of animal	Number of observ- ations	Growth ratio b*	Se b	log a	r**	Significance *** of difference between groups
Distal forelimb							
	Greyhounds	18	1·103+	0·042	-2·612	0·9885	NS
	Other dogs	9	1·097	0·041	-2·553	0·9951	
	Thoroughbreds	7	1·020	0·077	-2·237	0·9862	NS
	Other horses	7	1·041	0·103	-2·441	0·9763	
Brachial							
	Greyhounds	18	1·203+	0·171	-2·364	0·9984	Greyhounds $P < \cdot 05$
	Other dogs	9	1·158+	0·044	-2·233	0·9950	
	Thoroughbreds	7	1·052	0·057	-1·908	0·9928	NS
	Other horses	7	1·014	0·044	-1·780	0·9953	
Pectoral girdle							
	Greyhounds	18	1·153+	0·034	-2·032	0·9931	Greyhounds $P < \cdot 05$
	Other dogs	9	1·208+	0·057	-2·370	0·9922	
	Thoroughbreds	7	1·042	0·090	-1·802	0·9817	NS
	Other horses	6	0·987	0·050	-1·481	0·9948	
Longissimus							
	Greyhounds	18	1·420+	0·031	-3·336	0·9961	Greyhounds $P < \cdot 01$
	Other dogs	9	1·255	0·124	-2·829	0·9677	
	Thoroughbreds	7	0·994	0·158	-1·916	0·9424	NS
	Other horses	6	0·690+	0·092	-0·360	0·9664	
Femoral							
	Greyhounds	24	1·357+	0·018	-2·715	0·9980	Greyhounds $P < \cdot 01$
	Other dogs	21	1·315	0·032	-2·662	0·9943	
	Thoroughbreds	19	1·150+ c	0·032	-1·972	0·9935	NS
	Other horses	17	1·049 c	0·028	-1·457	0·9947	
Distal hindlimb							
	Greyhounds	19	1·227+	0·023	-3·016	0·9971	NS
	Other dogs	9	1·130	0·043	-2·616	0·9949	
	Thoroughbreds	8	1·108 c	0·057	-2·528	0·9920	NS
	Other horses	10	0·966 c	0·020	-1·943	0·9983	

* Regression coefficient b, standard error Se b.

\+ Values of b bearing this superscript are significantly different ($P < 0{\cdot}05$) from 1.

c Values of b for similar muscle groups bearing this superscript are significantly different ($P < 0{\cdot}02$) from one another.

** Correlation coefficient r.

*** Significance of difference between adjusted means of groups tested by analysis of covariance; NS = not significant.

Table 16 Weights (in g) of 6 muscle groups of Greyhounds and other dogs at 0·5 kg and 30 kg liveweight, calculated from the allometric equations given in Table 15.

	Liveweight			
	0·5 kg		30 kg	
	Greyhounds	Other dogs	Greyhounds	Other dogs
Distal forelimb	2·32	2·56	212	228
95% limits*	(1·76 - 3·06)	(1·84 - 3·56)	(177 - 254)	(200 - 260)
Brachial	7·64	7·81	1,052	894
95% limits*	(6·83 - 8·54)	(5·47 - 11·14)	(977 - 1,132)	(776 - 1,030)
Pectoral girdle	12·02	7·77	1,349	1,092
95% limits*	(9·64 - 15·0)	(4·90 - 12·3)	(1,168 - 1,559)	(909 - 1,313)
Longissimus	3·14	3·62	1,050**	616**
95% limits*	(2·55 - 3·86)	(1·34 - 9·79)	(918 - 1,202)	(414 - 916)
Femoral	8·86	7·71	2,293**	1,680**
95% limits*	(7·80 - 10·1)	(6·52 - 9·12)	(2,146 - 2,450)	(1,412 - 1,999)
Distal hindlimb	1·98	2·72	300	277
95% limits*	(1·70 - 2·30)	(1·92 - 3·85)	(273 - 330)	(242 - 319)

* Probability of a value outside these limits < 0.05.

** Values followed by this superscript are significantly different ($P < 0.05$) between the two types of dog.

Table 17 Weights (in kg) of 6 muscle groups of Thoroughbreds and other horses at 50 kg and 500 kg liveweight, calculated from the allometric equations given in Table 15.

	Liveweight			
	50 kg		500 kg	
Muscle group	Thoroughbreds	Other horses	Thoroughbreds	Other horses
Distal forelimb	·36	·28	3·77	3·10
95% limits*	(·25-·52)	(·18-·45)	(1·91-7·41)	(1·75-5·51)
Brachial	1·08	·97	12·2	9·97
95% limits*	(·82-1·4)	(·79-1·18)	(7·4-20·2)	(7·8-12·7)
Pectoral girdle	1·24	1·44	13·6	13·9
95% limits*	(·78-1·93)	(1·10-1·86)	(6·13-30·3)	(10·1-19·2)
Longissimus	·57	·76	5·61	3·74
95% limits*	(·26-1·23)	(·47-1·23)	(1·39-22·6)	(2·08-6·70)
Femoral	2·70	2·96	38·2	33·2
95% limits*	(2·41-3·03)	(2·67-3·29)	(29·5-49·5)	(30·0-36·7)
Distal hindlimb	·48	·39	6·12	3·65
95% limits*	(·37-·61)	(·36-·43)	(3·81-9·81)	(3·35-3·97)

* Probability of a value outside these limits 0·05.

Fig. 10.

Topographical location of muscle groups and their proportion of liveweight in adult Greyhounds, other dogs, Thoroughbreds and other horses. Muscles are grouped according to their skeletal attachments and the proportions are calculated for one side of the body only. Where present, significant differences ($P < 0{\cdot}02$) in groups between "athletes" and "non-athletes" are indicated.

MUSCLE GROUPS AS PROPORTIONS OF LIVEWEIGHT

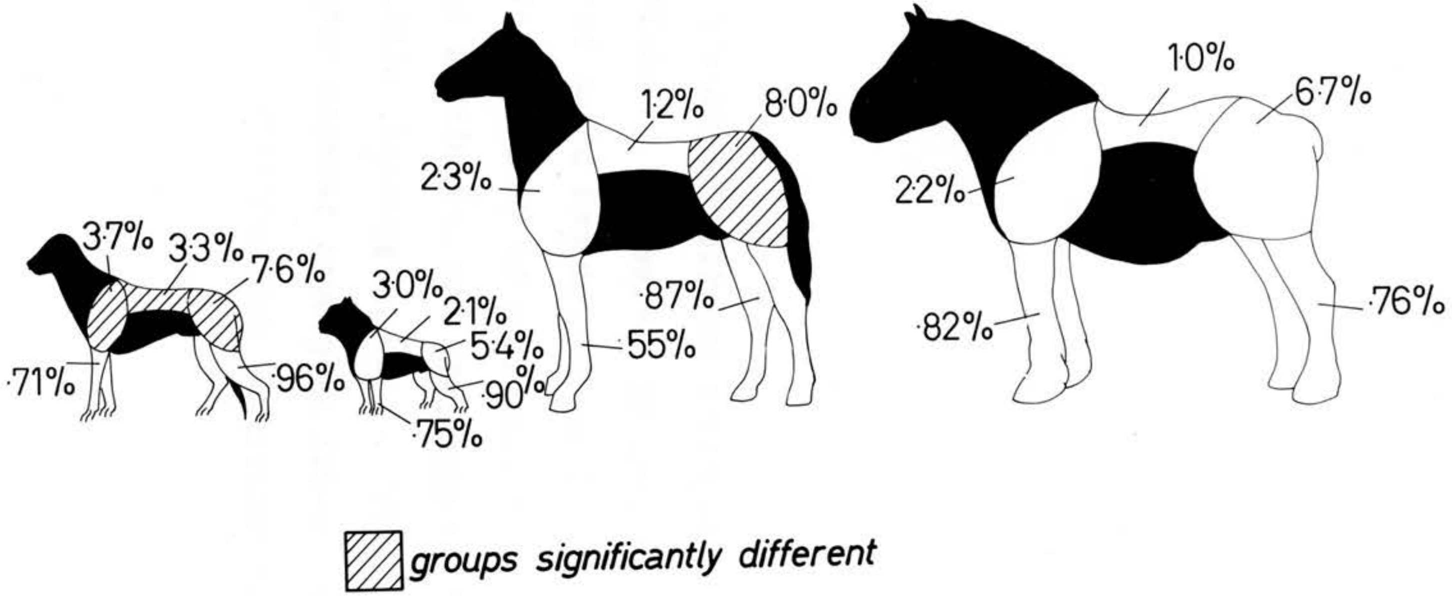


Fig. 11.

Growth changes in muscle distribution relative to liveweight in Greyhounds from birth to 37 kg; other dogs from birth to 47 kg, Thoroughbreds from 0·7 kg to 480 kg and other horses from 3·0 kg to 530 kg liveweight. Muscle groups are graded according to their growth ratio -b-. Significant differences in values of b ($P < 0{\cdot}02$) and adjusted group means ($P < 0{\cdot}05$) between "athletes" and "non-athletes" are indicated.

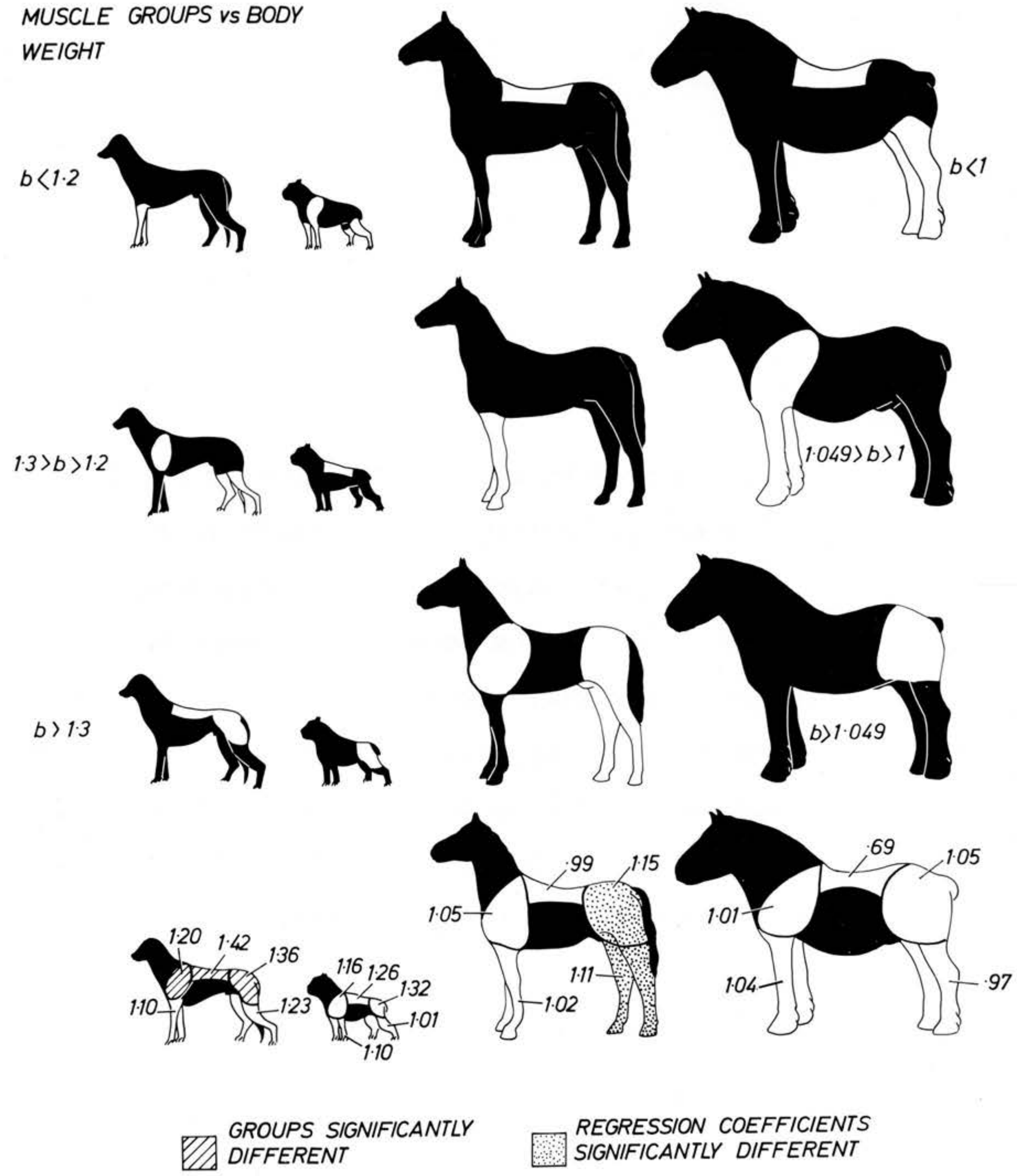

MUSCLE GROUPS vs BODY WEIGHT
b<1·2
b<1
1·3>b>1·2
1·049>b>1
b>1·3
b>1·049
1·20
1·42
1·36
1·10
1·23
1·16
1·26
1·32
1·01
1·10
·99
1·15
1·05
1·11
1·02
·69
1·05
1·01
1·04
·97
GROUPS SIGNIFICANTLY DIFFERENT
REGRESSION COEFFICIENTS SIGNIFICANTLY DIFFERENT

Table 18 Logarithmic regression equations comparing the growth of six muscle groups relative to total muscle weight in 18 Greyhounds from birth to 30 kg, 9 other dogs from birth to 47·0 kg; 7 Thoroughbreds from 0·7 kg to 430 kg, and 6 other horses from 3·0 kg to 500 kg liveweight.

Muscle Group	Type of Animal	Growth ratio b*	Se b	log a	r**	Significance*** of difference between groups
Distal forelimb						
	Greyhounds	0·904+	0·029	-1·488	0·9917	Other dogs $P < 0\cdot05$
	Other dogs	0·953	0·041	-1·567	0·9937	
	Thoroughbreds	0·984	0·059	-1·649	0·9913	NS
	Other horses	1·056	0·089	-2·071	0·9863	
Brachial						
	Greyhounds	0·984+	0·460	-1·132	0·9995	NS
	Other dogs	1·010	0·026	-1·208	0·9976	
	Thoroughbreds	1·016	0·025	-1·303	0·9985	Thoroughbreds $P < 0\cdot05$
	Other horses	1·019	0·027	-1·392	0·9986	
Pectoral girdle						
	Greyhounds	0.944+c	0.018	-0.856	0.9970	NS
	Other dogs	1.055 c	0.036	-1.305	0.9961	
	Thoroughbreds	1.016	0.034	-1.244	0.9972	NS
	Other horses	0.993	0.023	-1.106	0.9990	
Longissimus						
	Greyhounds	1·161+	0·020	-1·884	0·9976	Greyhounds $P < 0\cdot05$
	Other dogs	1·109	0·078	-1·772	0·9833	
	Thoroughbreds	0·953	0·153	-1·328	0·9410	NS
	Other horses	0·700+	0·072	-0·128	0·9795	
Femoral						
	Greyhounds	1·109+c	0·012	-1·324	·9991	NS
	Other dogs	1·042 c	0·024	-1·077	·9982	
	Thoroughbreds	1·063+	0·015	-1·080	·9995	NS
	Other horses	1·048+	0·027	-1·033	·9987	
Distal hindlimb						
	Greyhounds	1·005	0·014	-1·765	·9984	NS
	Other dogs	0·986	0·023	-1·617	·9981	
	Thoroughbreds	1·060	0·062	-1·868	·9914	NS
	Other horses	0·964	0·016	-1·549	·9995	

* Regression coefficient b, standard error Se b

\+ Values of b bearing this superscript are significantly different ($P < 0\cdot05$) from 1.

c Values of b for similar muscle groups bearing this superscript are significantly different ($P < 0\cdot05$) from one another.

** Correlation coefficient r.

*** Significance of difference between adjusted means of groups tested by analysis of covariance; NS = not significant.

Table 19 Logarithmic regression equations comparing the growth of six muscle groups relative to total muscle weight in dogs aged up to 15 months postnatal age (young dogs) comprising 11 Greyhounds from birth to 23·5 kg, 4 other pups from birth to 9·9 kg liveweight; and in horses less than 2 years of postnatal age (young horses) comprising 7 Thoroughbreds from 0·7 kg to 430 kg and 3 other horses from 3 kg to 115 kg liveweight.

Muscle group	Type of animal	Growth ratio b*	Se b	log a	r**	Significance*** of difference between groups
Distal forelimb						
	Greyhounds	0·930	0·053	-1·555	0·9858	NS
	Other dogs	0·975	0·060	-1·626	0·9962	
	Thoroughbreds	0·984	0·059	-1·649	0·9913	NS
	Other horses	0·981	0·029	-1·780	0·9996	
Brachial						
	Greyhounds	0·978	0·013	-1·117	0·9992	NS
	Other dogs	0·974+	0·003	-1·087	1·0000	
	Thoroughbreds	1·016	0·025	-1·303	0·9985	Thoroughbreds $P < 0·05$
	Other horses	0.999	0·065	-1·321	0·9979	
Pectoral girdle						
	Greyhounds	0·907+c	0·028	-0·760	0·9958	NS
	Other dogs	1·092 c	0·070	-1·414	0·9959	
	Thoroughbreds	1·016	0·034	-1·244	0·9972	NS
	Other horses	0·951	0·034	-0·957	0·9994	
Longissimus						
	Greyhounds	1·206+	0·018	-2·001	0·9990	NS
	Other dogs	1·092	0·243	-1·726	0·9537	
	Thoroughbreds	0·953	0·153	-1·318	0·9410	NS
	Other horses	0·543+	0·002	-0·452	0·9999	
Femoral						
	Greyhounds	1·134	0·018	-1·389	0·9989	NS
	Other dogs	1·053	0·027	-1·117	0·9994	
	Thoroughbreds	1·063+	0·015	-1·080	0·9995	NS
	Other horses	1·090+	0·005	-1·187	1·0000	
Distal hindlimb						
	Greyhounds	1·043	0·019	-1·863	0·9984	Other dogs $P < 0·01$
	Other dogs	1·037	0·013	-1·763	0·9999	
	Thoroughbreds	1·060	0·062	-1·868	0·9914	NS
	Other horses	0·998	0·010	-1·674	0·9999	

* Regression coefficient b, standard error Se b.

\+ Values of b bearing this superscript are significantly different ($P < 0·05$) from 1.

c Values of b for similar muscle groups bearing this superscript are significantly different ($P < 0·05$) from one another.

** Correlation coefficient r.

*** Significance of difference between adjusted group means tested by analysis of covariance; NS = not significant.

Fig. 12.

Topographical location of muscle groups and their proportion of total muscle weight in adult Greyhounds, adult other dogs, the largest Thoroughbred investigated and adult other horses. Where present, significant differences ($P < 0{\cdot}005$) in groups between "athletes" and "non-athletes" are indicated.

MUSCLE GROUPS AS PROPORTIONS OF TOTAL MUSCLE WEIGHT

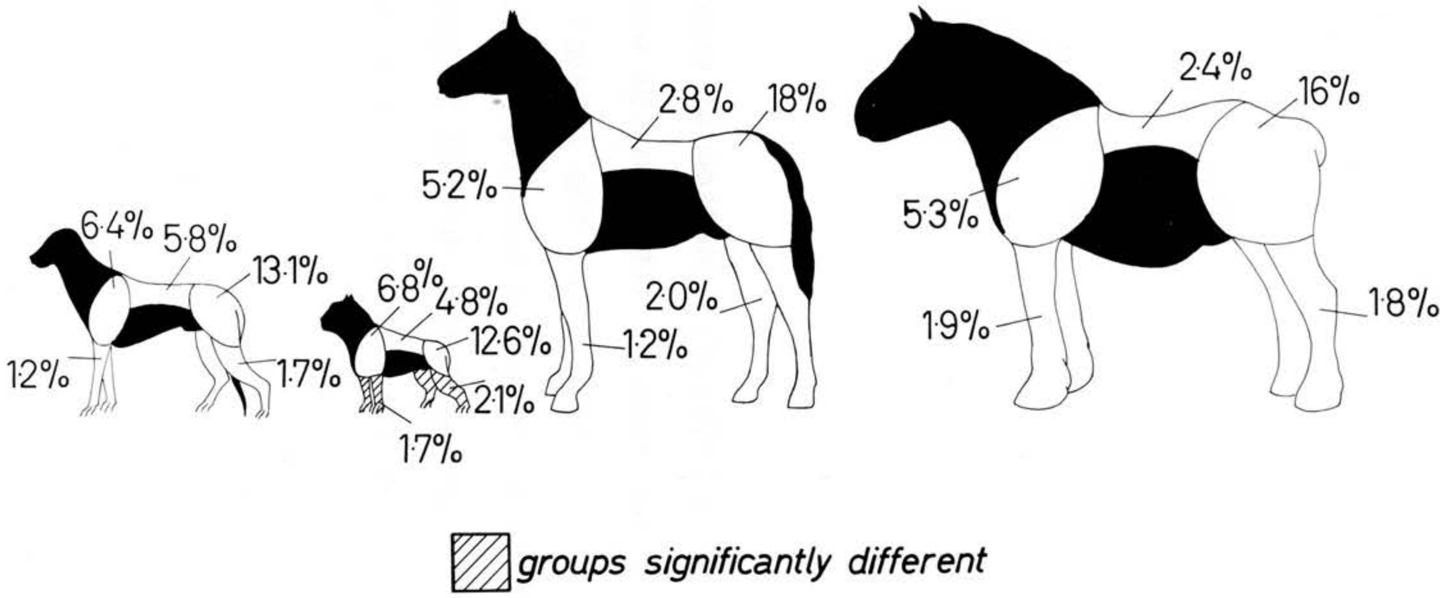


Fig. 13.

Growth changes in muscle distribution relative to total muscle weight in Greyhounds between birth and 30 kg, other dogs between birth and 47 kg; Thoroughbreds between 0·7 kg and 430 kg and other horses between 3·0 kg and 500 kg liveweight. Muscle groups are graded according to the values of their growth ratios -b-. Significant differences in values of b ($P < 0{\cdot}05$) and the adjusted group means between "athletes" and "non-athletes" ($P < 0{\cdot}05$) are indicated.

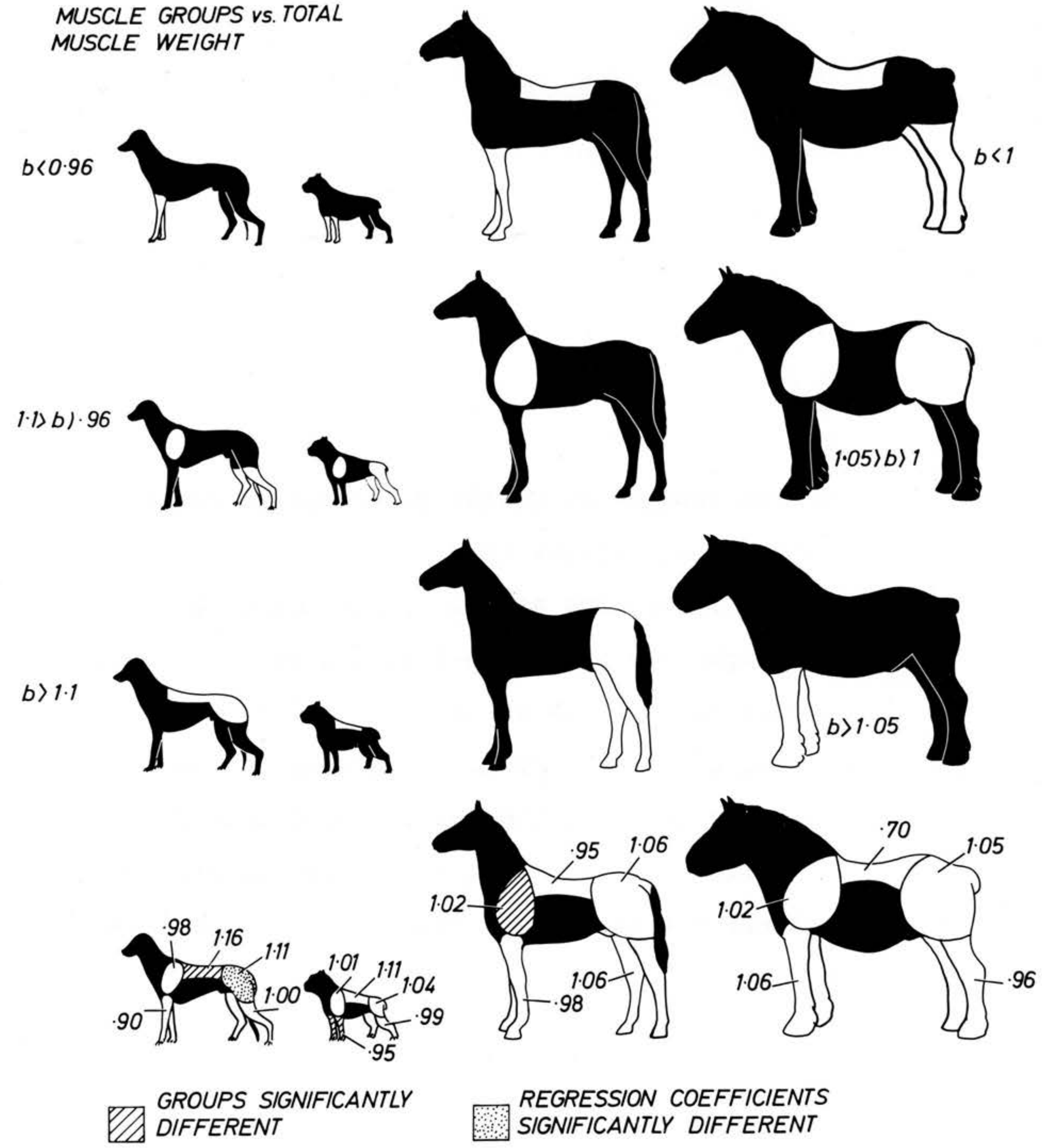

MUSCLE GROUPS vs. TOTAL MUSCLE WEIGHT
b<0·96
b<1
1·1>b>·96
1·05>b>1
b>1·1
b>1·05
·98
1·16
1·11
1·00
·90
1·01
1·11
1·04
·99
·95
·95
1·06
1·02
1·06
·98
·70
1·05
1·02
1·06
·96
GROUPS SIGNIFICANTLY DIFFERENT
REGRESSION COEFFICIENTS SIGNIFICANTLY DIFFERENT

Fig. 14.

Allometric equations comparing the growth of brachial and femoral muscle groups and m. longissimus, relative to total muscle weight between Greyhounds and other dogs.

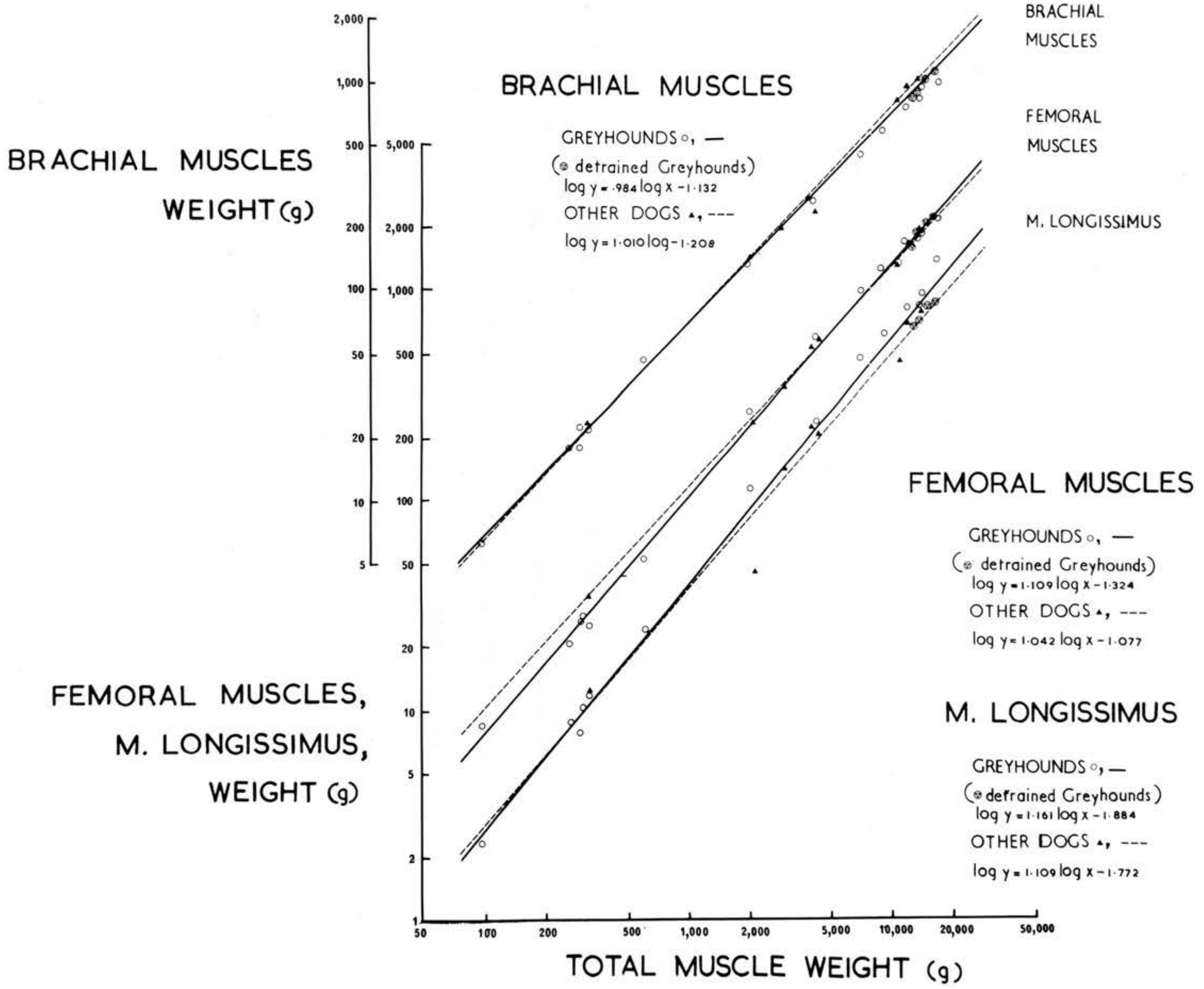

BRACHIAL MUSCLES WEIGHT (g)
FEMORAL MUSCLES, M. LONGISSIMUS, WEIGHT (g)
TOTAL MUSCLE WEIGHT (g)
2,000
1,000
500
200
100
50
20
10
5
5,000
2,000
1,000
500
200
100
50
20
10
5
2
1
50
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
BRACHIAL MUSCLES
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = ·984 log x − 1·132
OTHER DOGS ▲, ---
log y = 1·010 log − 1·208
FEMORAL MUSCLES
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = 1·109 log x − 1·324
OTHER DOGS ▲, ---
log y = 1·042 log x − 1·077
M. LONGISSIMUS
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = 1·161 log x − 1·884
OTHER DOGS ▲, ---
log y = 1·109 log x − 1·772
BRACHIAL MUSCLES
FEMORAL MUSCLES
M. LONGISSIMUS

Fig. 15.

Allometric equations comparing the growth of brachial, femoral and distal forelimb muscle groups relative to total muscle weight between Thoroughbreds and other horses.

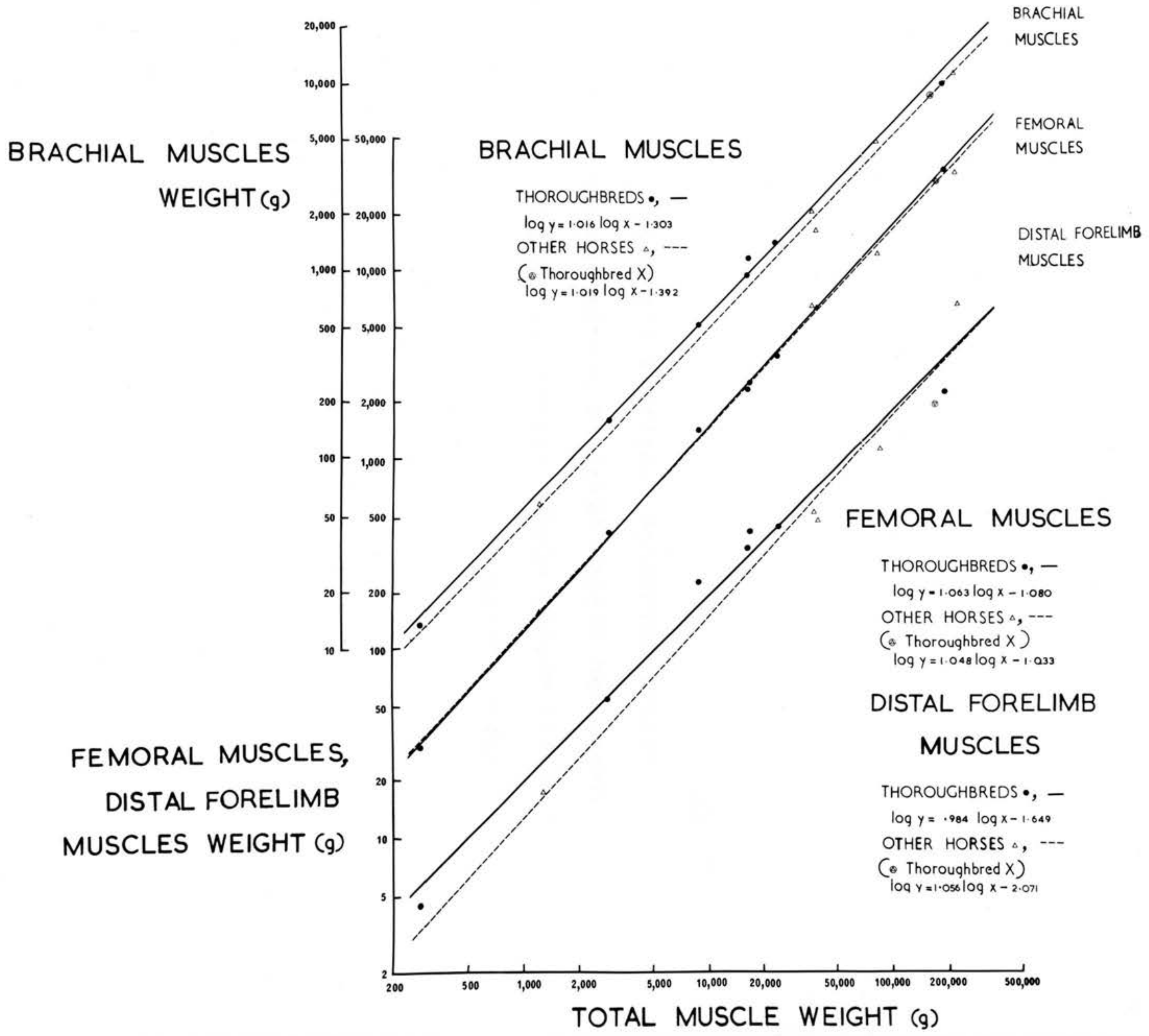

BRACHIAL MUSCLES WEIGHT (g)
FEMORAL MUSCLES, DISTAL FORELIMB MUSCLES WEIGHT (g)
TOTAL MUSCLE WEIGHT (g)
20,000
10,000
5,000
2,000
1,000
500
200
100
50
20
10
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
50
20
10
5
2
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
200,000
500,000
BRACHIAL MUSCLES
THOROUGHBREDS •, —
log y = 1·016 log x − 1·303
OTHER HORSES △, ---
(⊕ Thoroughbred X)
log y = 1·019 log x − 1·392
FEMORAL MUSCLES
THOROUGHBREDS •, —
log y = 1·063 log x − 1·080
OTHER HORSES △, ---
(⊕ Thoroughbred X)
log y = 1·048 log x − 1·033
DISTAL FORELIMB MUSCLES
THOROUGHBREDS •, —
log y = ·984 log x − 1·649
OTHER HORSES △, ---
(⊕ Thoroughbred X)
log y = 1·056 log x − 2·071
BRACHIAL MUSCLES
FEMORAL MUSCLES
DISTAL FORELIMB MUSCLES

Table 20 Logarithmic regression equations comparing the growth of the proximal hindlimb muscle group with the distal hindlimb muscle group in 19 Greyhounds from birth to 30 kg, 9 other dogs from birth to 47 kg; 7 Thoroughbreds from 13·4 kg to 430 kg and 10 other horses from 3·0 kg to 530 kg liveweight.

Type of animal	Growth ratio b*	Se b	log a	r**	Significance*** of difference between groups
Greyhounds	1·108	0·014	0·623+	0·9986	Greyhounds $P < 0{\cdot}01$
Other dogs	1·051	0·041	0·643	0·9948	
Thoroughbreds	1·148	0·064	0·370	0·9922	NS
Other horses	1·102	0·024	0·615+	0·9982	

* Regression coefficient b, standard error Se b.

\+ Values of b bearing this superscript are significantly different ($P < 0{\cdot}05$) from 1.

** Correlation coefficient r.

*** Significance of the difference between groups, tested by analysis of covariance; NS = not significant.

Fig. 16.

Allometric equations comparing the growth of the proximal hindlimb muscle relative to the distal hindlimb muscle in Greyhounds between birth and 30 kg, other dogs between birth and 47 kg; Thoroughbreds between 13·4 and 430 kg and other horses between 3·0 kg and 530 kg liveweight.

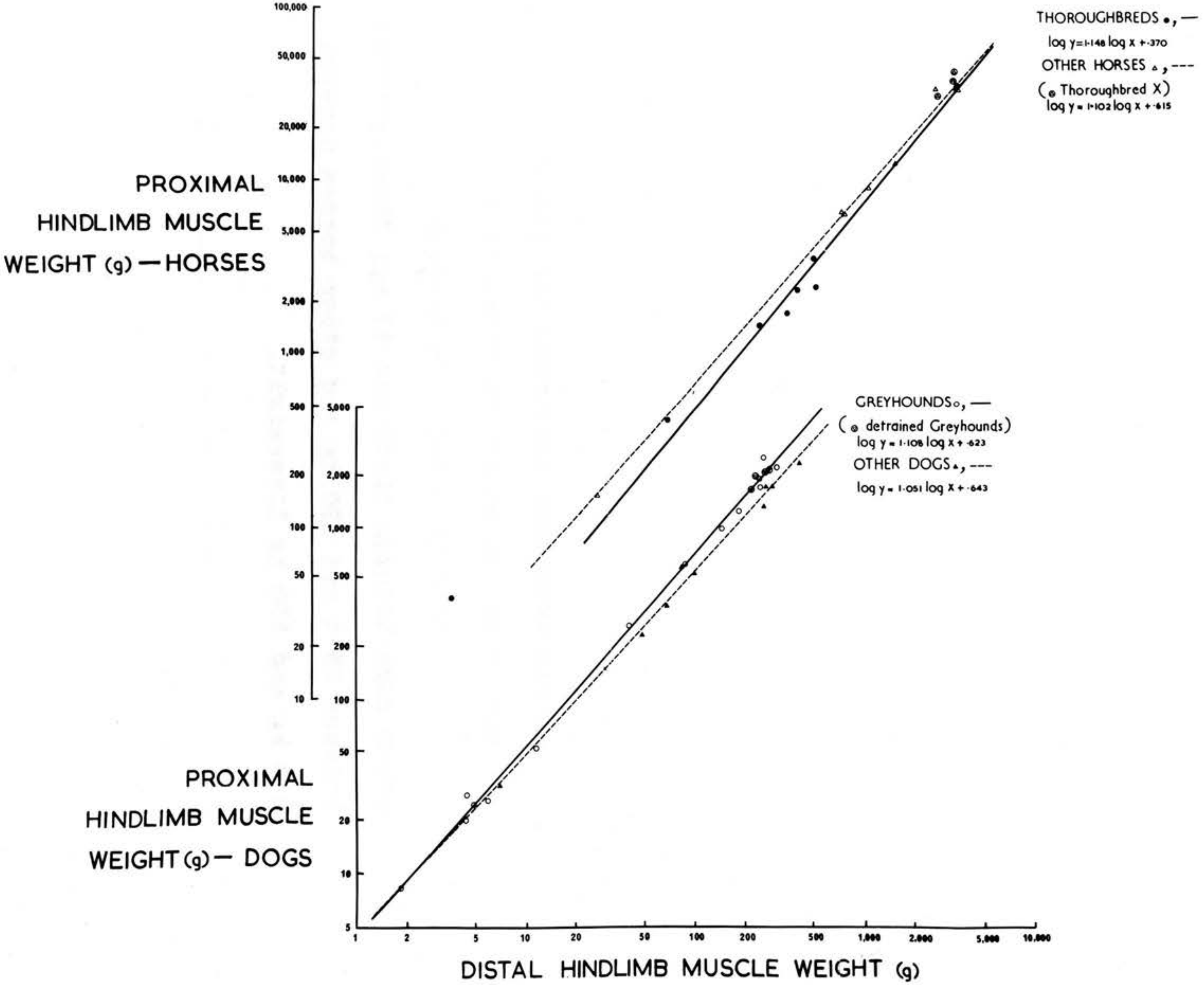

THOROUGHBREDS ●, —
log y = 1·148 log x + ·370
OTHER HORSES △, ---
(⊚ Thoroughbred X)
log y = 1·102 log x + ·615
GREYHOUNDS ○, —
(⊚ detrained Greyhounds)
log y = 1·108 log x + ·623
OTHER DOGS ▲, ---
log y = 1·051 log x + ·643
PROXIMAL HINDLIMB MUSCLE WEIGHT (g) — HORSES
10
20
50
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
PROXIMAL HINDLIMB MUSCLE WEIGHT (g) — DOGS
5
10
20
50
100
200
500
1,000
2,000
5,000
DISTAL HINDLIMB MUSCLE WEIGHT (g)
1
2
5
10
20
50
100
200
500
1,000
2,000
5,000
10,000

Table 21 Weight in g of total forelimb bone, total hindlimb bone, humerus and femur and their percentage of liveweight, total bone and where relevant total forelimb and total hindlimb bone in adult Greyhounds and adult other dogs.

				Total forelimb bone			Total hindlimb bone			Humerus				Femur			
					Percentage of:			Percentage of:			Percentage of:				Percentage of:		
Type of Dog	Live-weight (g)	Total bone weight (g)	Sex	Weight (g)	Live-weight	Total bone	Weight	Live-weight	Total bone	Weight	Live-weight	Total bone	Fore-limb bore weight	Weight	Live-weight	Total bone	Hind-limb bone weight
Grey-hound (D)	24,150	2,550	♀	302	1·25	11·8	283	1·17	11·1	101	0·42	3·96	33·4	103	0·43	4·04	36·4
Grey-hound	25,000	2,819	♀	342	1·37	12·1	338	1·34	12·0	113	0·45	4·00	33·0	121	0·48	4·29	35·8
Grey-hound	25,200	3,306	♂	406	1·61	12·3	340	1·35	10·3	135	0·54	4·08	33·3	137	0·54	4·14	40·3
Grey-hound	25,200	-	♂	-	-	-	-	-	-	-	-	-	-	137	0·50	-	-
Grey-hound (D)	25,300	3,123	♂	363	1·43	11·6	350	1·38	11·2	116	0·46	3·71	32·0	126	0·50	4·03	36·0
Grey-hound	27,500	-	♂	-	-	-	-	-	-	-	-	-	-	135	0·49	-	-
Grey-hound	28,000	-	♂	-	-	-	-	-	-	-	-	-	-	137	0·49	-	-
Grey-hound (D)	28,500	3,259	♀	305	1·07	9·36	386	1·35	11·8	126	0·44	3·87	41·3	141	0·49	4·33	36·5
Grey-hound	29,750	4,310	♀	486	1·63	11·3	472	1·59	11·0	162	0·54	3·76	33·3	172	0·58	3·99	36·4
Grey-hound (D)	30,000	3,684	♂	439	1·46	11·9	405	1·35	11·0	142	0·47	3·85	32·3	149	0·49	4·04	36·8
Grey-hound	30,000	-	♂	-	-	-	-	-	-	-	-	-	-	139	0·46	-	-
Grey-hound	33,608	-	♀	-	-	-	-	-	-	-	-	-	-	157	0·47	-	-
Grey-hound	37,000	-	♂	-	-	-	-	-	-	-	-	-	-	165	0·45	-	-
	Mean %				1·40	11·5		1·36	11·2		0·47	3·89	34·0		0·49+	4·12+	36·9
	SD				0·20	0·99		0·12	0·56		0·05	0·13	3·12		0·04	0·14	1·54
	Mean	3,293		377·6	1·59	11·5	367	1·37	11·2	127·9	0·47	3·88	33·9	139·9	0·49	4·11	36·9
Collie X	10,400	1,031	♀	101	0·97	9·80	112	1·08	10·9	39	0·38	3·78	38·6	40	0·38	3·9	39·6
Collie	11,000	-	♀	-	-	-	-	-	-	-	-	-	-	39	0·35	-	-
Collie X	12,000	-	♀	-	-	-	-	-	-	-	-	-	-	45	0·38	-	-
Collie	14,000	-	♂	-	-	-	-	-	-	-	-	-	-	65	0·46	-	-
Collie	22,000	-	♀	-	-	-	-	-	-	-	-	-	-	75	0·34	-	-
Afghan	25,100	3,276	♀	401	1·60	12·2	372	1·48	11·4	129	0·51	3·94	32·2	137	0·55	4·18	36·8
Afghan	31,900	3,698	♂	453	1·42	12·2	385	1·21	10·4	148	0·46	4·00	32·7	146	0·46	3·95	37·9
Labrador	33,000	3,470	♀	399	1·21	11·5	346	1·05	9·97	125	0·38	3·60	31·3	119	0·36	3·43	34·4
Great Dane	46,500	7,396	♂	892	1·92	12·1	793	1·71	10·7	278	0·60	3·76	31·2	276	0·59	3·73	34·8
	Mean %				1·42	11·61		1·30	10·7		0·47	3·81	33·2		0·43+	3·84+	36·7
	SD				0·36	1·03		0·28	0·54		0·09	0·16	3·08		0·09	0·28	2·17
	Mean	3,774		449·2	1·53	11·9	401·6	1·37	10·6	143·8	0·49	3·81	32·0	143·6	0·49	3·81	35·8

D - Detrained Greyhounds

\+ Values followed by this superscipt are significantly different ($P < 0{\cdot}05$) between the two types of dog.

Table 22 Weight in g of total forelimb bone, total hindlimb bone, humerus and femur and their percentage of liveweight, total bone and of total forelimb bone for the humerus and total hindlimb bone for the femur in adult horses*

Type of animal	Live-weight (g)	Total bone weight (g)	Sex	Total forelimb bone			Total hindlimb bone			Humerus				Femur			
				Weight (g)	Percentage of: Live-weight	Percentage of: Total bone	Weight	Percentage of: Live-weight	Percentage of: Total bone	Weight	Percentage of: Live-weight	Percentage of: Total bone	Fore-limb bone weight	Weight	Percentage of: Live-weight	Percentage of: Total bone	Hind-limb bone weight
Thoroughbred	432,727	53,855	♂	5,961	1·37	11·1	7,023	1·62	13·0	1,844	0·43	3·42	30·9	2,880	0·67	5·3	41·0
Thoroughbred	458,182	-	♀	-	-	-	-	-	-	-	-	-	-	2,650	0·58	-	-
Thoroughbred	470,909	-	♀	-	-	-	-	-	-	-	-	-	-	2,272	0·48	-	-
Thoroughbred	470,909	-	♀	-	-	-	-	-	-	-	-	-	-	2,414	0·51	-	-
Thoroughbred	483,636	-	♀	-	-	-	-	-	-	-	-	-	-	2,360	0·49	-	-
	Mean % (of adults)				1·37	11·1		1·62	13·0		0·43	3·42	30·9		0·51	5·3	41·0
	SD				-	-		-	-		-	-	-		0·05	-	-
	Mean				-	-		-	-		-	-	-	2,424	0·51	-	-
Shetland	153,727	-	♂	-	-	-	-	-	-	-	-	-	-	510	0·33	-	-
Welsh Mountain	178,182	-	♂	-	-	-	-	-	-	-	-	-	-	1,132	0·64	-	-
Shetland	203,636	27,402	♂	2,442	1·20	8·91	2,712	1·33	9·90	790	0·39	2·88	32·4	1,127	0·55	4·11	41·6
Welsh Mountain	229,091	-	♀	-	-	-	-	-	-	-	-	-	-	945	0·41	-	-
Shetland	280,000	-	♂	-	-	-	-	-	-	-	-	-	-	925	0·33	-	-
Thoroughbred X	369,091	-	♂	-	-	-	-	-	-	-	-	-	-	3,135	0·85	-	-
Thoroughbred X	432,727	34,564	♂	4,231	0·98	12·2	4,843	1·12	14·0	1,380	0·32	3·99	32·6	2,032	0·47	5·88	42·0
Connemara X	445,455	-	♀	-	-	-	-	-	-	-	-	-	-	1,955	0·44	-	-
Clydesdale	496,364	70,420	♀	7,872	1·59	11·2	8,652	1·74	12·3	2,300	0·46	3·27	29·2	3,680	0·74	5·23	42·5
Thoroughbred X	521,818	-	♂	-	-	-	-	-	-	-	-	-	-	2,576	0·49	-	-
Thoroughbred X	534,545	-	♀	-	-	-	-	-	-	-	-	-	-	2,360	0·44	-	-
	Mean %				1·26	10·8		1·40	12·1		0·39	3·38	31·4		0·52	5·07	42·0
	SD				0'31	1·70		0·32	2·06		0·07	0·56	1·91		0·17	0·90	0·45
	Mean			4,848	1·28	11·0	5,402	1·55	12·2	1,490	0·43	3·38	30·7	1,853	0·53	5·16	42·2

* The values of the weights given for Thoroughbreds are, with the exception of those for the femur, those for the largest (young) Thoroughbred in which these values were assessed.

Table 23 Logarithmic regression equations comparing the growth of forelimb bone with total bone, hindlimb bone with total bone, humerus with total forelimb bone and femur with total hindlimb bone in Greyhounds from birth to 30 kg, other dogs from birth to 47 kg; Thoroughbreds from 0·7 kg to 430 kg and other horses from 3·0kg to 500 kg liveweight.

Dependent variable	Independent variable	Number of observations	Type of animal	Growth ratio b*	Se b	log a	r**
Forelimb bone	Total bone						
		18	Greyhounds	0·956+	0·015	−0·776	0·9981
		9	Other dogs	1·019	0·035	−0·984	0·9958
		7	Thoroughbreds	0·997	0·024	−0·878	0·9986
		6	Other horses	0·989	0·029	−0·914	0·9982
Hindlimb bone	Total bone						
		18	Greyhounds	1·060+c	0·017	−1·141	0·9980
		9	Other dogs	0·957 c	0·016	−0·813	0·9990
		7	Thoroughbreds	1·034	0·036	−0·926	0·9970
		6	Other horses	0·975	0·031	−0·791	0·9975
Humerus	Forelimb bone						
		18	Greyhounds	0·987	0·011	−0·444	0·9989
		9	Other dogs	0·946	0·027	−0·361	0·9972
		7	Thoroughbreds	1·018	0·016	−0·609	0·9993
		7	Other horses	1·019	0·013	−0·566	0·9996
Femur	Hindlimb bone						
		18	Greyhounds	0·985	0·009	−0·404	0·9993
		9	Other dogs	0·999	0·014	−0·448	0·9993
		7	Thoroughbreds	1·021	0·011	−0·495	0·9997
		8	Other horses	1·006	0·030	−0·425	0·9973

* Regression coefficient b, standard error Se b.

\+ Values of b bearing this superscript are significantly different ($P < 0·05$) from 1.

c Values of b bearing this superscript are significantly different ($P < 0·05$) from one another.

** Correlation coefficient r.

Table 24 Ratios of brachial muscle weight to humerus weight and femoral muscle weight to the femur in adult dogs.

Type of dog	Liveweight (g)	Sex	Brachial ratio	Femoral ratio
Greyhound	24,150	♀ D*	8·47	11·3
Greyhound	25,000	♀	7·52	15·1
Greyhound	25,200	♂	7·08	13·9
Greyhound	25,200	♂	-	14·3
Greyhound	25,300	♂ D*	7·76	16·2
Greyhound	27,500	♂	-	17·2
Greyhound	28,000	♂	-	18·5
Greyhound	28,500	♀ D*	8·26	15·2
Greyhound	29,750	♀	6·91	13·2
Greyhound	30,000	♂ D*	7·97	15·3
Greyhound	30,000	♂	-	15·4
Greyhound	33,608	♀	-	15·8
Greyhound	37,000	♂	7·71	16·5
	Mean		7·71+	15·22+
	SD		0·58	1·82
Collie X	10,400	♀	6·15	14·9
Afghan	25,100	♀	7·34	12·7
Afghan	31,900	♂	6·90	13·2
Labrador	33,000	♀	6·43	11·0
Great Dane	46,500	♂	5·17	8·5
	Mean		6·40+	12·1+
	SD		0·82	2·43

D* Detrained Greyhounds.

\+ Values followed by this superscript are significantly different ($P < 0{\cdot}01$) between each type of dog.

Table 25 Ratios of brachial muscle weight to humerus weight and femoral muscle weight to femur in adult horses.

Type of horse	Liveweight (g)	Sex	Brachial ratio	Femoral ratio
Thoroughbred *	432,727	♂	5·39	11·9
Thoroughbred	470,909	♀	-	17·6
Thoroughbred	470,909	♀	-	13·8
Thoroughbred	483,636	♀	-	17·7
	Mean of adults		-	16·4
	SD		-	2·22
Shetland	153,727	♂	-	14·3
Shetland	203,636	⚦	6·06	10·9
Shetland	280,000	♂	-	15·5
Thoroughbred X **	369,091	♂	-	9·12
Thoroughbred X **	432,727	♂	6·16	15·0
Connemara X	445,455	♀	-	13·7
Clydesdale	496,364	♀	5·0	8·99
Thoroughbred X **	521,818	♂	-	14·4
Thoroughbred X **	534,545	♀	-	17·5
	Mean		5·74	13·3
	SD		0·64	2·95

* Young Thoroughbred

** Thoroughbred cross.

Table 26 Logarithmic regression equations comparing the growth of the brachial muscles with that of the humerus in Greyhounds from birth to 30 kg, other dogs from birth to 47 kg; Thoroughbreds from 0·7 kg to 430 kg and other horses from 3·0 kg to 500 kg liveweight; and the growth of femoral muscles relative to the femur in Greyhounds from birth to 37 kg, other dogs from birth to 47 kg; Thoroughbreds from 0·7 kg to 480 kg and other horses from 3·0 kg to 530 kg liveweight.

Muscle group	Bone	Type of Animal	Number of observ-ations	Growth ratio b*	Se b	log a	r**
Brachial	Humerus						
		Greyhounds	18	1·378+c	0·049	0·055	0·9900
		Other dogs	9	1·149+c	0·057	0·479	0·9915
		Thoroughbreds	7	1·020	0·086	0·394	0·9825
		Other horses	7	1·029	0·041	0·622	0·9960
Femoral	Femur						
		Greyhounds	24	1·418+c	0·048	0·270	0·9876
		Other dogs	21	1·271+c	0·047	0·450	0·9871
		Thoroughbreds	19	1·232+	0·106	0·049	0·9421
		Other horses	16	1·132	0·076	0·634	0·9699

* Regression coefficient b, standard error Se b.

\+ Values of b bearing this superscript are significantly different ($P < 0{\cdot}05$) from 1.

c Values of b bearing this superscript within each limb are significantly different ($P < 0{\cdot}05$) from one another.

** Correlation coefficient.

Table 27 Heart weight (in g) and its percentage of liveweight and total muscle weight in adult dogs.

Type of dog	Liveweight (g)	Sex	Total muscle weight (g)	Heart		
				Weight	Percentage of: Live-weight	Total muscle
Greyhound	24,150 D*	♀	13,297	334	1·38	2·51
Greyhound	25,000	♀	14,088	419	1·68	2·97
Greyhound	25,200	♂	14,692	365	1·45	2·48
Greyhound	25,300 D*	♂	14,422	326	1·29	2·26
Greyhound	28,500 D*	♀	15,742	422	1·48	2·68
Greyhound	29,750	♀	17,983	460	1·55	2·56
Greyhound	30,000 D*	♂	17,213	449	1·50	2·61
	Mean percentage				1·48^{+}	2·58^{+}
	SD				0·12	0·22
	Mean			396	1·48	2·58
	Mean percentage of (D*) detrained Greyhounds				1·41^{+}	2·52
	SD				0·90	0·18
Collie X	10,400	♀	4,453	108	1·04	2·43
Afghan	25,100	♀	12,639	258	1·03	2·04
Afghan	31,900	♂	14,509	330	1·03	2·27
Labrador	33,000	♀	11,250	272	0·82	2·42
Great Dane	46,500	♂	20,875	414	0.89	1·98
	Mean percentage				0·96^{+}	2·23^{+}
	SD				0·10	0·21
	Mean			276	0·94	2·17

\+ Values with this superscript are significantly different ($P < 0{\cdot}02$) between breeds.

Table 28 Heart weight (in g) and its percentage of liveweight and total muscle weight in horses.

Type of horse	Liveweight (g)	Sex	Total muscle weight (g)	Heart		
					Percentage of:	
				Weight	Live-weight	Total muscle
Thorough-bred	432,727	♂	191,883	3,689	0·85	1·92
Welsh Mountain	178,182	♂	-	1,200	0·67	-
Shetland	203,636	⚦	85,054	1,471	0·72	1·73
Arab	305,455	♀	-	2,170	0·71	-
Piebald	318,182	♀	-	2,405	0·76	-
Thorough-bred X	369,091	♂	-	3,310	0·90	-
Exmoor X	480,000	♂	-	3,850	0·80	-
Clydesdale	496,364	♀	223,997	3,510	0·71	1·57
Cob	547,273	⚦	-	4,410	0·81	-
	Mean percentage				0·76	1·65
	SD				0·07	0·11
	Mean			2,791	0·73	1·61

* Values are those for the largest young Thoroughbred in the series.

Table 29 Logarithmic regression equations comparing the growth of heart relative to liveweight in Greyhounds from birth to 30 kg, and other dogs from birth to 47 kg liveweight; Thoroughbreds from 0·7 kg to 430 kg and other horses from 3·0 kg to 550 kg liveweight; and the growth of heart weight relative to total muscle weight in Greyhounds from birth to 30 kg, other dogs from birth to 47 kg; Thoroughbreds from 0·7 kg to 430 kg and other horses from 3·0 kg to 500 kg liveweight.

Independent variable	Type of animal	Number of observ-ations	Growth ratio b*	Se b	log a	r**
Liveweight						
	Greyhounds	18	0·987	0·040	-1·844	0·9873
	Other dogs	9	0·998	0·036	-2·027	0·9955
	Thoroughbreds	8	0·969	0·034	-1·808	0·9962
	Other horses	12	0·968	0·021	-1·982	0·9876
Total muscle						
	Greyhounds	18	0·808^{+}	0·030	-0·835	0·9891
	Other dogs	9	0·868^{+}	0·033	-1·134	0·9951
	Thoroughbreds	7	0·916	0·073	-1·190	0·9846
	Other horses	5	0·921^{+}	0·025	-1·392	0·9989

* Regression coefficient b, standard error Se b.

\+ Values of b followed by this superscript are significantly different ($P < 0{\cdot}05$) from 1.

** Correlation coefficient r.

Fig. 17.

Changes in heart weight with increasing liveweight and total muscle weight in Greyhounds and other dogs.

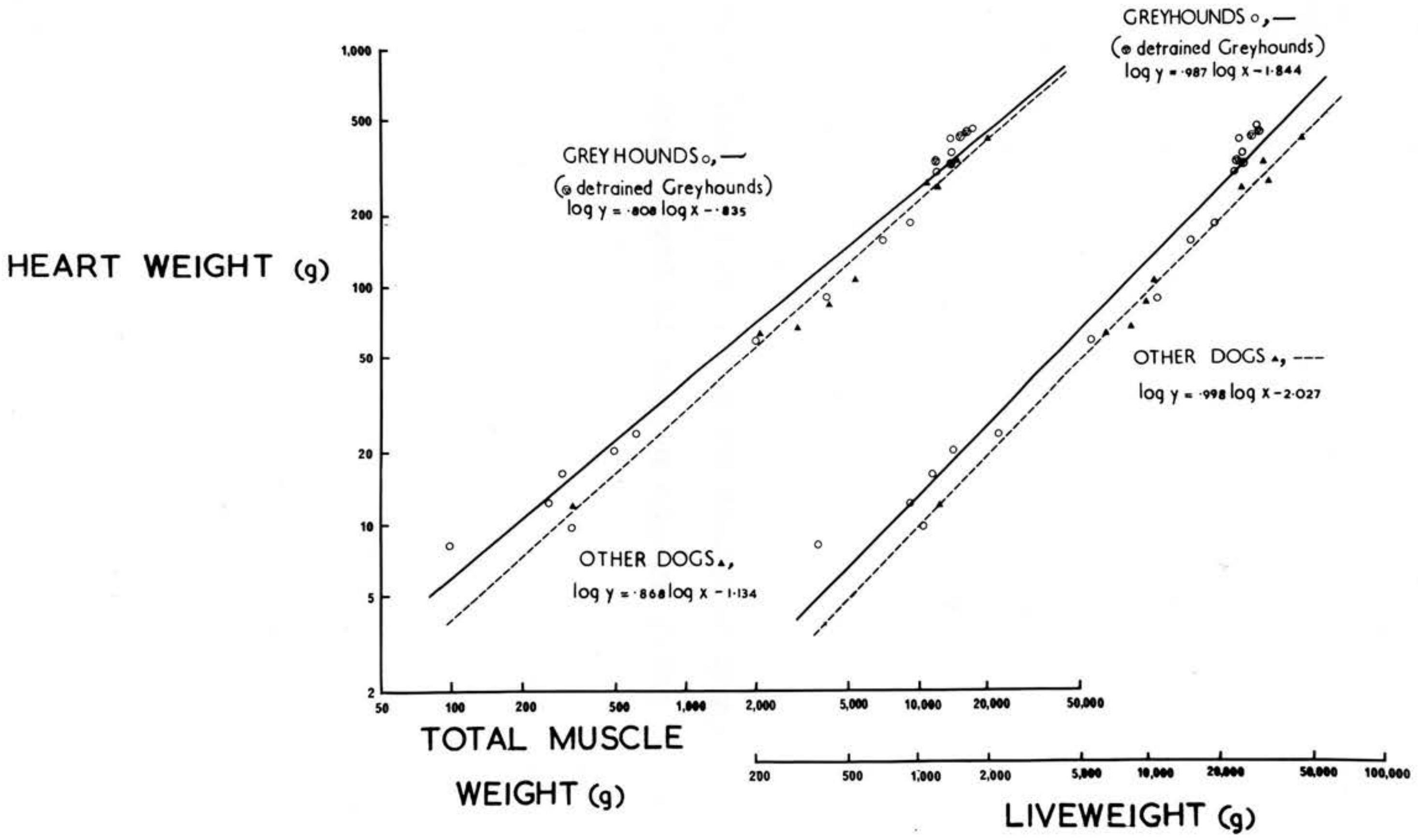

HEART WEIGHT (g)
1,000
500
200
100
50
20
10
5
2
50
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
TOTAL MUSCLE WEIGHT (g)
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
LIVEWEIGHT (g)
GREY HOUNDS ○, —
(◎ detrained Greyhounds)
log y = ·808 log x – ·835
OTHER DOGS ▲,
log y = ·868 log x – 1·134
GREYHOUNDS ○, —
(◎ detrained Greyhounds)
log y = ·987 log x – 1·844
OTHER DOGS ▲, ---
log y = ·998 log x – 2·027

Fig. 18.

Changes in heart weight with increasing liveweight and total muscle weight in Thoroughbreds and other horses.

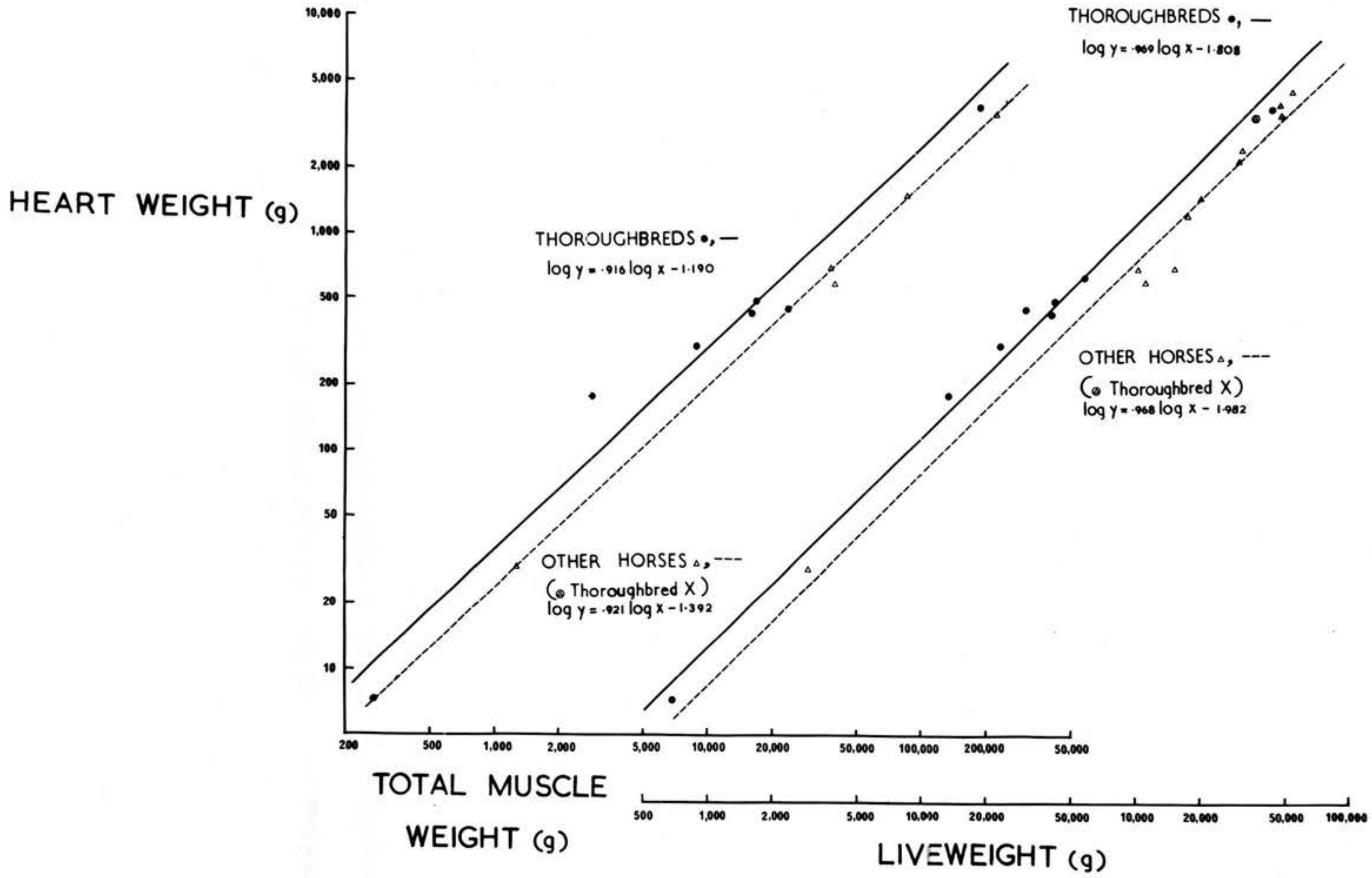

THOROUGHBREDS ●, —
log y = ·969 log x - 1·808
HEART WEIGHT (g)
10,000
5,000
2,000
1,000
500
200
100
50
20
10
THOROUGHBREDS ●, —
log y = ·916 log x - 1·190
OTHER HORSES △, ---
(◎ Thoroughbred X)
log y = ·968 log x - 1·982
OTHER HORSES △, ---
(◎ Thoroughbred X)
log y = ·921 log x - 1·392
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
200,000
50,000
TOTAL MUSCLE
WEIGHT (g)
500
1,000
2,000
5,000
10,000
20,000
50,000
10,000
20,000
50,000
100,000
LIVEWEIGHT (g)

Table 30 Logarithmic regression equations comparing the growth of m. semitendinosus with the femoral muscles in Greyhounds from birth to 37 kg, other dogs from birth to 47 kg; Thoroughbreds from 0·7 kg to 480 kg and other horses from 3·0 kg to 530 kg liveweight.

Type of animal	Number of observations	Growth ratio b*	Se b	log a	r**
Greyhounds	24	1·032 $^{+}$c	0·007	-1·294	0·9995
Other dogs	21	0·985 c	0·010	-1·176	0·9991
Thoroughbreds	19	1·074 $^{+}$c	0·014	-1·337	0·9984
Other horses	17	1·012 c	0·014	-1·126	0·9985

* Regression coefficient b, standard error Se b.

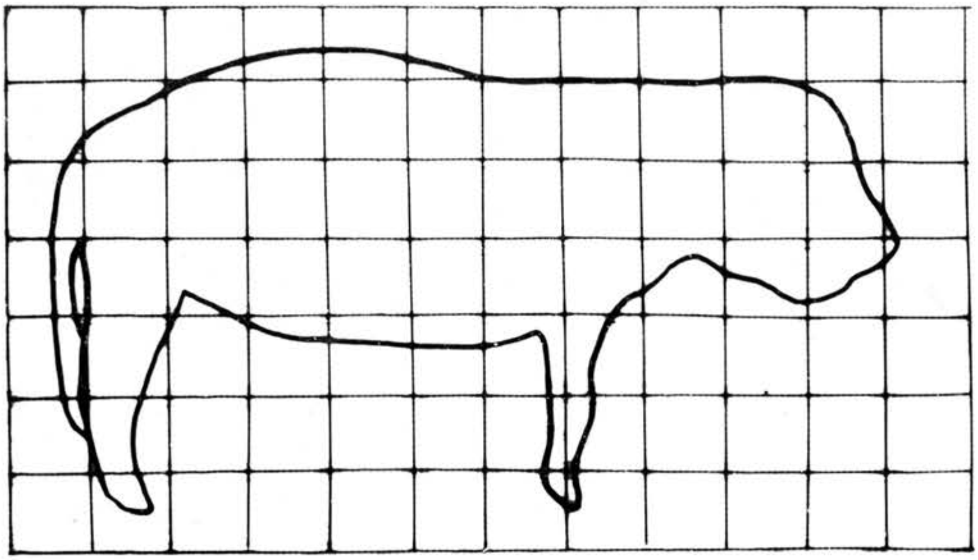
\+ Values of b followed by this superscript are significantly different ($P < 0·05$) from 1.

c Values of b bearing this superscript within a species are significantly different ($P < 0·05$) from one another.

** Correlation coefficient r.

Fig. 19.

Cartesian transformation of body shape in the dog. The outlines are scaled to the same body length. The figures represent neonatal and three year old male Greyhounds and are adapted from photographs taken by the author.



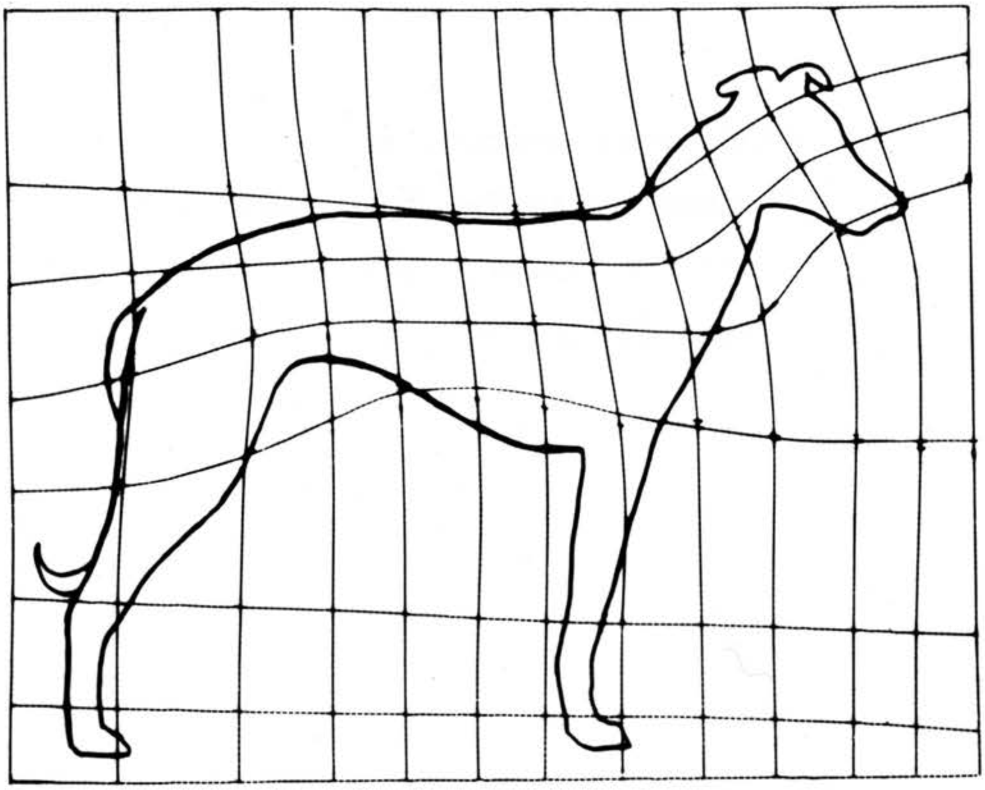
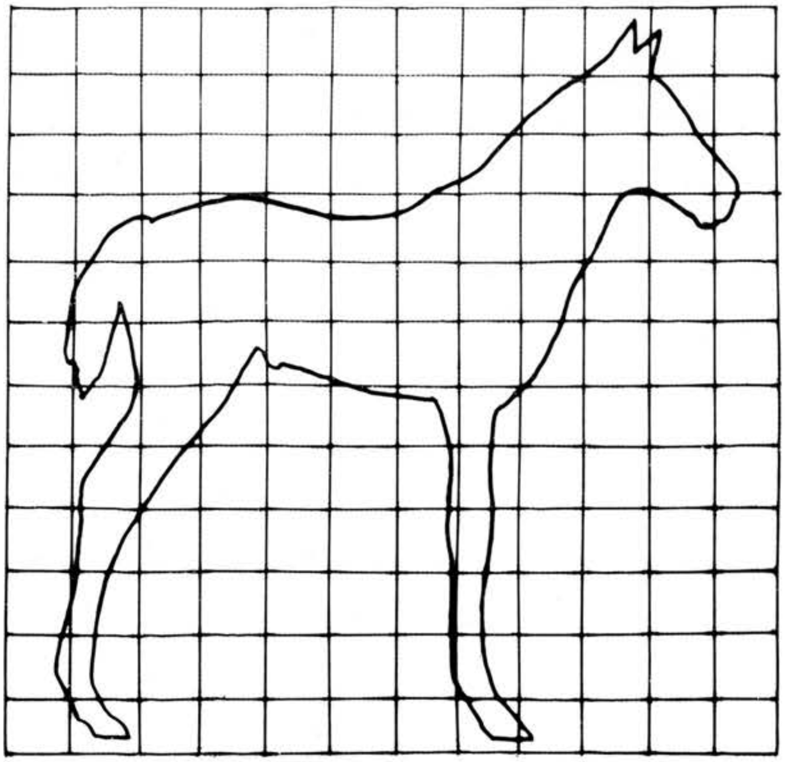


Fig. 20.

Cartesian transformation of body shape in the horse. The outlines are scaled to the same body length. The figures represent a neonatal female and a four year old male Thoroughbred, both are adapted from photographs taken by the author.



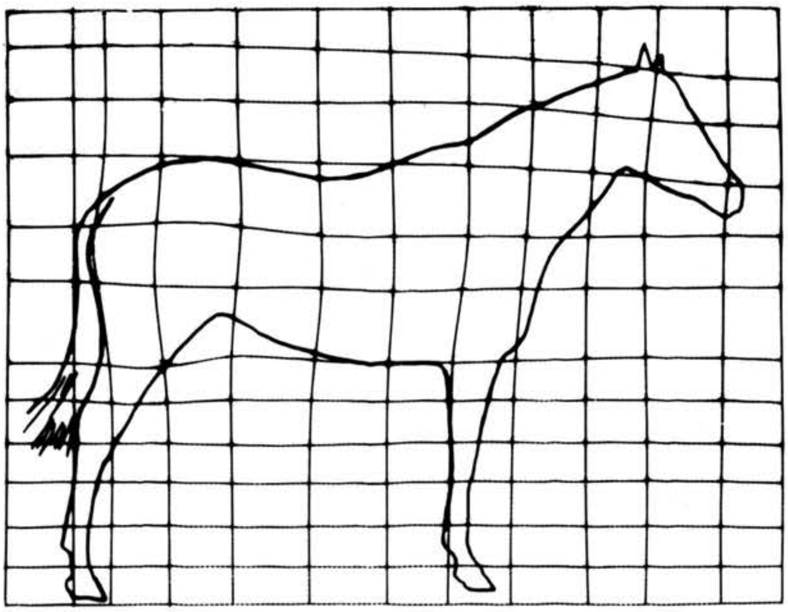


Table 31 Number of samples of m. semitendinosus, m. diaphragma and m. pectoralis transversus taken from 74 horses and 59 dogs and used for histometric and histochemical analysis.

	M. semitendinosus	M. diaphragma	M. pectoralis transversus
Young Greyhounds (Weights ·22 to 23·4 kg)	12	12	12
Adult Greyhounds (Weights 19 to 37 kg)	21	10	9
Young other dogs (Weights ·46 to 9·9 kg)	16	14	12
Adult other dogs (Weights 7·7 to 46·5 kg)	10	7	8
Young Thoroughbreds (Weights 11 to 433 kg)	24	17	20
Adult Thoroughbreds (Weights 446 to 598 kg)	10	6	10
Young other horses (Weights 2·3 to 207 kg)	12	9	12
Adult other horses (Weights 153 to 560 kg)	20	14	22

Table 32 Comparison of the fresh with the frozen transverse sectional areas (TSA); and mean fibre area of the transverse section with that of a superficial sample, of m. semitendinosus from 21 young Thoroughbreds.

Live-weight (g)	TSA (mm^2)		Mean fibre area (μm^2)	
	Fresh	Frozen	Total section	Super-ficial sample
11,000	176	174	265	280
13,429	91	91	115	118
16,000	232	224	194	196
19,000	147	153	253	270
23,872	489	475	529	533
24,000	423	415	512	510
28,000	417	419	420	422
29,000	392	401	320	314
30,965	582	569	390	383
31,500	545	544	442	445
32,000	592	596	493	492
33,500	504	516	524	522
34,500	487	469	368	368
34,800	389	386	435	445
38,636	976	1005	1146	1146
39,000	589	569	583	573
40,500	647	646	1101	836
42,000	321	320	426	406
42,962	789	782	856	758
50,000	474	460	434	431
58,664	660	674	718	679
Mean	472·5	470.9	501·0	482.4

Table 33 Regression equations comparing the TSA of m. semitendinosus with liveweight in dogs and horses.

Number of observations	Type of animal	Growth ratio b*	Se b	log a	r**
33	Greyhounds	0·814	0·023	5·359	0·9875
26	Other dogs	0·745	0·042	5·457	0·9643
28	Thoroughbreds	0·957c	0·052	4·333	0·9638
30	Other horses	0·669c	0·033	5·743	0·9670

* Regression coefficient b, standard error Se b

c values of b bearing this superscript are significantly different ($P < 0{\cdot}01$) from one another

** Correlation coefficient r.

Fig. 21.

Changes in TSA of m. semitendinosus with increasing liveweight in Greyhounds and other dogs.

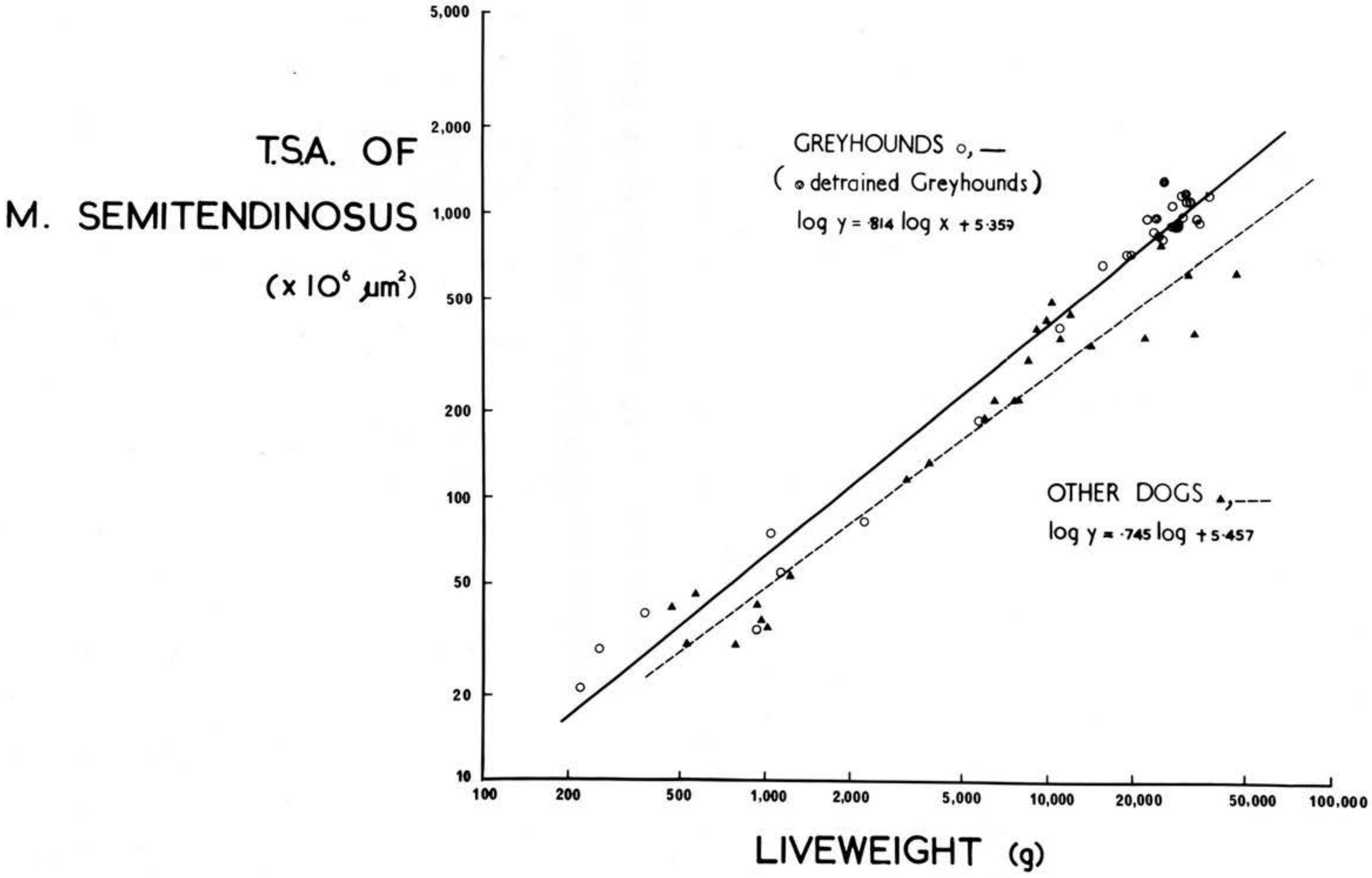

T.S.A. OF
M. SEMITENDINOSUS
(x 10⁶ µm²)
5,000
2,000
1,000
500
200
100
50
20
10
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
LIVEWEIGHT (g)
GREYHOUNDS ○, —
(● detrained Greyhounds)
log y = ·814 log x + 5·357
OTHER DOGS ▲,---
log y = ·745 log + 5·457

Fig. 22.

Changes in TSA of m. semitendinosus with increasing liveweight in Thoroughbreds and other horses.

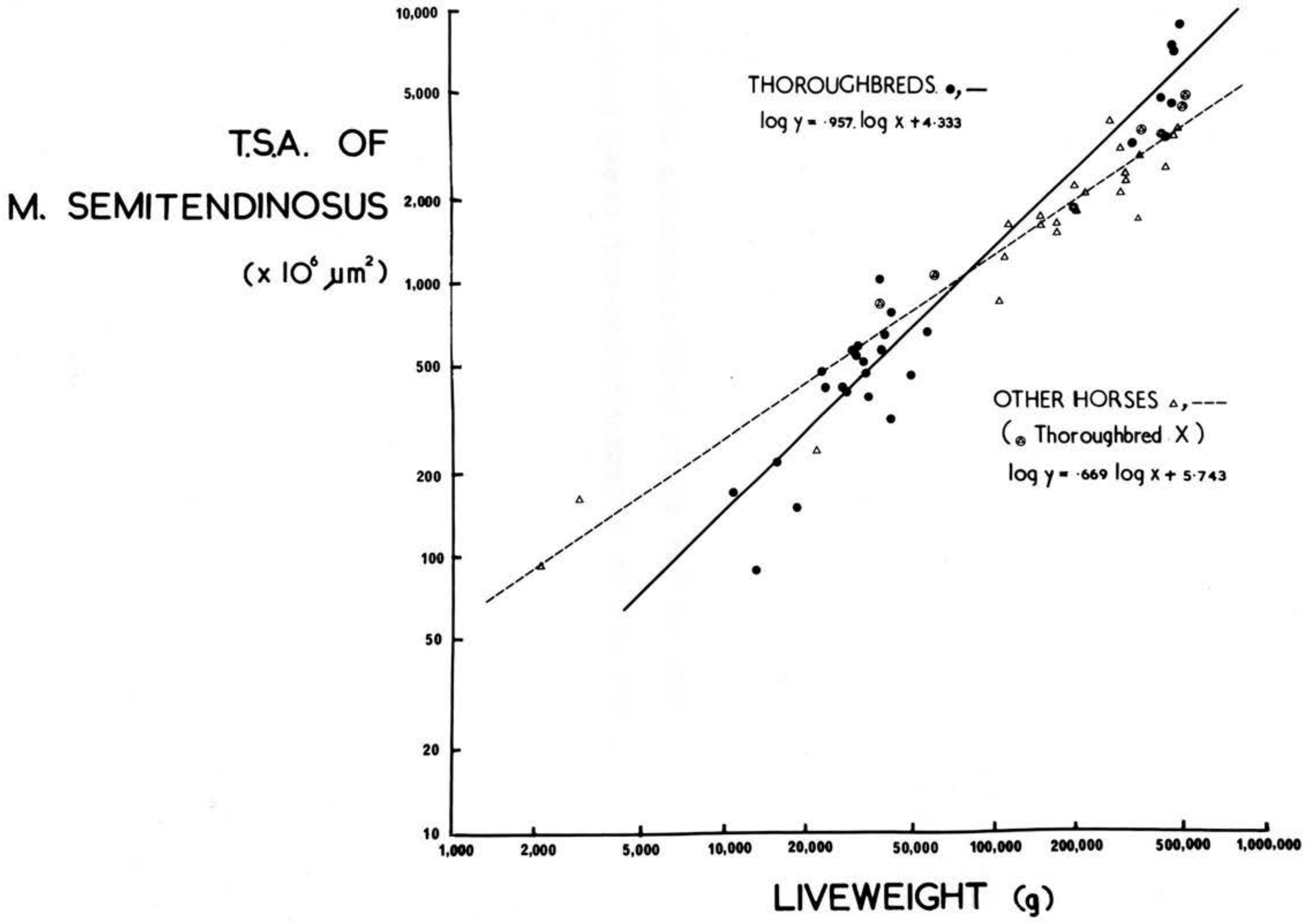

T.S.A. OF
M. SEMITENDINOSUS
(x 10^6 μm^2)
10,000
5,000
2,000
1,000
500
200
100
50
20
10
1,000
2,000
5,000
10,000
20,000
50,000
100,000
200,000
500,000
1,000,000
LIVEWEIGHT (g)
THOROUGHBREDS ●, —
log y = ·957. log x + 4·333
OTHER HORSES △, ---
(⊗ Thoroughbred X)
log y = ·669 log x + 5·743

Table 34 The total number of fibres in m. semitendinosus of adult dogs.

	Greyhounds			Other dogs			
	Live-weight (g)	Sex	Fibre numbers (x 1,000)	Breed	Live-weight (g)	Sex	Fibre numbers (x 1,000)
	19,000	♀	280	Collie	7,742	♀	132
	22,300	♀	295	Collie X	10,400	♀	184
	24,150	♀	230	Collie	11,000	♀	139
	24,884	♂	348	Collie	12,000	♀	188
	25,000	♀	322	Collie	14,100	♀	136
	25,200	♂	209	Collie	22,000	♀	155
	25,300	♂	529	Afghan	25,100	♀	214
	27,200	♂	313	Afghan	31,900	♂	194
	27,500	♂	282	Labrador	33,000	♀	175
	28,000	♂	232	Great Dane	46,500	♂	248
	28,500	♀	329				
	28,864	♂	328				
	29,750	♀	404				
	30,000	♂	352				
	30,000	♂	319				
	31,200	♂	348				
	31,400	♂	346				
	33,523	♀	306				
	33,608	♀	260				
	34,091	♂	320				
	37,000	♂	355				
Mean	28,407		319		21,370		177
SD	4,321		67		12,681		37

Difference between means of liveweight and total fibre numbers significant at the 5% and 0·1% levels respectively.

Table 35 The total number of fibres in m. semitendinosus of adult horses.

	Thoroughbreds			Other horses			
	Live-weight (kg)	Sex	Fibre numbers (x 1,000)	Breed	Live-weight (kg)	Sex	Fibre numbers (x 1,000)
	445	♀	1,140	Shetland	157	⚦	548
	471	♀	2,242	Welsh Mt.	178	⚦	610
	471	♀	1,245	Shetland	204	⚦	783
	484	♀	1,598	Welsh Mt.	229	♀	798
	509	♂	2,136	Shetland	280	⚦	1,127
				Connemara X	305	♀	838
				Arab	305	♀	899
				Connemara X	318	♀	610
				Piebald	318	♀	971
				Exmoor	356	♂	1,029
				Connemara X	445	♀	887
				Pony	480	⚦	636
				Clydesdale	496	♀	1,168
				(Mean	313		839)
				(SD	109		20)
				Thoroughbred X	356	♀	739
				Thoroughbred X	369	⚦	1,516
				Thoroughbred X	433	⚦	910
				Thoroughbred X	522	⚦	1,171
				Thoroughbred X	535	♀	1,149
				(Mean	443		1,097)
				(SD	83		294)
Mean	476		1,672		349		910
SD	23		503		117		251

The means of the Thoroughbred crosses are significantly greater ($P < 0{\cdot}05$) than those of the other horses. The means of the other horses without the Thoroughbred crosses are significantly less ($P < 0{\cdot}01$ for liveweight and $P < 0{\cdot}001$ for total fibre numbers) than in the Thoroughbreds. There is no significant difference between the means of the Thoroughbred crosses and the Thoroughbreds. The means of the Thoroughbreds are significantly greater ($P < 0{\cdot}05$ for liveweight and $P < 0{\cdot}001$ for total fibre numbers) than the means of both types of other horses combined.

Table 36 Regression equations comparing the total number of fibres in m. semitendinosus with liveweight, and the TSA of m. semitendinosus with the mean fibre area of that muscle.

Independent variable	Dependent variable	Type of animal	Growth ratio b*	Se b	log a	r**	Significance *** of difference between groups
Total number of fibres	Body weight						
	33	Greyhounds	0·078	0·022	5·147	0·5316	Greyhounds
	26	Other dogs	0·101	0·023	4·813	0·6229	P<O·01
	28	Thoroughbreds	0·181	0·038	5·165	0·6774	Thoroughbreds
	30	Other horses	0·215	0·093	4·766	0·6877	P<O·01
TSA of m. semi-tendinosus	Mean fibre area						
	33	Greyhounds	1·088	0·031	5·179	0·9875	Greyhounds
	26	Other dogs	1.126	0·042	4·802	0·9840	P<O·01
	28	Thoroughbreds	1.185	0.053	5·497	0·9751	Thoroughbreds
	30	Other horses	1.258	0.107	5·021	0·9120	P<O·01

* Regression coefficient b, standard error Se b

** Correlation coefficient r

*** Significance of the difference between groups tested by analysis of covariance;

Table 37 Predicted TSA and total fibre numbers of m. semitendinosus in dogs of 0·5 kg and 30 kg liveweight calculated from the logarithmic regression equations on Tables 33 & 36.

	Liveweight	
	0·5 kg	30 kg
TSA (mm^2)		
Greyhounds		
Mean	36·0	1,008*
95% limits$^+$	(30·5 - 42·5)	(924 - 1,100)
Other dogs		
Mean	29·4	620*
95% limits$^+$	(23·3 - 37·0)	(510 - 754)
Total fibre numbers (x 1,000)		
Greyhounds		
Mean	228*	314*
95% limits$^+$	(195 - 267)	(288 - 341)
Other dogs		
Mean	122*	184*
95% limits$^+$	(104 - 141)	(163 - 208)
Mean fibre area (μm^2)		
Greyhounds		
Mean	159*	3,248
95% limits$^+$	(134 - 188)	(2,975 - 3,547)
Other dogs		
Mean	254*	3,542
95% limits$^+$	(201 - 320)	(2,915 - 4,305)

\+ Probability of a value outside these limits $< 0{\cdot}05$.

* Values of predictions for similar muscles followed by this superscript are significantly different ($P < 0{\cdot}05$) between each type of dog.

Table 38 TSA and total fibre numbers of m. semitendinosus in horses of 50 kg and 500 kg liveweight calculated from the logarithmic regression equations on Tables 33 & 36

	Liveweight	
	50 kg	500 kg
TSA (mm^2)		
Thoroughbreds		
Mean	676	6,124*
95% limits+	(592 - 772)	(4,703 - 7,974)
Other horses		
Mean	770	3,595*
95% limits+	(683 - 869)	(3,188 - 4,053)
Total fibre numbers (x 1000)		
Thoroughbreds		
Mean	1,036*	1,572*
95% limits+	(940 - 1,143)	(1,293 - 1,912)
Other horses		
Mean	597*	980*
95% limits+	(512 - 698)	(840 - 1,144)
Mean fibre area (μm^2)		
Thoroughbreds		
Mean	670*	4,435
95% limits+	(595 - 753)	(3,713 - 5,298)
Other horses		
Mean	1,304*	3,710
95% limits+	(1,132 - 1,502)	(3,246 - 4,240)

\+ Probability of a value outside these limits $< 0{\cdot}05$.

* Values of predictions for similar muscles followed by this superscript are significantly different ($P < 0{\cdot}05$) between each type of horse.

Table 39 Mean fibre areas in μm^2 of m. semitendinosus, m. diaphragma and m. pectoralis transversus of dogs.

Type of animal	Live-weight (g)	Sex	Mean fibre area in:					
			m.semi-tendin-osus	(N•)	m.dia-phragma	(N•)	m.pector-alis tran-sversus	(N•)
Greyhounds								
Young dogs	222	♂	116		253		233	
	260	♂	128		257		130	
	377	♀	141		163		160	
	927	♀	158		328		339	
	1,056	♀	263		410		321	
	1,174	♀	183		360		294	
	2,280	♂	479		420		361	
	5,712	♀	915		821		710	
	11,000	♀	1,500		1,179		1,250	
	15,250	♀	2,460		1,109		1,684	
	19,750	♂	2,155		1,488		1,569	
	23,500	♀	2,595		2,193		2,604	
Adult Greyhounds								
All adults	Mean		3,179	21	1,801	10	3,468	9
	SD		546		361		473	
Males	Mean		3,203	13	1,982	5	3,458	4
	SD		530		445		329	
Females	Mean		3,140	8	1,621	5	3,531	5
	SD		605		120		548	
Detrained Adults	Mean		3,330	4	1,955	4	3,505	4
	SD		821		526		371	
Trained adults	Mean		3,144	17	1,699	6	3,439	5
	SD		489		194		523	
Other dogs								
Young dogs	464	♂	288		470		-	
	527	♀	252		675		571	
	573	♀	335		455		-	
	785	♀	233		344		339	
	931	♂	303		562		423	
	976	♂	379		469		358	
	1,010	♂	232		438		598	
	1,235	♂	472		617		623	
	3,180	♂	938		-		-	
	3,843	♀	716		617		798	
	6,000	♂	1,687		781		967	
	6,585	♀	1,232		1,237		1,450	
	7,960	♂	1,870		-		-	
	8,500	♂	1,841		1,542		1,618	
	9,023	♀	2,370		1,071		1,532	
	9,900	♀	1,931		1,933		1,913	
Adult other dogs								
All adults	Mean		2,602	10	1,427	7	3,111	8
	SD		552		199		1,456	
Males	Mean		2,767	3	1,534	2	3,763	3
	SD		410		361		123	
Females	Mean		2,532	7	1,385	5	2,720	5
	SD		618		138		1,564	

N• Number of adult samples.

Table 40 Logarithmic regression equations comparing the mean fibre area of m. semitendinosus, m. diaphragma and m. pectoralis transversus with liveweight in the dog and horse.

Dependent variable	Number of observations	Type of animal	Growth ratio b*	Se b	log a	r**	Significance *** of difference between groups
Mean fibre area of m. semitendinosus	33	Greyhounds	0.737 c	0.023	0.212	0.9847	NS
	26	Other dogs	0.644 c	0.042	0.666	0.9534	
	34	Thoroughbreds	0.821 d	0.039	-1.032	0.9659	NS
	32	Other horses	0.454 d	0.038	0.982	0.9072	
Mean fibre area of m. diaphragma	22	Greyhounds	0.463 c	0.024	1.181	0.9738	NS
	21	Other dogs	0.349 c	0.036	1.690	0.9110	
	23	Thoroughbreds	0.789 d	0.047	-0.936	0.9644	NS
	23	Other horses	0.504 d	0.049	0.647	0.9139	
Mean fibre area of m. pectoralis transversus	21	Greyhounds	0.661	0·034	0·532	0·9763	Other dogs $P<0·01$
	20	Other dogs	0·579	0·047	0·950	0·9501	
	30	Thoroughbreds	0·871 d	0·064	-1·232	0·9330	NS
	34	Other horses	0·517 d	0·056	0·712	0·8514	

* Regression coefficient b, standard error Se b

c,d Values of b bearing these superscripts within each muscle of dogs and horses respectively, are significantly different ($P < 0·05$) from one another

** Correlation coefficient r

*** Significance of difference between groups tested by analysis of covariance;

NS Not significant.

Table 41 Mean fibre areas (in μm^2) of m. semitendinosus, m. diaphragma and m. pectoralis transversus of dogs at 0·5 kg and 30 kg liveweight calculated from the allometric equations on Table 40.

	Liveweight	
	0·5 kg	30 kg
M. semitendinosus		
Greyhounds		
Mean	159*	3,248
95% limits+	(134 - 188)	(2,975 - 3,547)
Other dogs		
Mean	254*	3,542
95% limits+	(201 - 320)	(2,915 - 4,305)
M. diaphragma		
Greyhounds		
Mean	270*	1,794
95% limits+	(229 - 317)	(1,602 - 2,010)
Other dogs		
Mean	429*	1,789
95% limits+	(354 - 518)	(1,487 - 2,152)
M. pectoralis transversus		
Greyhounds		
Mean	207	3,100
95% limits+	(166 - 258)	(2,638 - 3,643)
Other dogs		
Mean	326	3,485
95% limits+	(249 - 426)	(2,825 - 4,300)

\+ Probability of a value outside these limits $< 0{\cdot}05$.

* Values of predictions for similar muscles followed by this superscript are significantly different ($P < 0{\cdot}05$) between each type of dog.

Table 42 Mean fibre areas in μm^2 of m. semitendinosus, m. diaphragma and m. pectoralis transversus of horses.

Type of animal	Live-weight (g)	Sex	Mean fibre area in: m.semi-tendinosus	(N*)	m.dia-phragma	(N*)	m.pector-alis transversus	(N*)
Thoroughbreds								
Young horses	11,000	♀	265		244		161	
	13,429	♀	115		-		-	
	16,000	♂	194		273		332	
	19,000	♀	253		382		319	
	23,872	♂	529		398		407	
	24,000	♀	512		357		448	
	28,000	♂	420		-		408	
	29,000	♂	320		372		378	
	30,965	♀	390		354		414	
	31,500	♂	442		-		648	
	32,000	♀	493		318		468	
	33,500	♂	524		264		302	
	34,500	♀	368		-		-	
	34,800	♀	435		-		-	
	38,636	♂	1,146		572		1,149	
	39,000	♂	583		-		309	
	40,500	♀	1,101		763		852	
	42,000	♂	426		366		418	
	42,962	♀	856		516		1,208	
	50,000	♀	434		320		568	
	58,664	♀	716		-		1,044	
	337,000	♀	2,967		1,978		2,328	
	420,000	♂	3,513		3,670		-	
	432,727	♂	2,821		2,392		3,584	
Adult Thoroughbreds								
All adults								
	Mean		4,675	10	4,246	6	4,664	10
	SD		1,350		1,250		897	
Entire males								
	Mean		4,277	2	3,926	1	4,236	2
	SD		113		-		362	
Castrated males								
	Mean		-		3,109	1	4,310	1
	SD		-		-		-	
Females								
	Mean		4,649	8	4,610	4	4,836	7
	SD		1,469		1,400		1,034	
Detrained adults								
	Mean		5,498	4	-		5,286	2
	SD		1,653		-		1,122	
Trained adults								
	Mean		4,126	6	4,246	6	4,508	8
	SD		859		1,250		846	
Other horses								
Young horses	2,150	♂	503		283		425	
	2,977	♂	372		243		442	
	22,000	♀	403		-		581	
	109,091	♂	1,916		1,135		2,090	
	114,546	♀	1,925		2,222		1,842	
	118,182	♂	2,196		1,473		2,809	
	153,727	♂	2,674		2,061		1,715	
	178,182	♂	2,959		-		5,208	
	207,273	♂	3,040		2,451		2,278	
T'bred X	39,000	♀	916		386		582	
T'bred X	62,000	♀	1,010		-		882	
T'bred X	203,636	♀	1,263		1,305		1,136	
Adult other horses								
All adults								
	Mean		3,285	20	2,901	14	4,424	22
	SD		757		734		1,814	
Thoroughbred crosses								
	Mean		3,365	5	3,289	3	3,821	6
	SD		921		1,173		876	
Other adults								
	Mean		3,258	15	2,796	11	4,654	16
	SD		730		607		2,057	
Entire males								
	Mean		3,541	3	3,024	2	3,454	1
	SD		432		677		-	
Castrated males								
	Mean		3,502	9	2,974	7	4,671	10
	SD		951		852		2,027	
Females								
	Mean		2,944	8	2,751	5	4,293	11
	SD		498		709		1,778	

N* Number of adult samples.

T'bred X Thoroughbred cross.

Table 43 Mean fibre areas in μm^2 of m. semitendinosus, m. diaphragma and m. pectoralis transversus of horses at 50 kg and 500 kg liveweight calculated from the allometric equations on Table 40.

	Liveweight	
	50 kg	500 kg
M. semitendinosus		
Thoroughbreds		
Mean	670*	4,435
95% limits+	(595 - 753)	(3,713 - 5,298)
Other horses		
Mean	1,304*	3,710
95% limits+	(1,132 - 1,502)	(3,246 - 4,240)
M. diaphragma		
Thoroughbreds		
Mean	591*	3,635
95% limits+	(511 - 684)	(2,913 - 4,537)
Other horses		
Mean	1,036*	3,306
95% limits+	(809 - 1,326)	(2,534 - 4,314)
M. pectoralis transversus		
Thoroughbreds		
Mean	726*	5,393
95% limits+	(597 - 883)	(4,056 - 7,172)
Other horses		
Mean	1,384*	4,554
95% limits+	(1,103 - 1,738)	(3,666 - 5,658)

+ Probability of a value outside these limits $< 0{\cdot}05$.

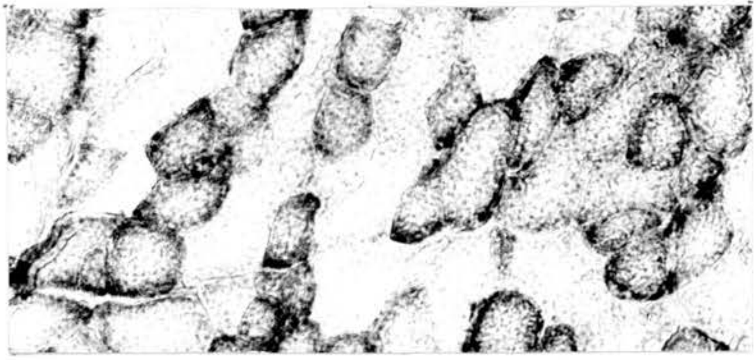
* Values of predictions for similar muscles followed by this superscript are significantly different ($P < 0{\cdot}05$) between each type of horse.

Figs. 23 - 26.

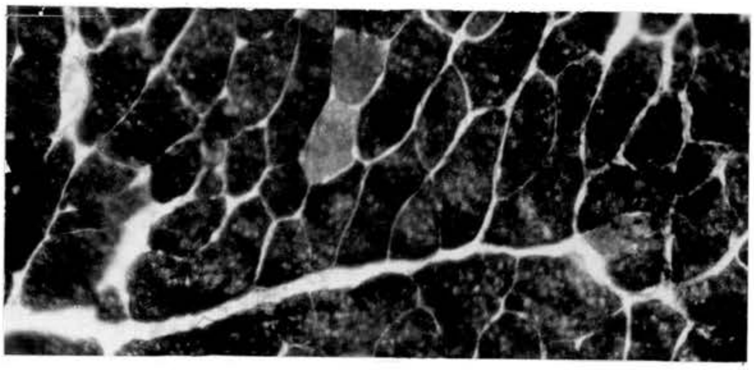
Transverse serial fresh frozen sections from the caudal superficial region of m. semitendinosus from a 318 kg six year old Piebald pony mare, demonstrating SDHase (Fig. 23), GPase (Fig. 24), myosin ATPase (Fig. 25) and fibre outlines with Erlich's haematoxylin (Fig. 26).

AH.SH.PH., AH.SL.PH. and AL.SH.PH fibres are apparent.

23

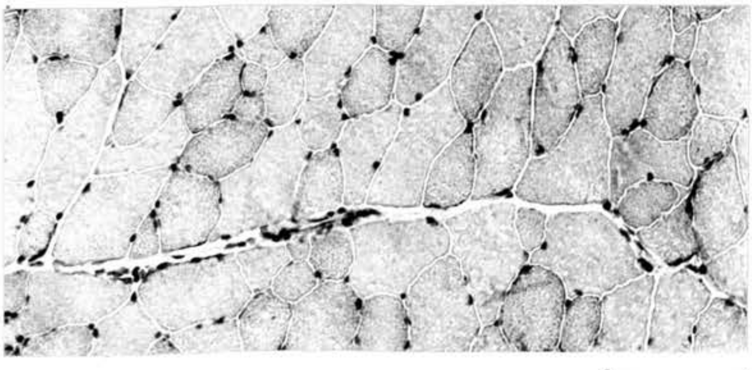


24



25

26



Figs. 27 - 29.

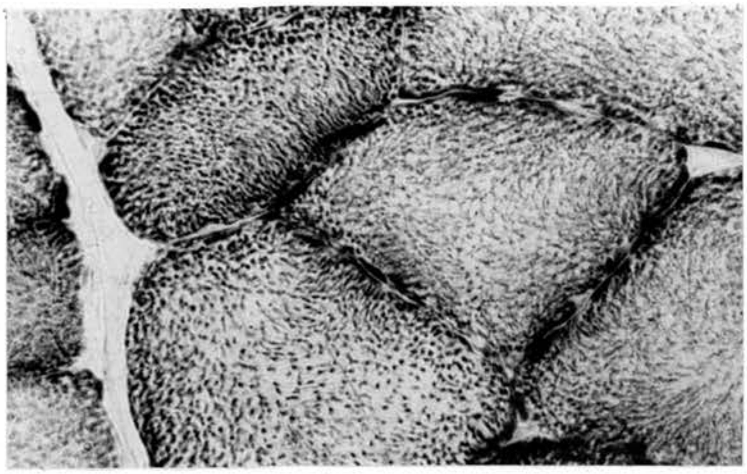
Transverse serial fresh frozen sections from the caudal superficial region of m. semitendinosus from a 318 kg six year old Piebald pony mare, demonstrating SDHase (Fig. 27), GPase (Fig. 28) and myosin ATPase (Fig. 29) activity. These coloured photographs correspond to Figs. 23, 24 and 25 respectively.

3 SLIDES
To Go
HERE

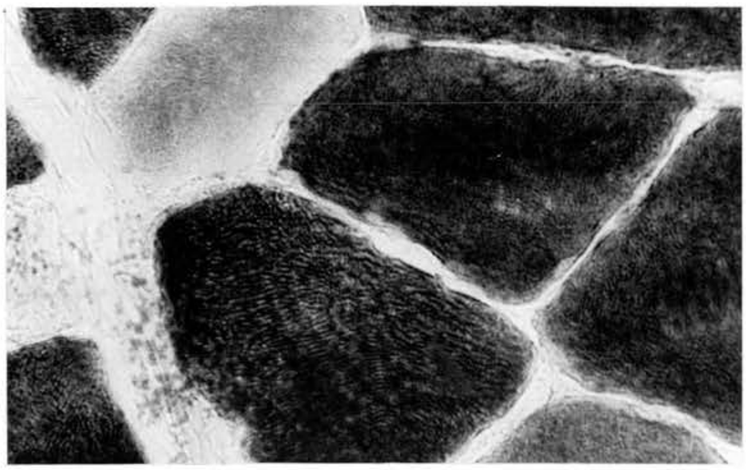
Figs. 30 - 32.

Transverse serial fresh frozen sections from the superficial region of m. pectoralis transversus of a 25 kg adult male Greyhound demonstrating SDHase (Fig. 30), GPase (Fig. 31) and myosin ATPase (Fig. 32) activity. The AH.SH.PH. fibres and AL.SH.PL. fibres show the disposition of the deposits from the reactions.

30.



31

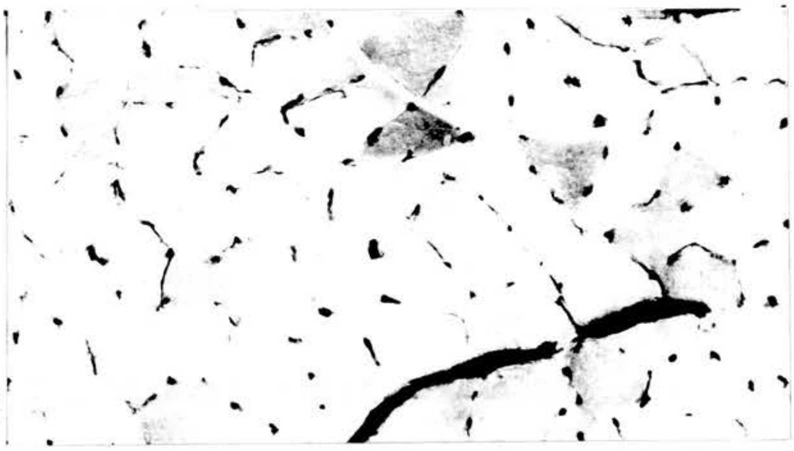


32

Figs. 33 and 34.

Transverse fresh frozen sections from the superficial region of m. pectoralis transversus of a 5 year old 25 kg detrained adult male Greyhound (Fig. 33) and from the superficial caudal region of m. semitendinosus of a 3 year old 458 kg Thoroughbred mare (Fig. 34) demonstrating capillaries.

33.



34

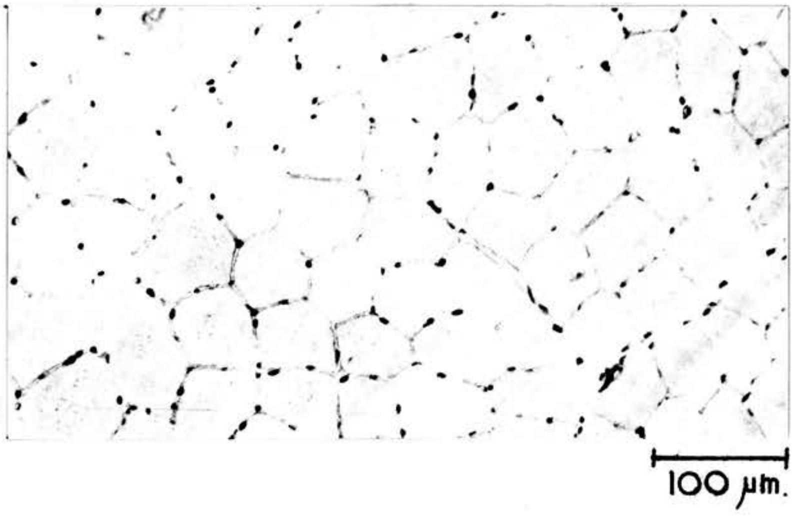


Table 44 QUANTITATIVE HISTOCHEMISTRY OF CANINE SKELETAL MUSCLE

Proportion of transverse section and transverse sectional areas of samples of m. semitendinosus, m. diaphragma and m. pectoralis transversus occupied by myosin ATPase low-reacting (AL) fibres.

GREYHOUNDS					OTHER DOGS				
	Sex	Body weight (kg)	% AL numbers	% AL area	Breed	Sex	Body weight (kg)	% AL numbers	% AL area
					MUSCULUS SEMITENDINOSUS				
	♀	19	1·8	1·6	Collie	♀	8	22	22
	♀	22	1·3	0·92	Terrier X	♀	10	20	14
D*	♀	24	9·7	5·0	Collie	♀	11	28	18
	♂	25	3·4	3·3	Collie	♀	12	34	27
	♀	25	1·7	1·1	Collie	♂	14	19	13
	♂	25	2·5	1·9	Collie	♀	22	12	10
D*	♂	25	2·1	1·6	Afghan	♀	25	15	11
	♂	27	4·3	3·2	Afghan	♂	32	10	7·0
	♂	28	2·1	1·6	Labrador	♀	33	12	15
	♂	28	2·6	1·1	Great Dane	♂	47	8·9	5·4
D*	♀	29	2·7	2·1					
	♂	29	0·97	0·82					
	♀	30	0·52	0·58					
	♂	30	0·33	0·32					
D*	♂	30	2·5	1·5					
	♂	31	5·3	5·1					
	♂	31	2·5	2·8					
	♀	34	4·8	3·3					
	♀	34	3·1	1·2					
	♂	34	4·5	2·8					
	♂	37	4·8	3·3					
		Mean	3·00	2·2			Mean	18·1	14·2
		SD	2·1	1·3			SD	8·2	6·7
					MUSCULUS DIAPHRAGMA				
D*	♀	24	39	25	Terrier X	♀	10	46	47
	♀	25	29	23	Collie	♀	11	55	72
	♂	25	27	31	Collie	♀	12	52	42
D*	♂	25	16	13	Collie	♂	14	54	41
D*	♀	29	23	13	Collie	♀	22	59	48
	♀	30	20	27	Afghan	♀	25	42	49
D*	♂	30	19	16	Afghan	♂	32	60	59
	♀	34	29	30					
	♂	34	30	27					
	♂	37	34	29					
		Mean	26·6	23·4			Mean	52·6	51·1
		SD	7·1	6·9			SD	6·6	10·9
					MUSCULUS PECTORALIS TRANSVERSUS				
D*	♀	24	42	22	Terrier X	♀	10	56	56
	♀	25	14	12	Collie	♀	11	60	78
	♂	25	16	13	Collie	♀	12	56	56
D*	♂	25	12	9	Collie	♂	14	47	38
D*	♀	29	13	9	Collie	♀	22	56	48
	♀	30	12	6	Afghan	♀	25	42	36
D*	♂	30	17	17	Afghan	♂	32	51	48
	♀	34	18	11	Great Dane	♂	47	50	44
	♂	37	25	20					
		Mean	18·8	13·2			Mean	52·3	50·5
		SD	9·6	5·4			SD	5·9	13·3

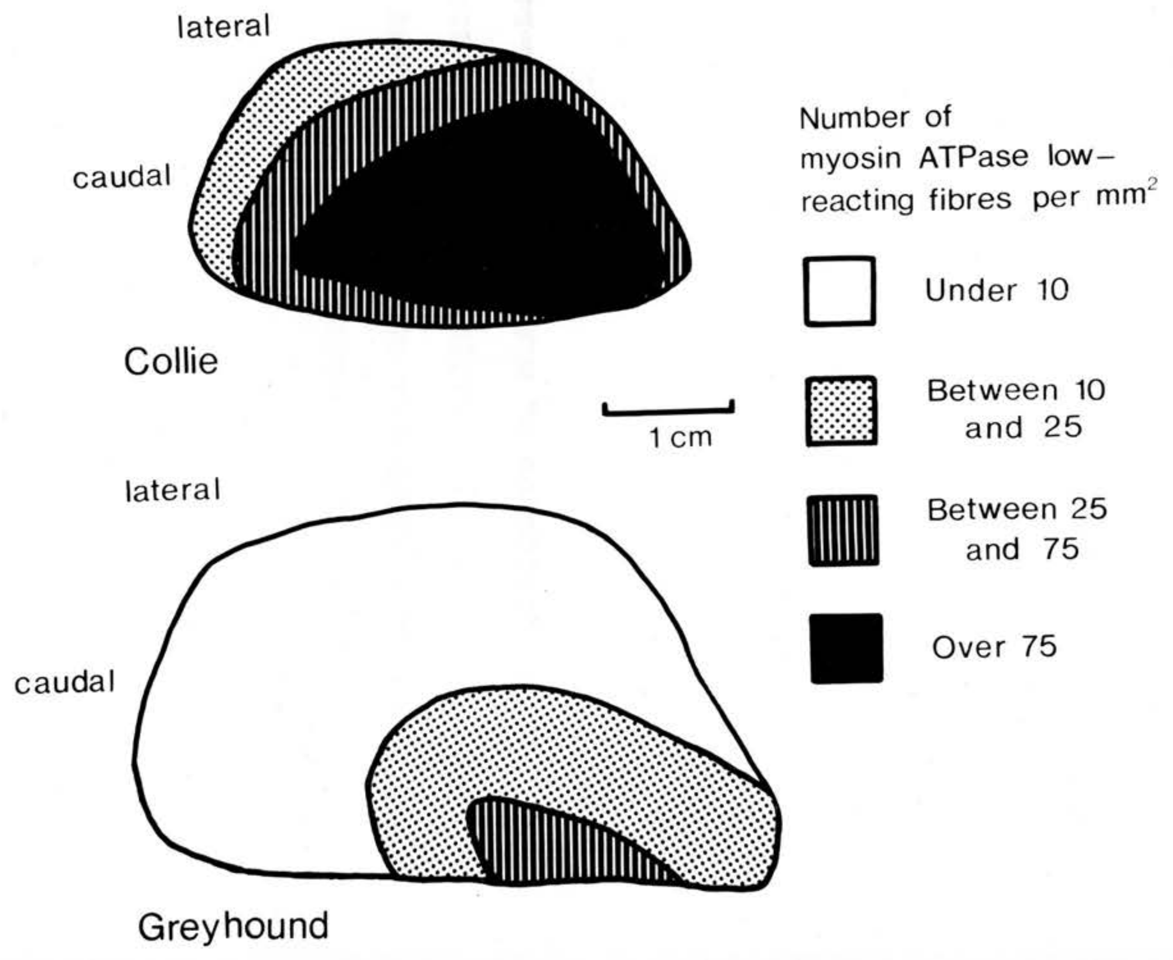
Difference between the means of % AL numbers and % AL areas for the same muscle in the two types of dog are significant at the 0·1% level.

D* Detrained Greyhounds.

Fig. 35.

The incidence of myosin ATPase low-reacting (AL) fibres in the complete transverse section of m. semitendinosus of a Greyhound and Collie both adapted for a liveweight of 30 kg.

DENSITY OF MYOSIN ATPase LOW-REACTING FIBRES IN COMPLETE TRANSVERSE SECTIONS OF M. SEMITENDINOSUS OF DOGS OF 30 KG. BODY WEIGHT



Figs. 36 and 40.

Transverse fresh frozen sections from the superficial caudal (Fig. 36) and deep medial (Fig. 40) region of m. semitendinosus of a 28 kg, 3 year old male Greyhound demonstrating ATPase activity.

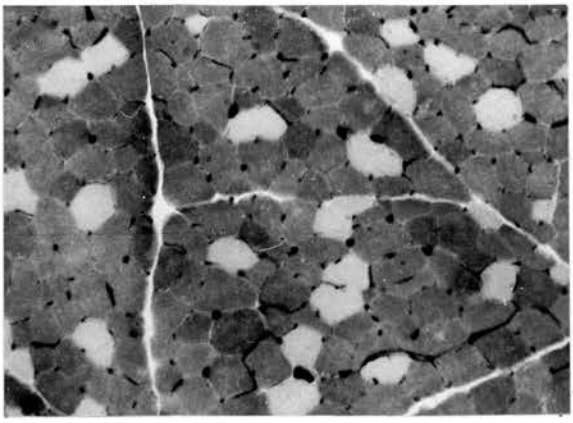
Figs. 37 - 39.

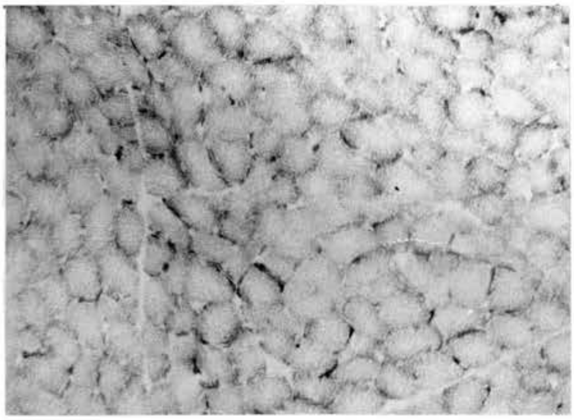
Transverse fresh frozen serial sections from the superficial caudal region of m. semitendinosus of an 8 kg, two year old Collie bitch; demonstrating myosin ATPase (Fig. 37), SDHase (Fig. 38) and GPase (Fig. 38) activity. AH.SH.PH. and AL.SH.PL. fibres are apparent.

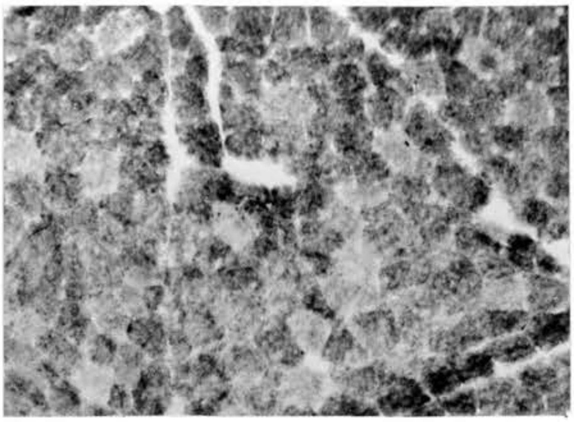
Fig. 41.

Transverse fresh frozen section from the deep medial region of m. semitendinosus from the same transverse section as Fig. 37.


36.


37


38


39


40

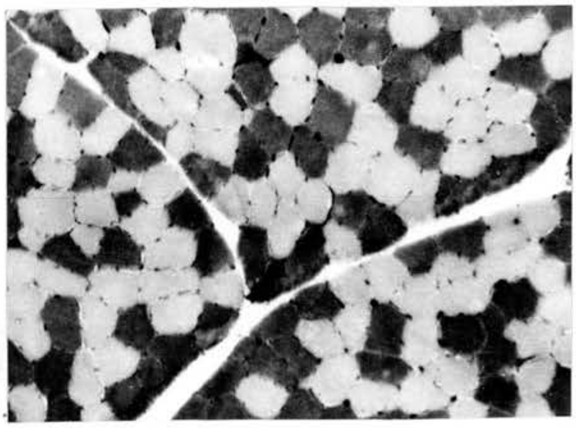

41

Fig. 42.

Transverse fresh frozen section from m. diaphragma of a 25 kg adult male Greyhound demonstrating myosin ATPase activity.

Fig. 43.

Transverse fresh frozen section from m. diaphragma of a four year old 32 kg adult male Afghan demonstrating myosin ATPase activity.

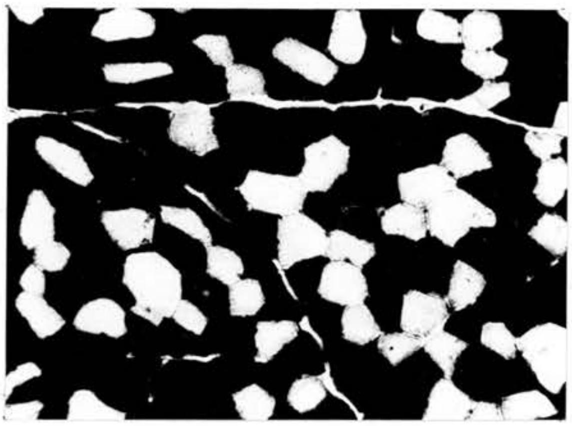
Figs. 44, 46 and 47.

Transverse serial fresh frozen sections from m. pectoralis transversus of a 25 kg adult male Greyhound demonstrating the activity of myosin ATPase (Fig. 44) SDHase (Fig. 46) and GPase (Fig. 47). Fibres are either AH.SH.PH. or AL.SH.PL.

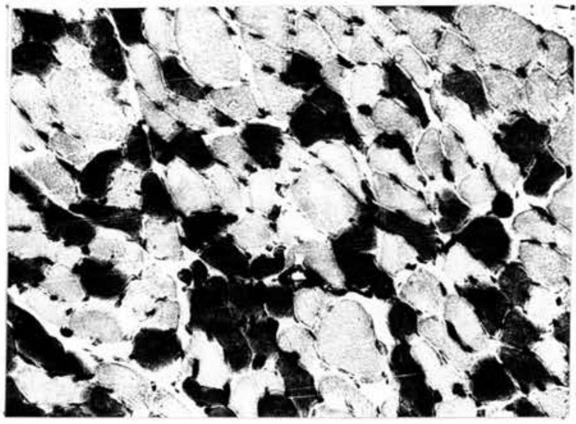
Figs. 30 - 32 and 42 are also from the same animal.

Fig. 45.

Transverse fresh frozen section from m. pectoralis transversus of a 10 year old, 22 kg female Collie demonstrating myosin ATPase activity.



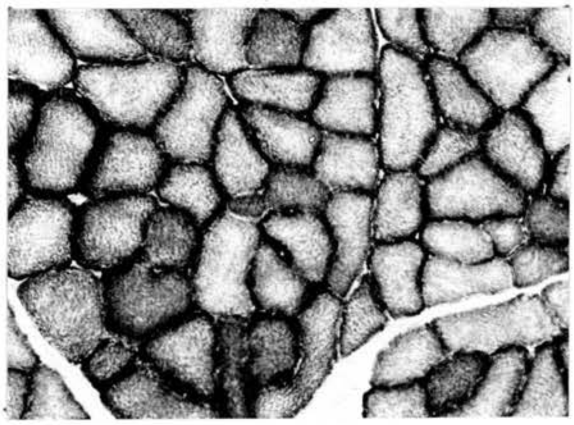
42.



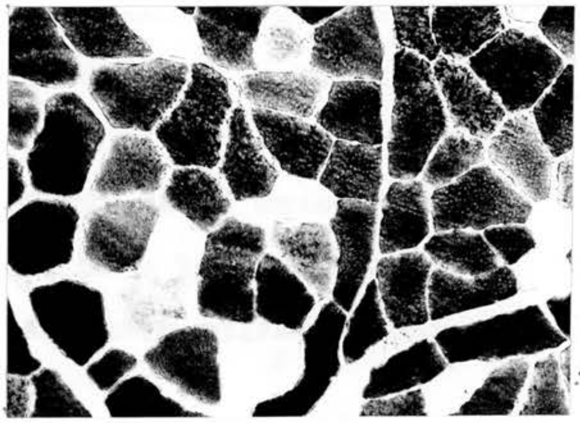
43

44.

45



46.



47

Table 45 QUANTITATIVE HISTOCHEMISTRY OF EQUINE SKELETAL MUSCLE

Proportion of transverse section and transverse sectional areas of samples of m. semitendinosus, m. diaphragma and m. pectoralis transversus occupied by myosin ATPase low-reacting (AL) fibres.

THOROUGHBREDS					OTHER HORSES				
	Sex	Body weight (kg)	% AL numbers	% AL area	Breed	Sex	Body weight (kg)	% AL numbers	% AL area
					MUSCULUS SEMITENDINOSUS				
	♀	445	4·4	2·0	Shetland	♂	154	13	5·1
	♀	458	2·8	2·7	Welsh Mountain	♂	178	19	7·7
	♀	471	5·3	1·7	Shetland	♂	204	12	7·8
D*	♀	471	6·2	2·8	Welsh Mountain	♀	229	8·4	4·4
	♂	484	10	5·5	Shetland	♂	280	20	9·6
	♀	484	7·8	3·6	Connemara X	♀	305	12	7·9
D*	♀	535	3·8	3·8	Arab	♀	305	15	7·0
D*	♀	560	0·15	0·25	Connemara X	♀	318	12	11
D*	♀	598	5·7	3·4	Piebald	♀	318	13	7·1
					Thoroughbred X	♀	356	11	6·5
					Exmoor X	♂	356	15	13·0
					Thoroughbred X	♂	369	12	5·0
					Thoroughbred X	♂	433	10	4·7
					Connemara X	♀	445	13	8·0
					Welsh Mountain	♂	458	12	9·1
					Exmoor X	♂	480	4·6	2·5
					Connemara X	♂	480	19	6·1
					Clydesdale	♀	496	14	9·3
					Thoroughbred X	♂	522	9·1	2·9
					Thoroughbred X	♀	535	6·6	3·0
		Mean	5·1	2·9			Mean	12·5	6·9
		SD	2·8	1·5			SD	3·9	2·8

Difference between means of % AL numbers and % AL areas is significant at the 0·1% level.

	Sex	Body weight (kg)	% AL numbers	% AL area	Breed	Sex	Body weight (kg)	% AL numbers	% AL area
					MUSCULUS DIAPHRAGMA				
	♀	445	73	73	Shetland	♂	154	73	83
	♀	458	58	61	Welsh Mountain	♂	178	68	73
	♀	471	61	70	Shetland	♂	204	79	82
	♂	496	67	69	Welsh Mountain	♀	229	63	75
	♂	509	74	78	Shetland	♂	280	74	84
	♀	585	68	69	Arab	♀	305	62	72
					Connemara X	♀	318	76	81
					Piebald	♀	318	69	75
					Thoroughbred X	♂	369	61	64
					Welsh Mountain	♂	458	83	84
					Connemara X	♂	480	77	78
					Clydesdale	♀	496	76	76
					Thoroughbred X	♂	522	70	73
					Thoroughbred X	♀	535	67	30
		Mean	66·8	70			Mean	71·3	73·4
		SD	6·4	5·6			SD	6·7	13·8

There is no significant difference between the means of the % AL numbers and % AL areas of the two types of horse.

	Sex	Body weight (kg)	% AL numbers	% AL area	Breed	Sex	Body weight (kg)	% AL numbers	% AL area
					MUSCULUS PECTORALIS TRANSVERSUS				
	♀	445	27	15	Shetland	♂	154	49	38
	♀	458	25	16	Welsh Mountain	♂	178	50	45
	♀	471	29	10	Shetland	♂	204	37	32
D*	♀	471	25	10	Welsh Mountain	♀	229	30	21
	♂	484	29	18	Shetland	♂	280	43	34
	♀	484	30	21	Pony	♀	305	38	28
D*	♂	496	36	21	Arab	♀	305	38	36
D*	♂	509	29	13	Connemara X	♀	318	47	37
	♀	535	37	26	Piebald	♀	318	54	35
	♀	585	36	23	Thoroughbred X	♀	356	37	29
					Pony	♂	356	46	34
					Thoroughbred X	♂	369	47	32
					Pony	♀	407	55	58
					Pony	♀	420	54	50
					Thoroughbred X	♂	433	33	21
					Connemara	♀	445	60	54
					Exmoor X	♂	480	22	14
					Clydesdale	♀	496	42	31
					Thoroughbred X	♂	521	45	38
					Thoroughbred X	♀	535	41	20
					Percheron X	♂	535	47	40
					Thoroughbred X	♂	560	44	32
		Mean	30·3	17·3			Mean	43·6	34·5
		SD	4·5	5·5			SD	8·9	10·8

Difference between means of % AL numbers and % AL areas is significant at the 0·1% level.

D* Horses out of training.

Table 46 The mean proportional numbers and areas of AL fibres in m. semitendinosus, m. diaphragma and m. pectoralis transversus of adult Thoroughbreds, adult Thoroughbred crosses and adult other horses and a comparison between corresponding values of the three types of horse using Student's 't' test.

	Number of observations		% AL numbers	% AL areas
M. Semitendinosus.				
Thoroughbreds	9	Mean SD	5·13 b 2·85	3·03 1·58
Thoroughbred crosses	5	Mean SD	9·80 b 1·92	4·60 a 1·67
Other horses	15	Mean SD	13·5 3·96	7·73 a 2·60
M. Diaphragma.				
Thoroughbreds	6	Mean SD	66·8 6·37	70·0 5·59
Thoroughbred crosses	3	Mean SD	66·0 4·58	55·7 b 22·7
Other horses	11	Mean SD	72·7 6·57	78·3 b 4·82
M. Pectoralis transversus.				
Thoroughbreds	10	Mean SD	30·3 d 4·50	17·3 c 5·46
Thoroughbred crosses	6	Mean SD	41·2 d 5·31	28·7 c 6·98
Other horses	16	Mean SD	44·5 9·87	36·7 11·3

a,b,c,d, Values followed by the same superscript within a muscle are significantly different ($P < 0{\cdot}025$; $P < 0{\cdot}01$; $P < 0{\cdot}005$ and $P < 0{\cdot}001$ respectively) from one another.

Table 47 The incidence of fibre types in musculus semitendinosus of the adult horse as differentiated by the succinate dehydrogenase reaction.

THOROUGHBREDS

	Sex	Body weight (kg)	% SH**	% AH.SH***
	♀	458	100	97
	♀	471	63	58
	♂	484	58	48
D*	♀	535	42	38
D*	♀	560	99	99
D*	♀	598	74	68
All adult Thoroughbreds				
		Mean	72·7	68·0
		SD	23·2	25·3
Detrained adult Thoroughbreds				
		Mean	71·7	68·3
		SD	28·6	30·5
Trained Thoroughbreds				
		Mean	73·7	67·7
		SD	22·9	25·9

OTHER HORSES

Breed	Sex	Body weight (kg)	% SH**	% AH.SH***
Shetland	♂	154	54	41
Welsh Mountain	♂	178	55	36
Shetland	♂	204	34	22
Welsh Mountain	♀	229	46	38
Shetland	♂	280	51	31
Connemara X	♀	305	46	34
Arab	♀	305	58	43
Piebald	♀	318	62	49
Thoroughbred X	♀	356	52	41
Exmoor X	♂	356	82	67
Thoroughbred X	♂	369	38	26
Thoroughbred X	♂	433	76	66
Connemara	♀	445	80	67
Welsh Mountain	♂	458	100	88
Exmoor X	♂	480	43	38
Connemara X	♂	480	83	64
Clydesdale	♀	496	65	51
Thoroughbred X	♂	522	79	70
Thoroughbred X	♀	535	51	44
All adult other horses				
		Mean	60·8	48·2
		SD	17·9	17·5
Thoroughbred cross adults				
		Mean	59·2	49·4
		SD	17·6	18·4
		Mean	61·4	18·6
		SD	47·8	17·9

Difference between means of the percentage of SH fibres is not significant between types.

Difference between means of the percentage of AH SH fibres is significantly different ($P < 0{\cdot}05$) between types.

D* Horses out of training.

** Fibres having a high reaction for succinate dehydrogenase.

*** Fibres having a high reaction for both myosin ATPase and succinate dehydrogenase.

Figs. 48 and 49.

Transverse fresh frozen serial sections from the superficial caudal region of m. semitendinosus of a 458 kg 3 year old Thoroughbred mare demonstrating myosin ATPase (Fig. 48) and SDHase (Fig. 49) activity.

Figs. 50 and 51.

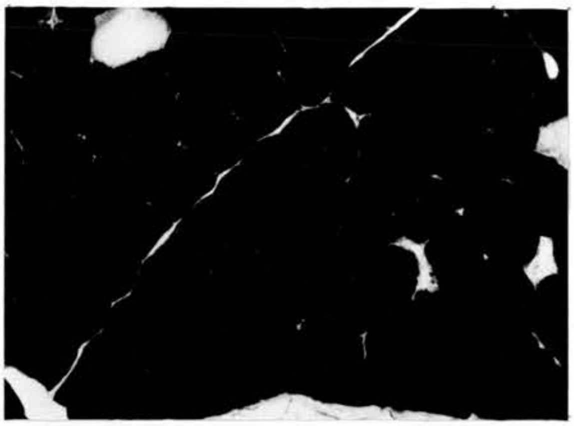
Transverse fresh frozen serial sections from the deep medial region of m. semitendinosus from the same animal as Figs. 48 and 49, demonstrating myosin ATPase (Fig. 50) and SDHase (Fig. 51) activity.

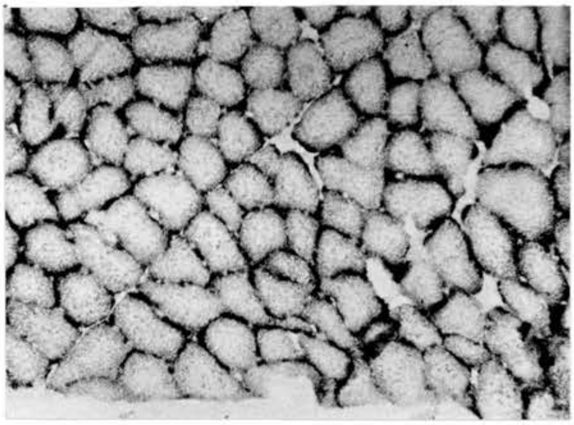
Figs. 52 and 53.

Transverse fresh frozen serial sections from the superficial caudal region of m. semitendinosus of a 318 kg six year old Piebald pony mare demonstrating myosin ATPase (Fig. 52) and SDHase (Fig. 53) activity.

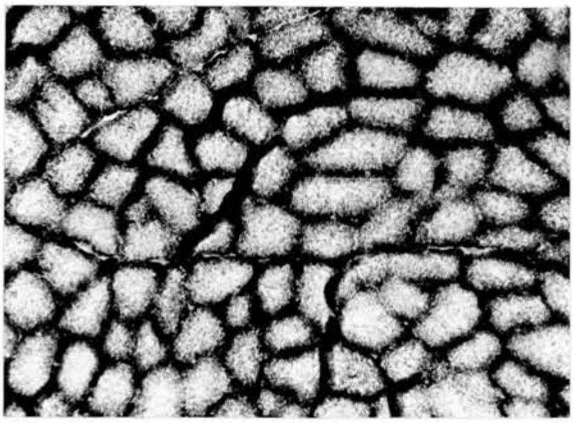
Figs. 54 and 55.

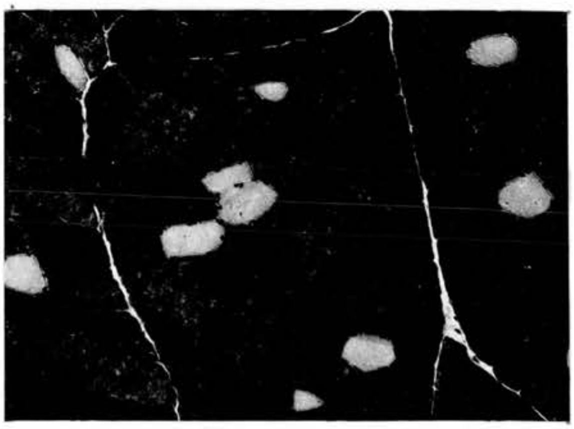
Transverse fresh frozen serial sections from the deep medial region of m. semitendinosus from the same animal as Figs. 52 and 53 and also Figs. 23 - 29, demonstrating myosin ATPase (Fig. 54) and SDHase (Fig. 55) activity.

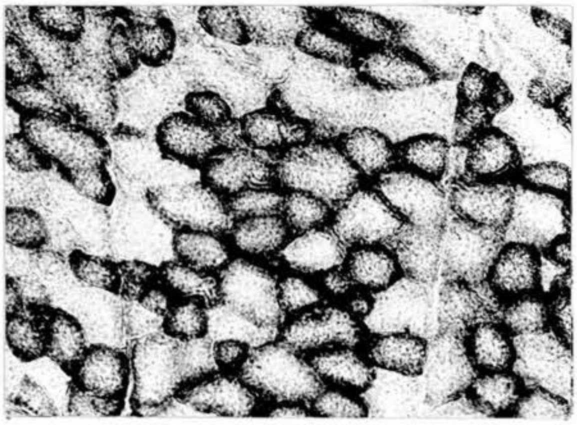

48.

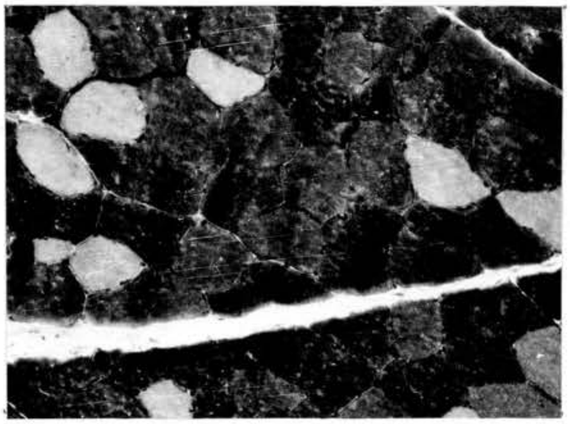

49

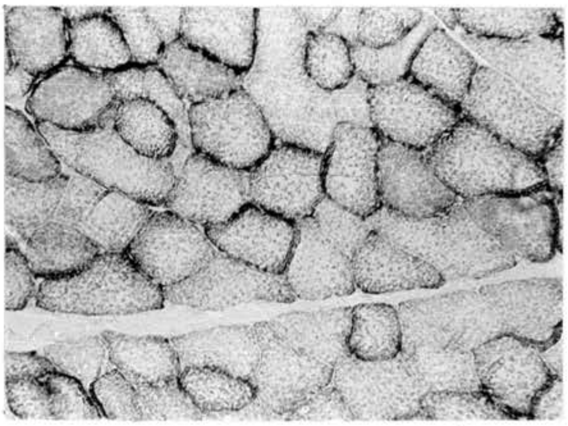

50


51


52.


53


54


55

100 µm

Fig. 56.

Transverse fresh frozen section from m. diaphragma of a 458 kg, three year old Thoroughbred mare demonstrating myosin ATPase activity.

Figs. 57 - 59.

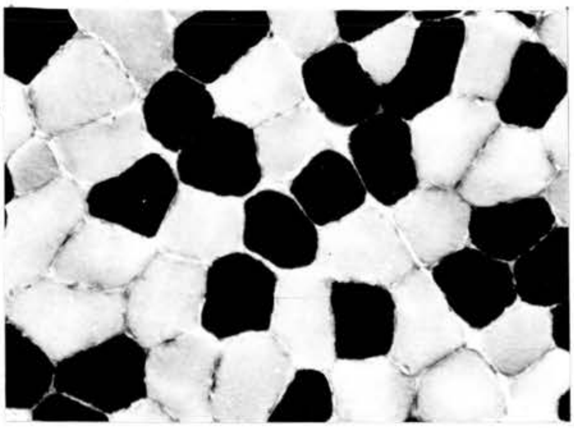
Transverse fresh frozen serial sections from m. diaphragma of a 318 kg six year old Piebald pony mare demonstrating myosin ATPase (Fig. 56), SDHase (Fig. 57) and GPase (Fig. 58) activity. Some AL fibres have a lower GPase activity than AH fibres.

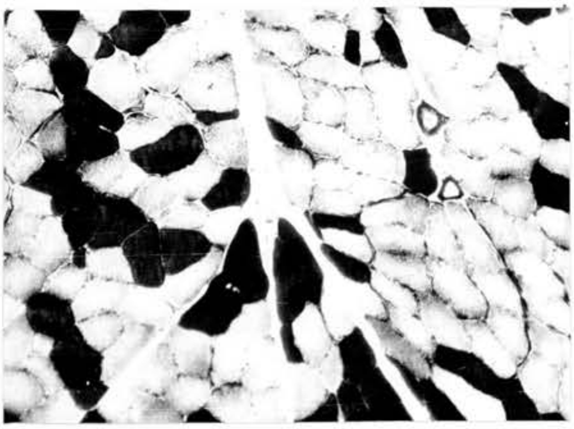
Figs. 60, 62 and 63.

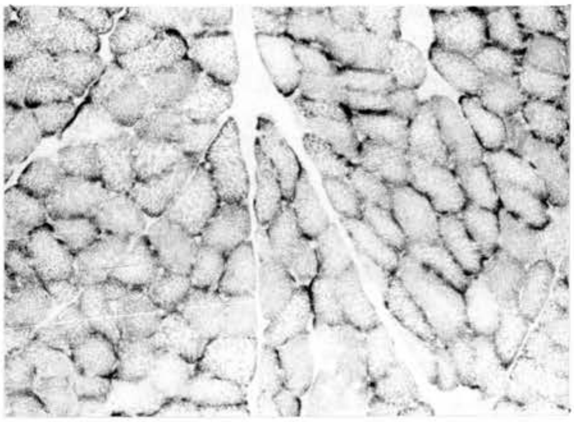
Transverse fresh frozen serial sections from m. pectoralis transversus of a 458 kg, three year old Thoroughbred mare demonstrating myosin ATPase (Fig. 60) SDHase (Fig. 62) and GPase (Fig. 63) activity. These sections are taken from the same animal as Figs. 48 - 51 and 56.

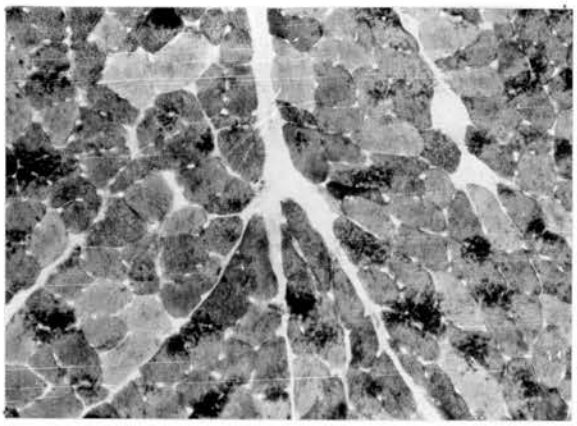
Fig. 61

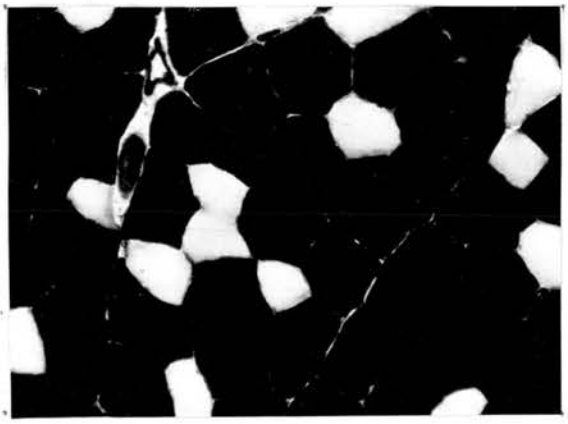
Fresh frozen transverse section from m. pectoralis transversus of a 318 kg, siz year old Piebald mare demonstrating myosin ATPase activity. This section is taken from the same animal as those for Figs. 23 - 29, 52 - 55 and 57 - 59.

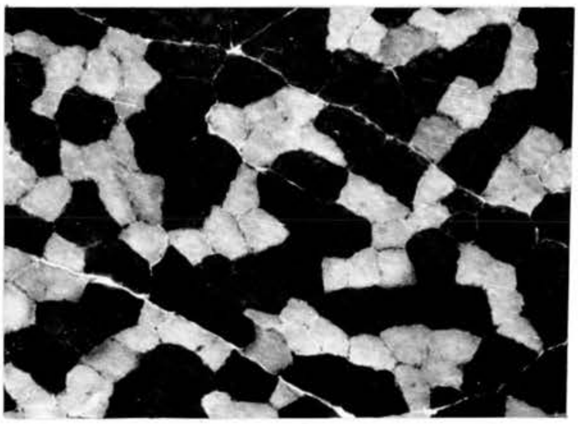

56

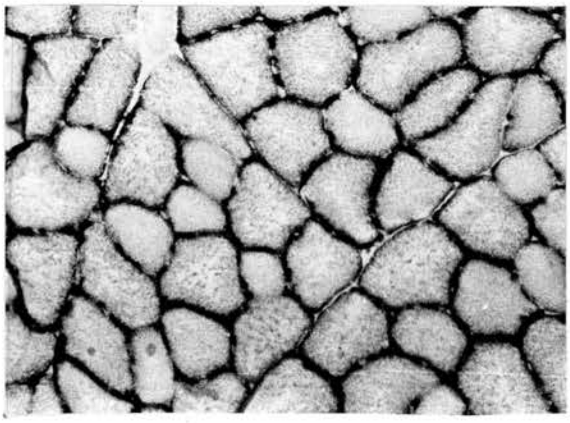

57

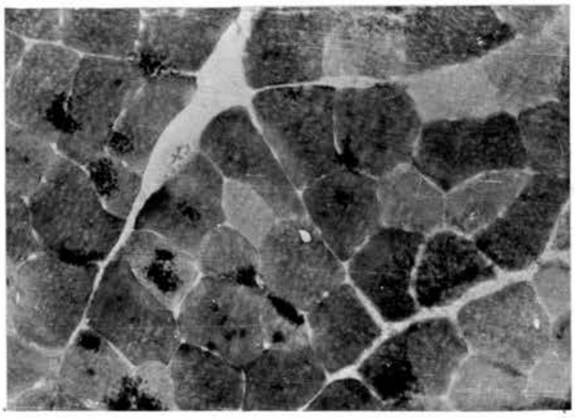

58


59


60


61


62


63

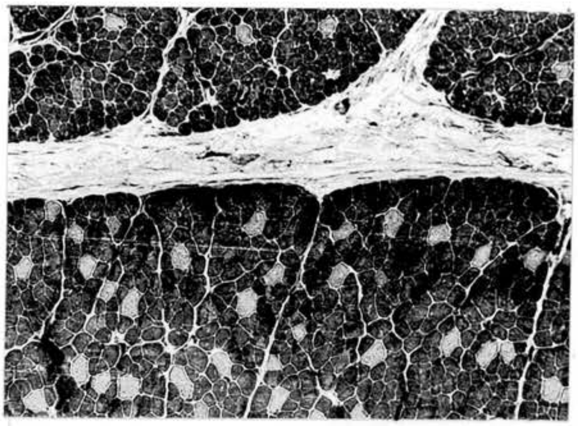
100μm

Figs. 64 - 66.

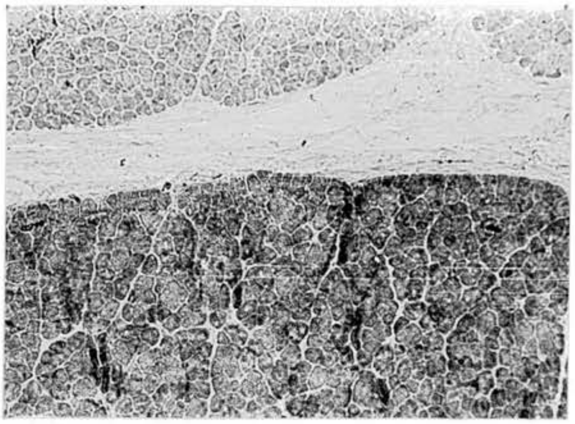
Transverse fresh frozen serial sections from the superficial caudal region of m. semitendinosus and m. diaphragma of a 0·46 kg, two day old male Labrador demonstrating myosin ATPase (Fig. 64), SDHase (Fig. 65) and GPase (Fig. 66) activity.

Figs. 67 - 69.

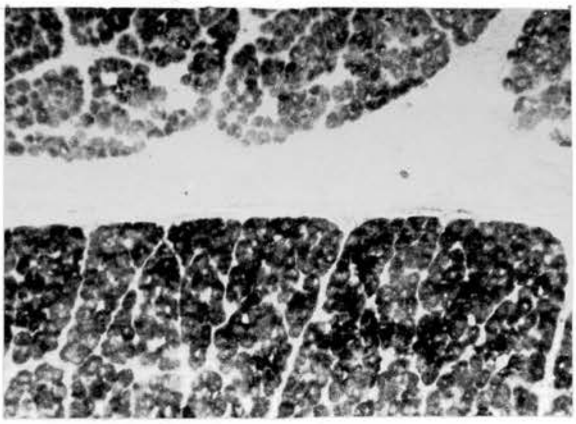
Transverse fresh frozen serial sections from the superficial region of m. pectoralis transversus of a 0·26 kg neonatal male Greyhound demonstrating myosin ATPase (Fig. 67), SDHase (Fig. 68) and GPase (Fig. 69) activity.



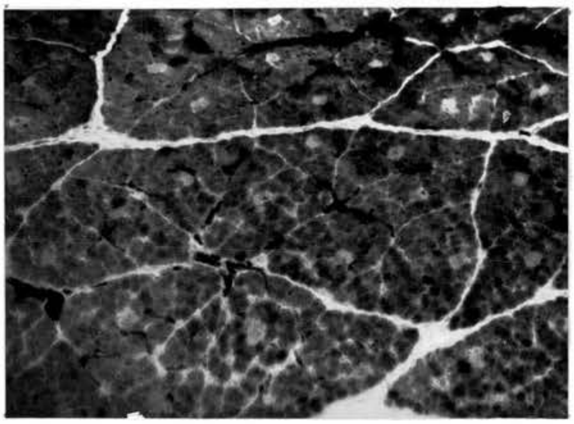
64



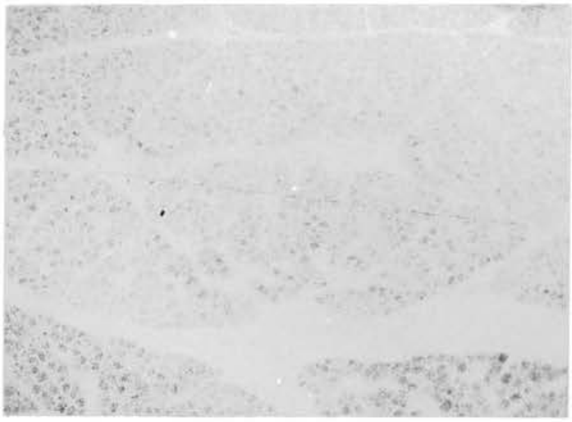
65



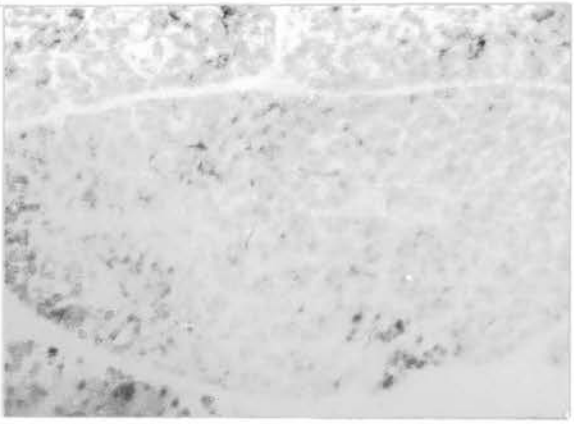
66



67



68



69

100µm

Table 48 Percentage number of, and area of, myosin ATPase low-reacting fibres in m. semitendinosus, m. diaphragma and m. pectoralis transversus of young dogs.

Type of dog	Live-weight (kg)	Age (days)	Myosin ATPase low-reacting (AL) fibres					
			m. semitendinosus		m. diaphragma		m. pectoralis transversus	
			% Numbers	% Area	% Numbers	% Area	% Numbers	% Area
Greyhound	0·222	1	3·0	4·2	7·5	9·8	6.1	4.3
Greyhound	0·260	1	1·8	3·50	4·4	8.10	2.02	2.9
Greyhound	0·377	7	1·9	4·4	3·4	7·6	2.3	5.6
Greyhound	0·927	1	2·0	2·3	8·2	6·2	4.2	2.6
Greyhound	1·06	14	1·6	2·8	8·1	8·9	2.4	3.2
Greyhound	1·17	21	1·5	4·3	16·0	34·0	2.4	4.5
Greyhound	2·28	42	22·02	22·0	36·0	40·0	23·0	28·0
Greyhound	5·71	77	20·02	14·0	27·0	24·0	28·0	23·0
Greyhound	11·0	119	16·01	11·0	32·0	16·0	29·0	17·0
Greyhound	15·3	168	8·7	8·2	33·0	23·0	23·0	22·0
Greyhound	19·8	175	8·1	6·7	35·0	31·0	30·0	27·0
Greyhound	23·5	365	7·9	5·7	39·0	24·0	23·0	13·0
Labrador	0.464	2	4·0	4·4	8·7	11·0	*	*
Collie X	0·527	14	4·0	4·7	9·3	9·5	5·7	6·1
Labrador	0·573	2	3·6	3·8	6·2	6·7	*	*
Collie X	0·785	23	6·2	7·4	38·0	40·0	24·0	21·0
Collie X	0·931	21	7·0	7·9	36·0	38·0	22·0	33·0
Collie	0·976	42	29·2	21·0	45·0	39·0	41·0	44·0
Labrador	1·01	14	3·04	4·0	16·0	14·0	13·0	14·0
Collie X	1·24	35	16·2	17·0	39·0	33·0	40·0	30·0
Collie X	3·18	106	43·9	30·0	*	*	*	*
Collie X	3·84	106	26·2	24·0	49·0	48·0	32·0	37·0
Collie X	6.00	183	36·5	31·0	43·0	52·0	58·0	32·0
Boxer X	6·59	91	18·6	12·0	54·0	41·0	52·0	35·0
Terrier X	7·96	152	27·2	21·0	*	*	*	*
Boxer X	8·50	133	26·5	17·0	53·0	49·0	46·0	43·0
Collie	9·02	183	34·5	31·0	49·0	50·0	52·0	44·0
Boxer X	9·90	161	16·8	15·0	51·0	51·0	53·0	42·0

* No data.

Table 49 Logarithmic regression equations comparing the rate of increase in total sectional area and total area occupied by myosin ATPase low reacting (AL) fibres in m. semitendinosus of 9 Greyhound and 16 other pups less than 12 kg liveweight.

Type of dog	Dependent variable	Growth ratio b*	Se b	log a	r **
Greyhounds	Total sectional area	0·676	0·075	-0·251	0.9595
	Total AL area	1·062	0·185	-2·683	0·9083
Other dogs	Total sectional area	0·821 ^{ac}	0·056	-0·774	0·9694
	Total AL area	1·321 ^{bc}	0·111	-3·356	0·9537

* Regression coefficient b, standard error Se b.

a Value of b significantly greater ($P < 0·02$) than 0·666

b Value of b significantly greater ($P < 0·02$) than 1.

c Values of b bearing this superscript are significantly different ($P < 0·002$) from one another.

Table 50 Logarithmic regression equations comparing the areas of samples of m. semitendinosus, m. diaphragma and m. pectoralis transversus occupied by myosin ATPase low-reacting (AL) fibres with liveweight in dogs and horses (non-significant regressions are excluded).

Dependent variable	Type of animal	Number of observ-ations	Regression coefficient	Se b*	log a	r **
% AL area in m. semi-tendinosus	Other horses	32	0·186	0·089	-0·267	0·356
% AL area in m. diaphragma	Greyhounds	22	0·189	0·055	0·539	0·614
	Other dogs	21	0·344	0·071	0·292	0·746
	Thoroughbreds	23	0·180 c	0·030	0·832	0·790
	Other horses	23	0·343 c	0·044	-0·020	0·862
% AL area in m. pectoralis transversus	Greyhounds	21	0·279	0·072	-0·060	0·665
	Other dogs	20	0·272	0·070	0·527	0·677
	Other horses	34	0·250	0·046	0·142	0·696

* Regression coefficient b, standard error Se b.
(all values of b are significantly greater($P < 0·05$ than 0)

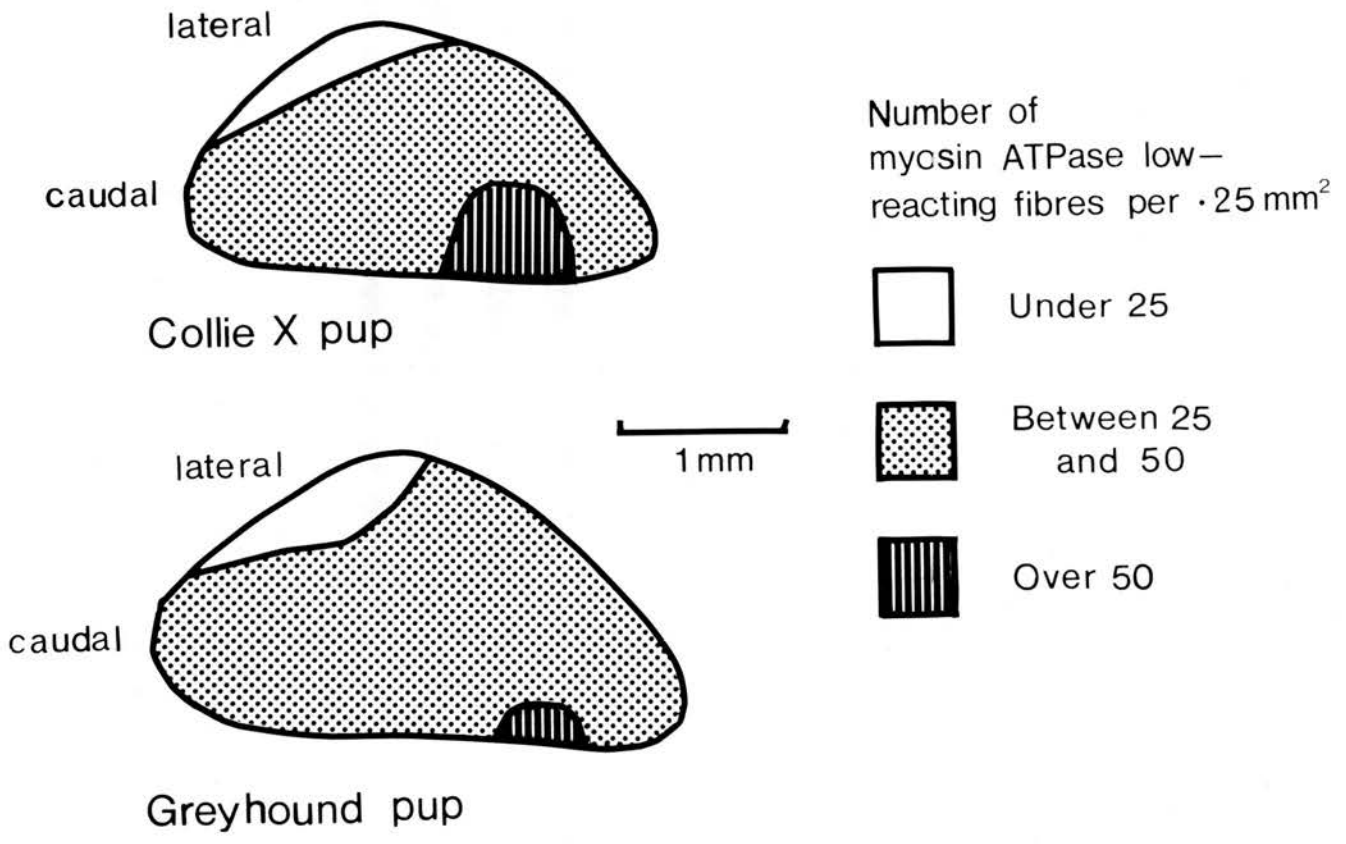
c Values of b bearing this superscript are significantly different ($P < 0·01$) from one another.

** Correlation coefficient r.

Fig. 70.

The incidence of myosin ATPase low-reacting (AL) fibres in the complete cross section of m. semitendinosus of a neonatal Greyhound and Collie adjusted to a liveweight of 0·5 kg.

DENSITY OF MYOSIN ATPase LOW-REACTING FIBRES IN COMPLETE TRANSVERSE SECTIONS OF M. SEMITENDINOSUS OF DOGS OF 0·5 KG. BODY WEIGHT



Collie X pup

Greyhound pup

Figs. 71 and 73.

Transverse fresh frozen sections from the superficial lateral (Fig. 71) and deep medial (Fig. 73) regions of m. semitendinosus of a 0·26 kg neonatal male Greyhound demonstrating myosin ATPase activity.

Figs. 72 and 74.

Transverse fresh frozen sections from the superficial lateral (Fig. 72) and deep medial (Fig. 74) regions of m. semitendinosus of a 0·46 kg, two day old male Labrador demonstrating myosin ATPase activity.

Figs. 75 and 77.

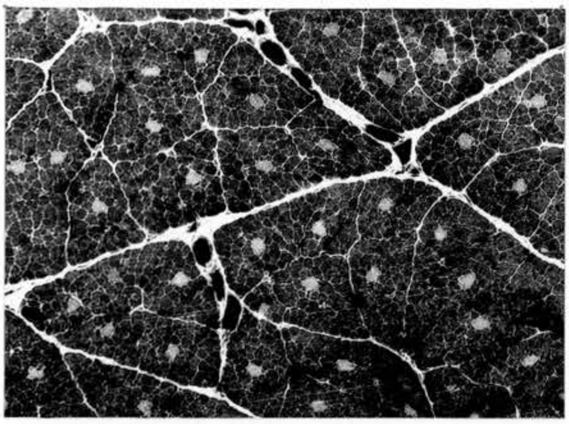
Transverse fresh frozen sections of m. diaphragma (Fig. 75) and m.pectoralis transversus (Fig. 77) from the same animal as Figs. 71 and 73, demonstrating myosin ATPase activity.

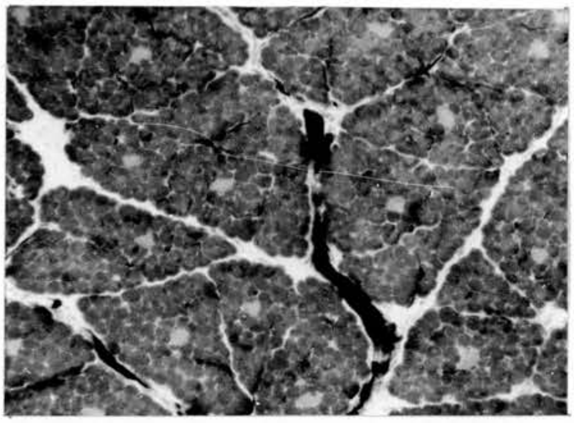
Fig. 76.

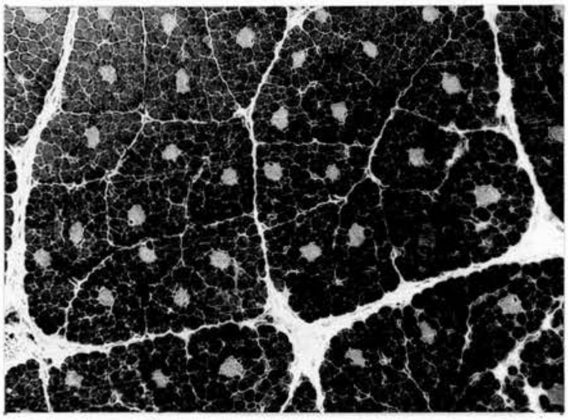
Transverse fresh frozen section of m. diaphragma from a 0·46 kg, two day old male Labrador demonstrating myosin ATPase activity.

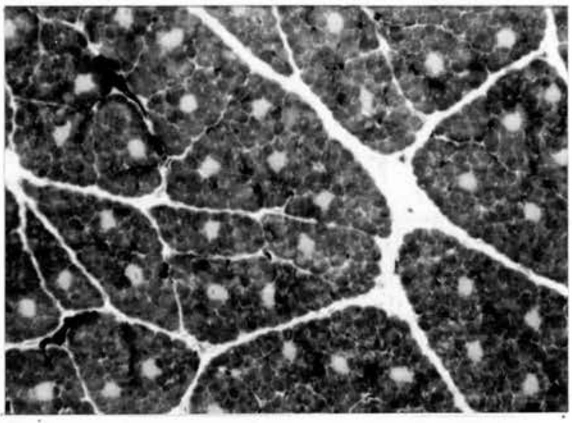
Fig. 78.

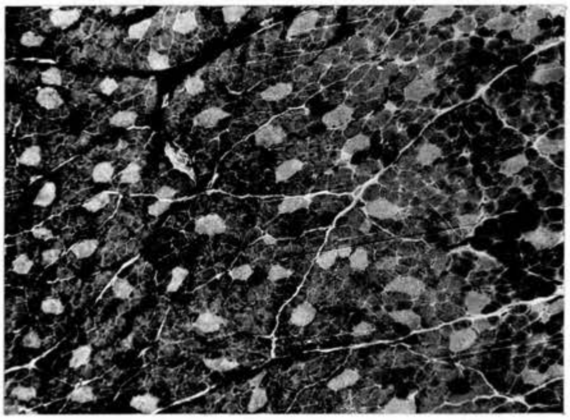
Transverse fresh frozen section of m. pectoralis transversus from a 0·53 kg, two week old female Collie cross pup, demonstrating myosin ATPase activity.

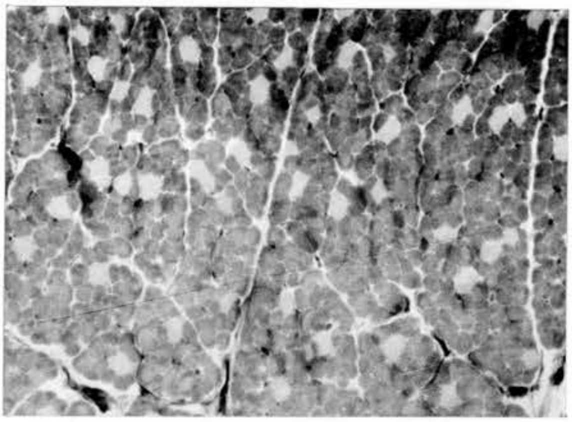

71

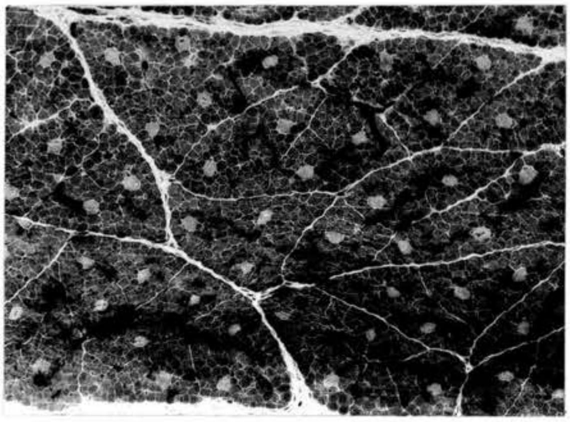

72

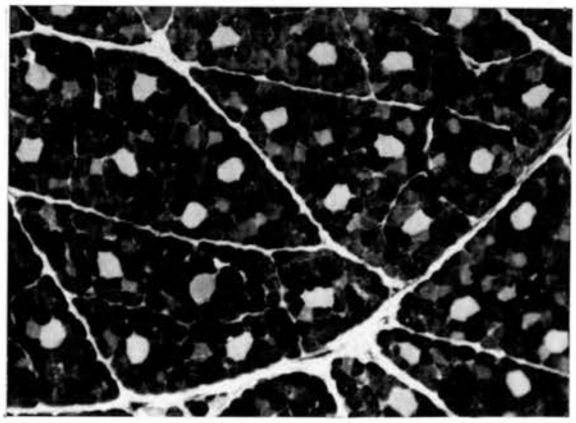

73


74


75


76


77


78

100µm

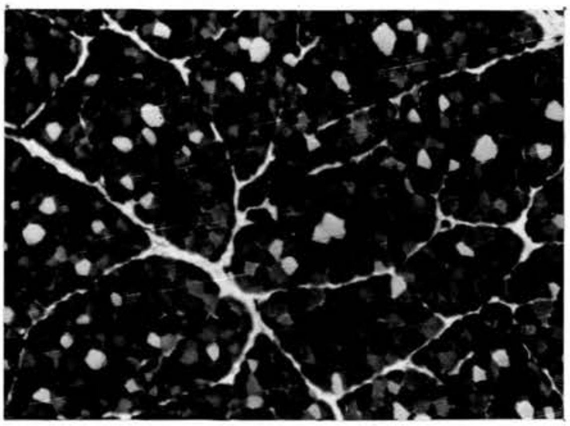
Figs. 79, 81 and 83.

Fresh frozen transverse section from the superficial caudal region of m. semitendinosus (Fig. 79), m. diaphragma (Fig. 81) and m. pectoralis transversus of a 2·3 kg, six week old male Greyhound demonstrating myosin ATPase activity. Fibres with an "intermediate" reaction for myosin ATPase are apparent.

Figs. 80, 82 and 84.

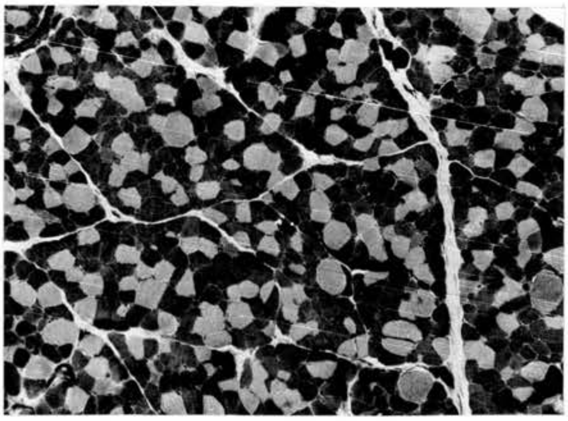
Fresh frozen transverse sections of the superficial caudal region of m. semitendinosus (Fig. 80) m. diaphragma (Fig. 82) and m. pectoralis transversus (Fig. 84) of a 0·79 kg, four week old female Collie demonstrating myosin ATPase activity. Fibres with an intermediate reaction for myosin ATPase may be seen.

79

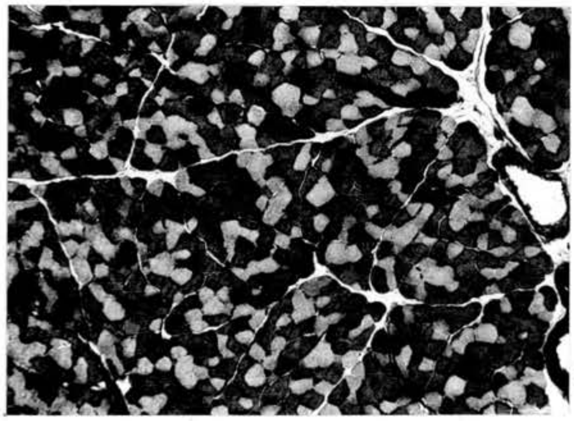


80

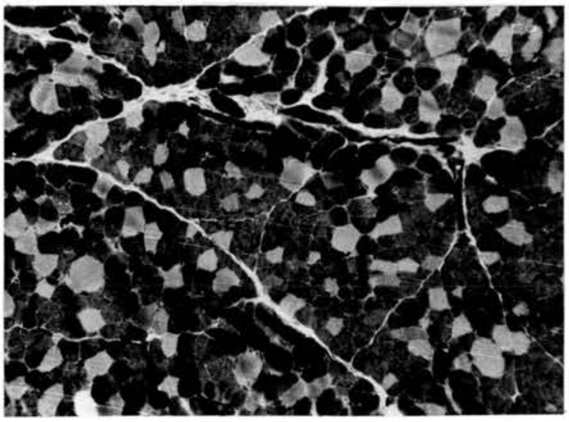
81



82



83



84

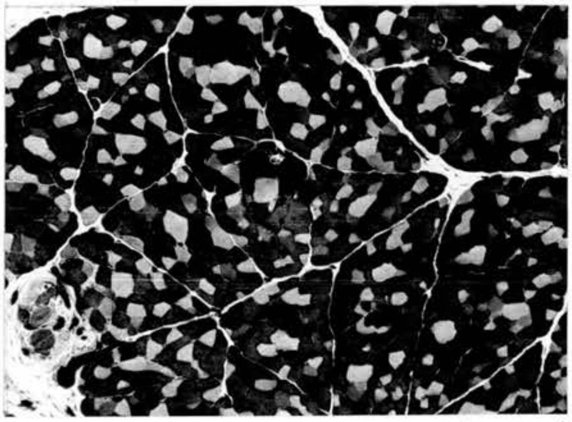


Fig. 85.

Changes in the numbers of myosin ATPase low-reacting fibres with increasing liveweight in m. semitendinosus of Greyhounds and other dogs.

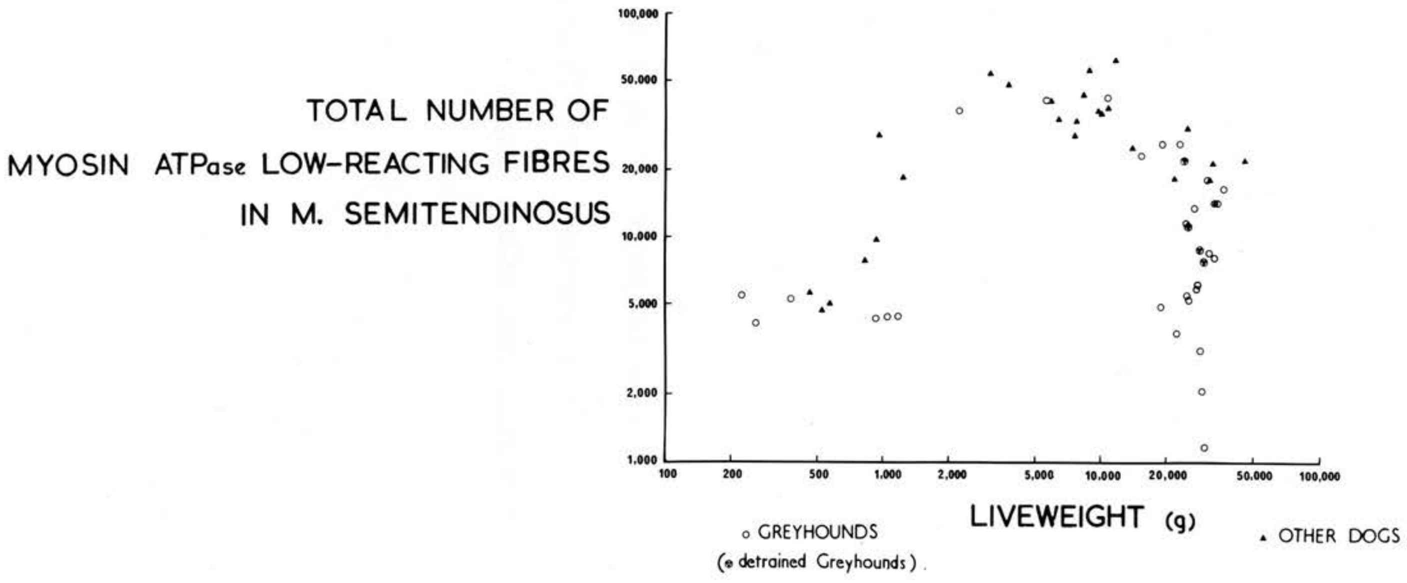

TOTAL NUMBER OF
MYOSIN ATPase LOW-REACTING FIBRES
IN M. SEMITENDINOSUS
100,000
50,000
20,000
10,000
5,000
2,000
1,000
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
100,000
LIVEWEIGHT (g)
○ GREYHOUNDS
(⊕ detrained Greyhounds)
▲ OTHER DOGS

Fig. 86.

Changes in the numbers of myosin ATPase low-reacting fibres in m. semitendinosus of Greyhounds and other dogs with increasing age.

TOTAL NUMBER OF
MYOSIN ATPase LOW-REACTING FIBRES
IN M. SEMITENDINOSUS

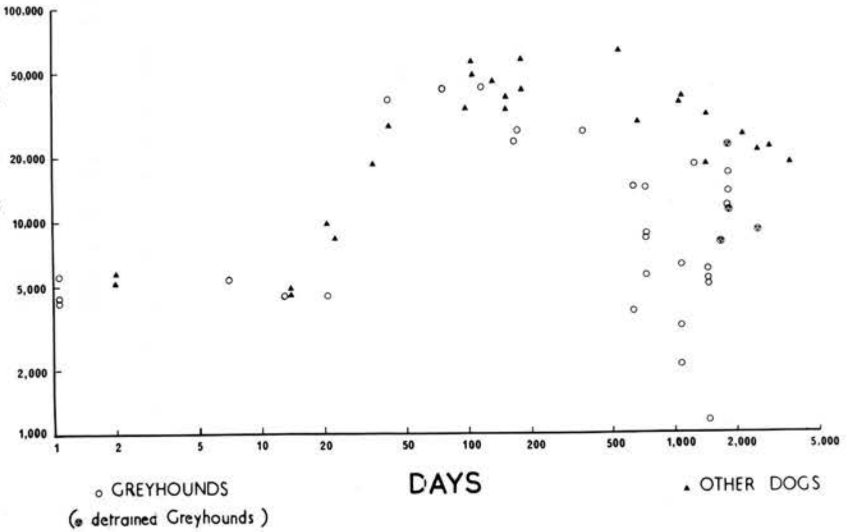


Fig. 87.

Growth changes in the proportion of myosin ATPase low-reacting fibres in m. semitendinosus of Greyhounds and other dogs.

PERCENTAGE NUMBERS OF
MYOSIN ATPase LOW-REACTING FIBRES
IN M. SEMITENDINOSUS

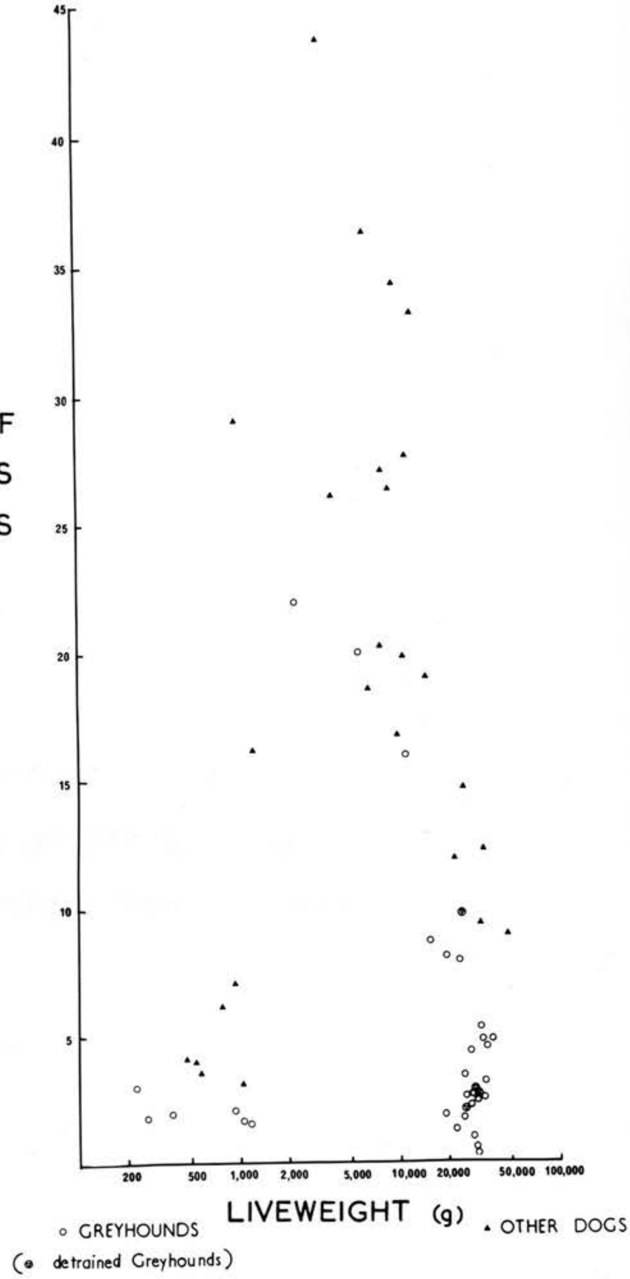


Fig. 88.

The incidence of myosin ATPase low-reacting (AL) fibres in the complete transverse section of m. semitendinosus of a Collie and Greyhound adjusted to a liveweight of 0·6 kg.

DENSITY OF MYOSIN ATPase LOW-REACTING FIBRES IN COMPLETE TRANSVERSE SECTIONS OF M. SEMITENDINOSUS OF DOGS OF 6·0 KG. BODY WEIGHT

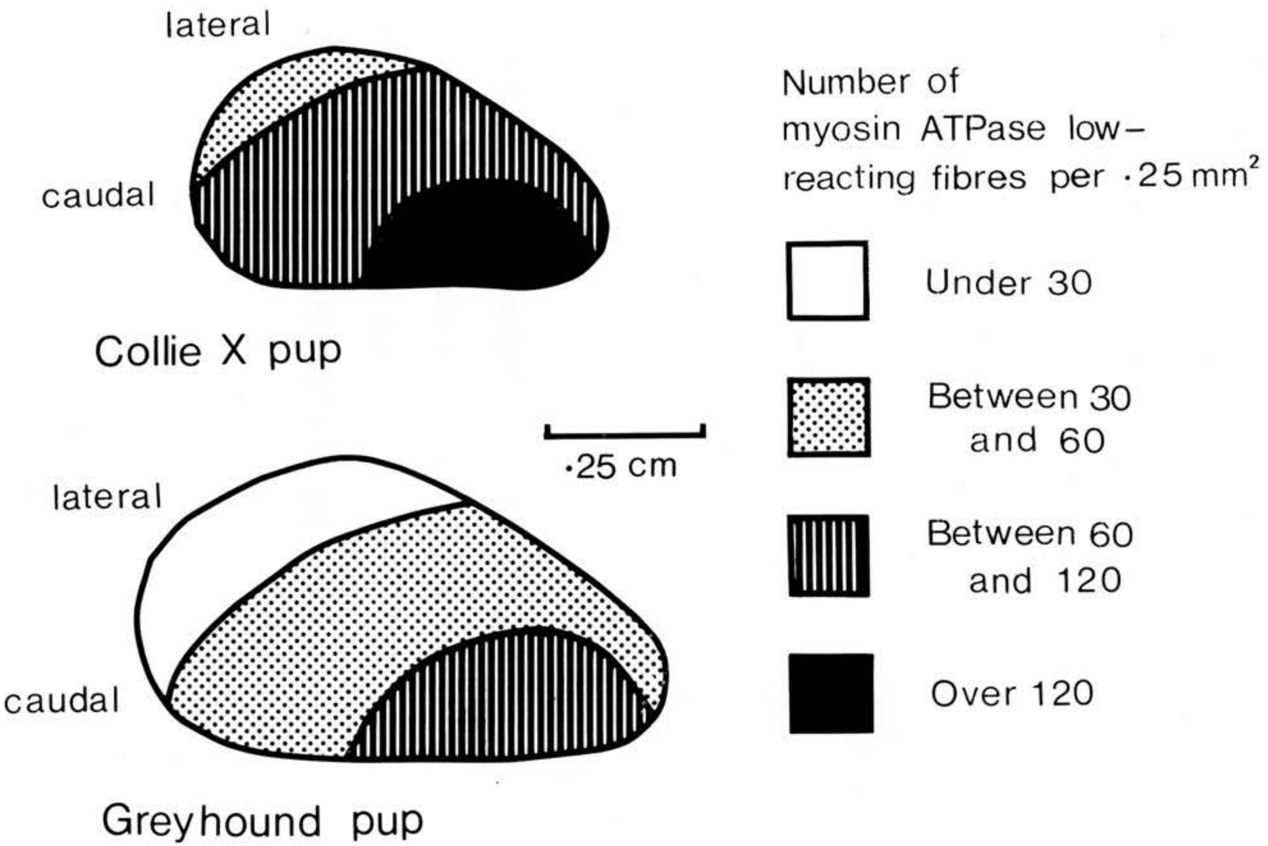
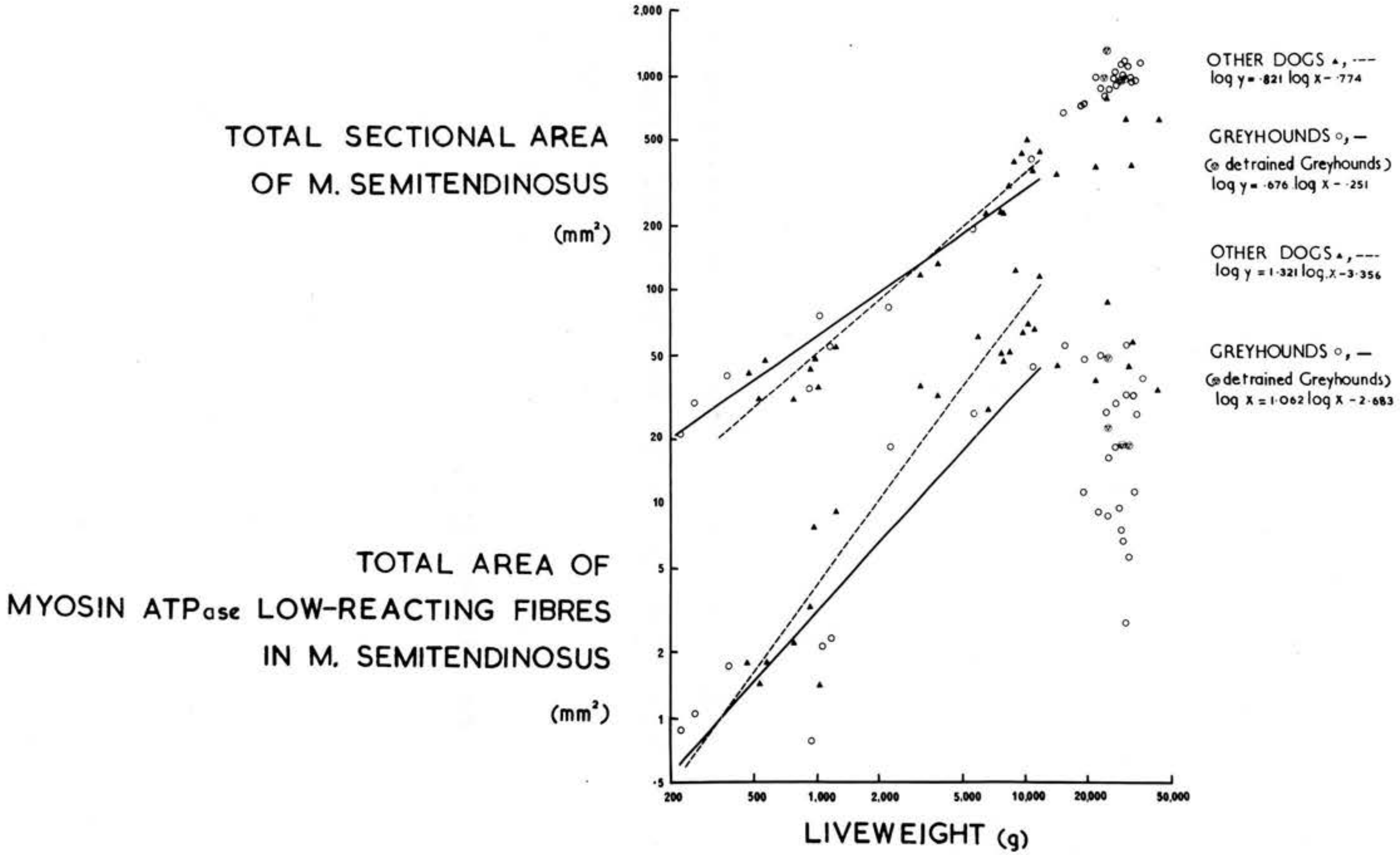


Fig. 89.

Growth changes in the TSA and total area of myosin ATPase low-reacting fibres in m. semitendinosus of Greyhounds and other dogs with regression equations and regression lines for young dogs less than 12 kg liveweight.



REGRESSION EQUATIONS AND LINES REFER TO YOUNG DOGS LESS THAN 12 KG LIVEWEIGHT

Fig. 90.

Growth changes in the proportion of myosin ATPase low-reacting fibres in m. semitendinosus, m. diaphragma and m.pectoralis transversus of Greyhounds and other dogs.

PERCENTAGE AREA OCCUPIED BY
MYOSIN ATPase LOW-REACTING FIBRES
IN SAMPLES OF:-

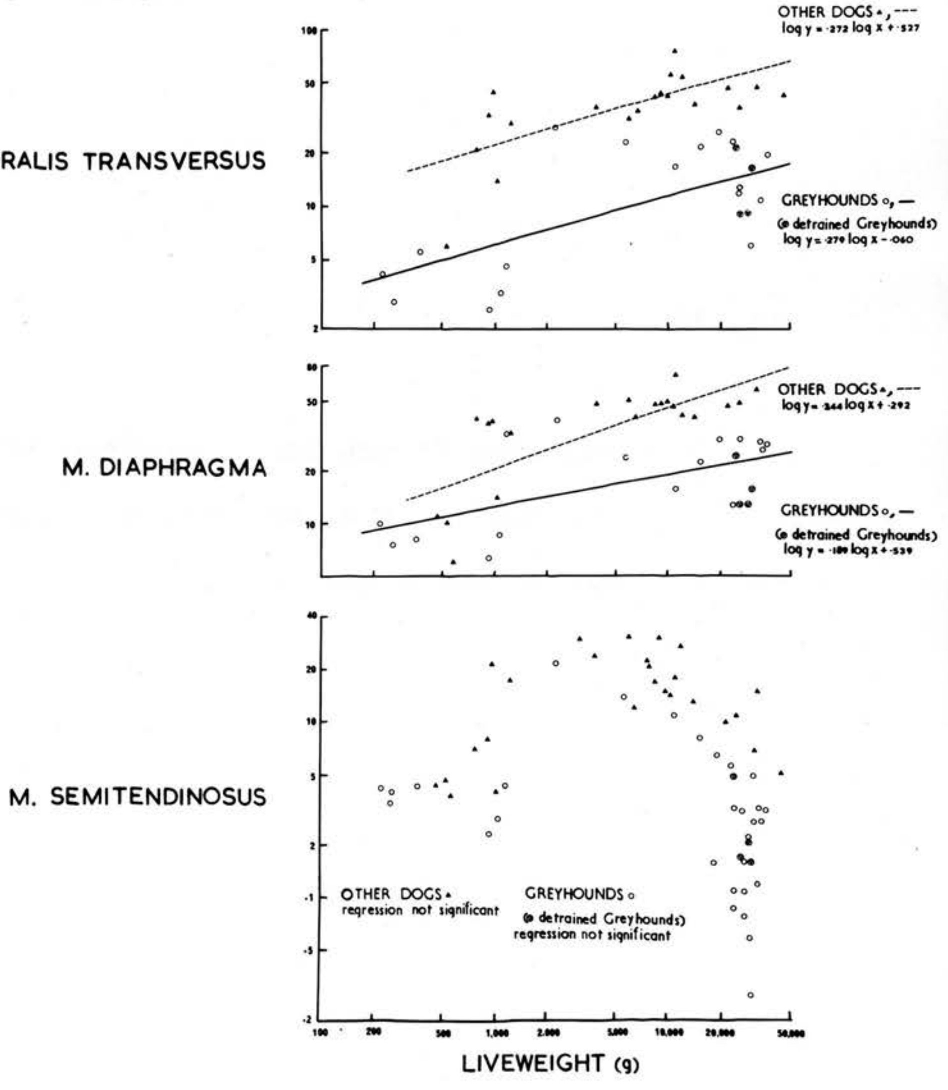


Table 51 Percentage of fibres sampled low in succinate dehydrogenase activity (SL), glycogen phosphorylase activity (PL), and myosin ATPase activity (AL), and percentage of area of samples occupied by AL fibres; in m. semitendinosus, m. diaphragma and m. pectoralis transversus of young horses.

Type of horse	Live-weight (kg)	Sex	Age*	M. semitendinosus				M. diaphragma				M. pectoralis transversus			
				SL	PL	AL	AL Area	SL	PL	AL	AL Area	SL	PL	AL	AL Area
Thoroughbred	11	♀	338	0	0	2·2	2·4	0	1	41	41	0	0	7·5	8·7
Thoroughbred	13	♀	274	89	0	1·7	1·6	**	**	**	**	**	**	**	**
Thoroughbred	16	♂	337	54	0	0·60	0·70	0	0	23	24	0	0	19	22
Thoroughbred	19	♀	326	47	0	0·81	0·71	0	2	35	43	0	0	21	25
Thoroughbred	24	♂	314	83	0	3·9	2·5	0	0	32	51	47	0	8·9	8·6
Thoroughbred	24	♀	318	33	0	1·9	1·2	0	0	26	33	0	0	13	12
Thoroughbred	28	♂	285	72	0	2·3	3·2	**	**	**	**	0	0	7·5	7·1
Thoroughbred	29	♂	326	46	0	1·7	2·2	0	2	36	64	0	0	18	22
Thoroughbred	31	♀	311	66	0	0·87	0·71	0	0	36	45	17	0	10	8·5
Thoroughbred	32	♂	321	62	0	1·4	1·0	**	**	**	**	0	0	22	18
Thoroughbred	32	♀	317	65	0	2·0	1·4	0	0	41	57	0	0	24	19
Thoroughbred	34	♂	330	53	0	4·2	2·6	0	0	41	49	0	0	22	18
Thoroughbred	35	♀	274	50	0	3·7	2·2	**	**	**	**	**	**	**	**
Thoroughbred	35	♀	341	62	0	2·4	6·8	**	**	**	**	**	**	**	**
Thoroughbred	39	♂	339	46	0	6·1	2·4	0	0	49	33	0	0	14	11
Thoroughbred	39	♂	338	35	0	1·9	1·4	**	**	**	**	0	0	15	16
Thoroughbred	41	♀	340	61	0	6·6	3·6	0	0	43	56	0	0	24	18
Thoroughbred	42	♂	338	**	**	1·7	1·5	**	**	40	41	**	**	21	19
Thoroughbred	43	♀	338	64	0	7·4	8·0	0	0	45	41	0	0	42	41
Thoroughbred	50	♀	338	52	0	1·3	0·7	0	0	41	42	0	0	34	28
Thoroughbred	59	♀	346	**	**	3·6	3·4	**	**	**	**	**	**	31	21
Thoroughbred	337	♀	703	46	4	3·7	1·9	0	0	69	76	0	0	24	9·1
Thoroughbred	420	♂	896	51	0	7·2	3·7	0	1	79	84	**	**	**	**
Thoroughbred	433	♂	886	49	0	2·3	1·2	0	1	67	63	0	0	43	29
Connemara X	2	♂	160	0	0	5·7	5·8	0	0	10	10	0	0	10	10
Welsh Mountain	3	♂	158	0	0	3·7	3·4	0	0	8·8	13	0	0	8·4	6·4
Dartmoor	22	♀	339	**	**	3·5	2·5	**	**	**	**	**	**	22	18
Thoroughbred X	39	♂	326	62	0	0·78	0·4	0	42	42	33	0	0	24	16
Thoroughbred X	62	♂	348	67	0	1·8	1·1	**	**	**	**	0	0	37	32
Welsh Mountain	109	♂	855	63	0	15	5·2	0	4	56	61	17	46	46	39
Welsh Mountain	115	♀	703	50	0	8·7	4·2	0	6	60	65	0	0	41	35
Welsh Mountain	118	♂	703	50	0	25	8·8	0	70	70	72	0	0	51	23
Welsh Mountain	154	♂	703	51	0	7·2	3·7	0	0	66	70	0	0	29	19
Welsh Mountain	178	♀	703	**	**	10	4·3	**	**	**	**	**	**	52	42
Thoroughbred X	203	♂	460	64	0	13	8·5	0	0	62	64	0	44	44	33
Fell X	207	♂	703	46	0	11	4·8	0	3	65	68	0	0	37	27

* Age is calculated in days from conception, (338 days is added to postnatal ages).

** No data.

Figs. 91 - 93.

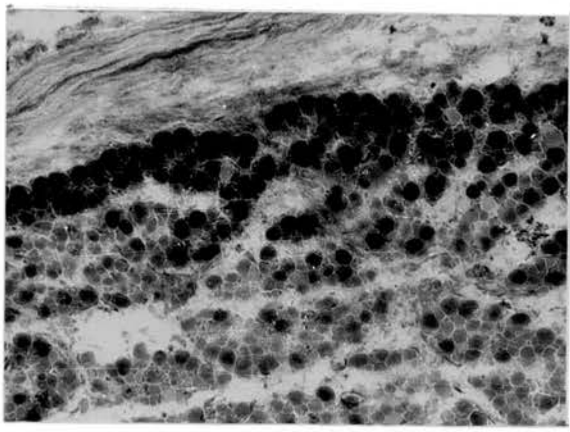
Fresh frozen transverse serial sections from the superficial caudal region of m. semitendinosus of a 2·2 kg, 160 day "in utero" male Connemara cross pony demonstrating myosin ATPase (Fig. 91), SDHase (Fig. 92) and GPase (Fig. 93) activity.

Figs. 94 and 95.

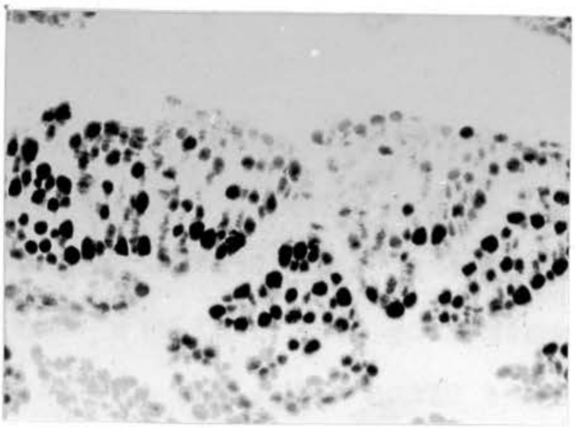
Fresh frozen transverse serial sections from m. diaphragma of the same animal as Figs. 91 - 93, demonstrating myosin ATPase (Fig. 94) and GPase (Fig. 95) activity.

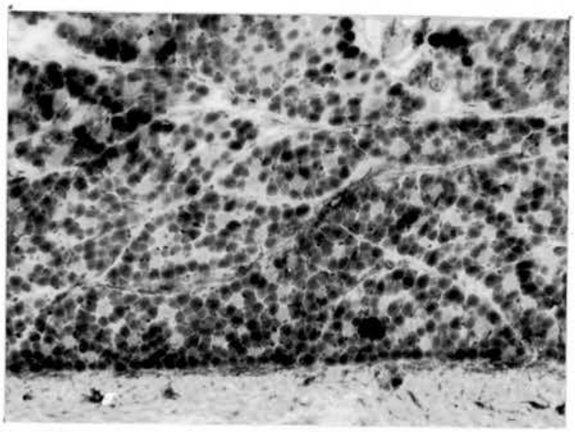
Figs. 96 and 97.

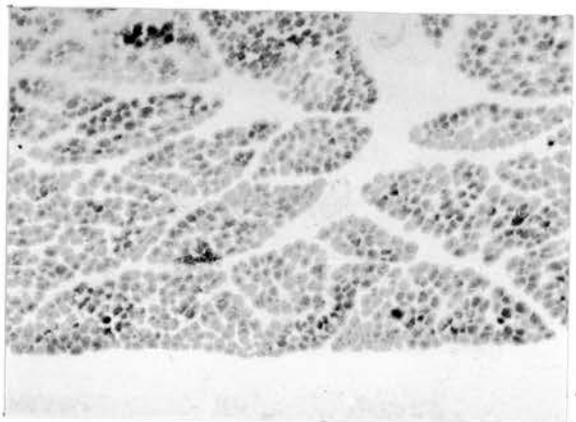
Fresh frozen transverse serial sections from the superficial region of m. pectoralis transversus of the same animal as Figs. 91 - 95 demonstrating myosin ATPase (Fig. 96) and GPase (Fig. 97) activity.

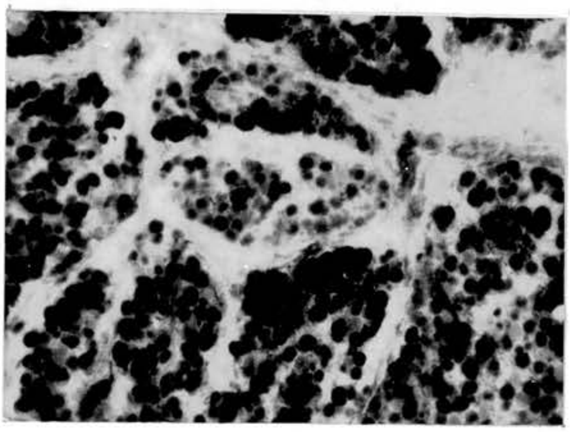

91.

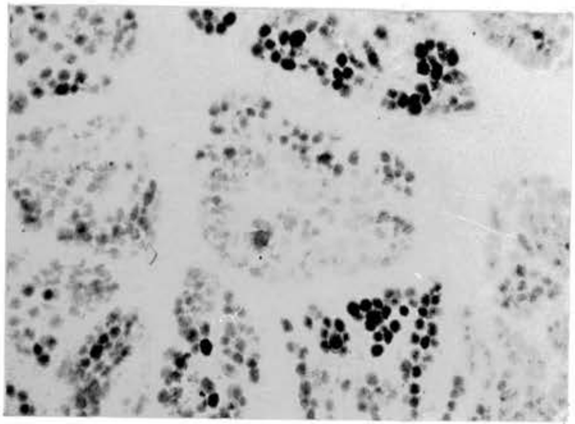

92


93.


94.


95


96.


97

100 µm

Figs. 98 and 99.

Transverse fresh frozen serial sections from m. semitendinosus of a 24 kg, 318 day "in utero" female Thoroughbred demonstrating myosin ATPase (Fig. 98) and SDHase (Fig. 99) activities.

Figs. 100 and 101.

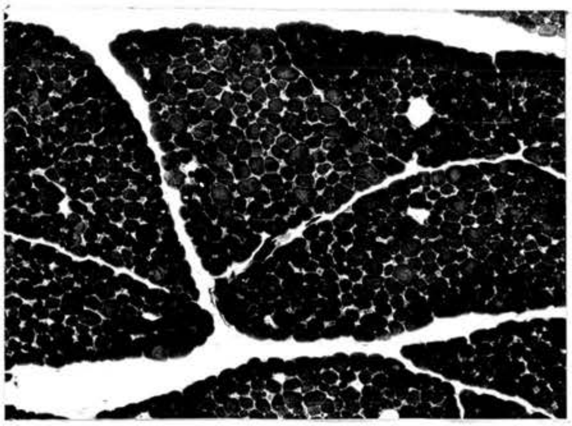
Fresh frozen transverse serial sections from m. diaphragma of the same animal as Figs. 98 and 99 demonstrating myosin ATPase (Fig. 100) and SDHase (Fig. 101) activity.

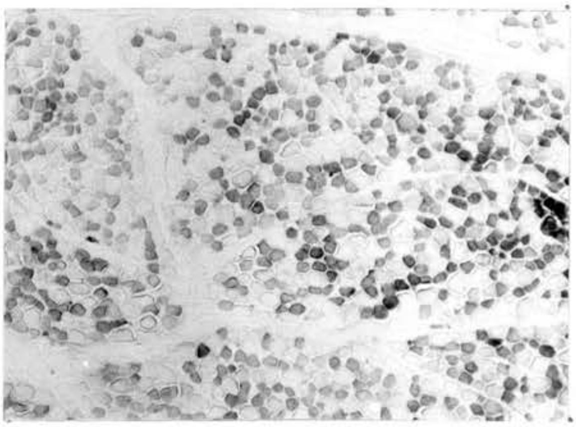
Fig. 102.

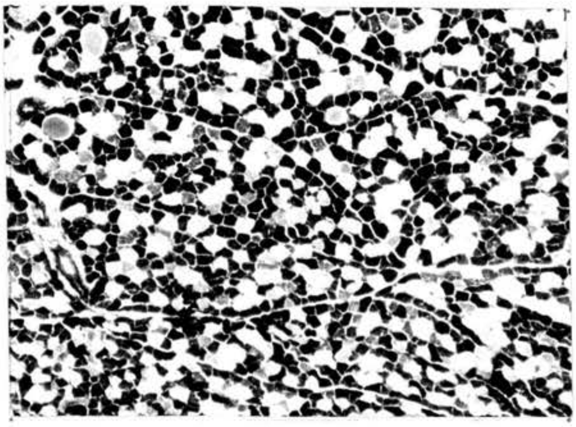
Fresh frozen transverse section from the deep medial region of m. semitendinosus of the same animal as Figs. 98 - 101 demonstrating myosin ATPase activity.

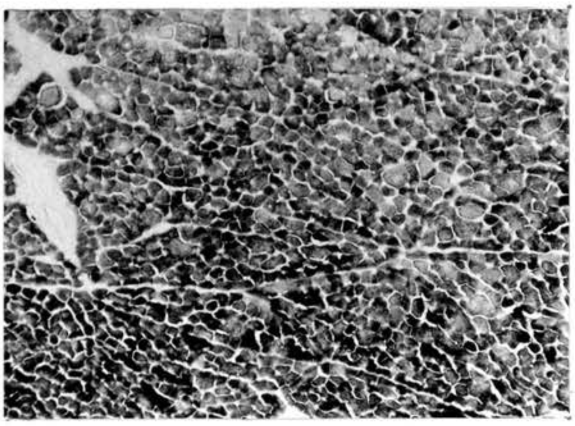
Figs. 103 - 105.

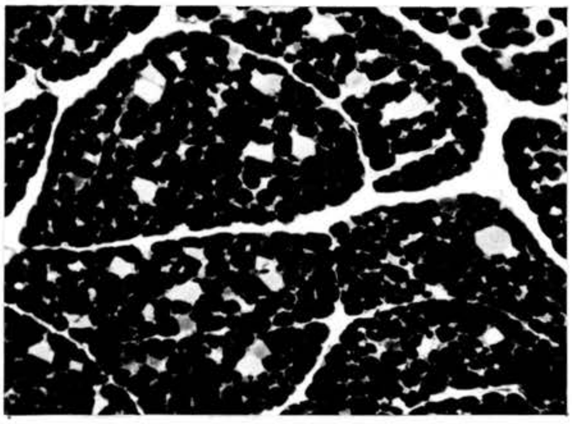
Fresh frozen transverse serial sections from the superficial region of m. pectoralis transversus of a 32 kg, 317 day "in utero" female Thoroughbred demonstrating myosin ATPase (Fig. 103), SDHase (Fig. 104) and GPase (Fig. 105) activity.

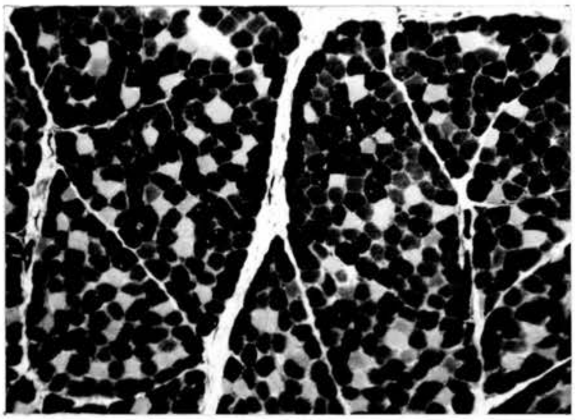

98.

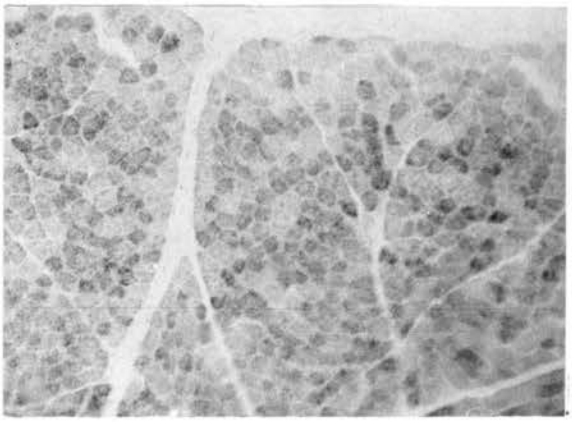

99

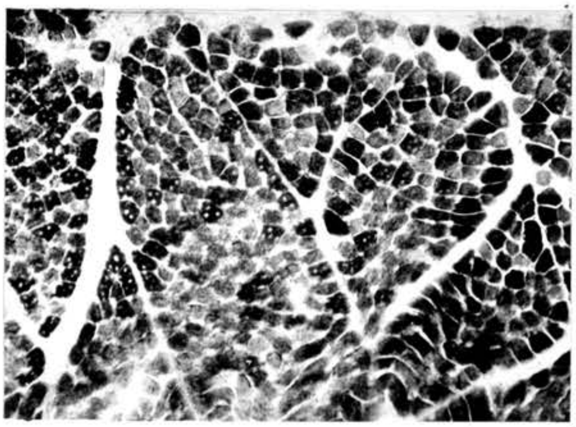

100.


101


102


103


104


105

100 μm

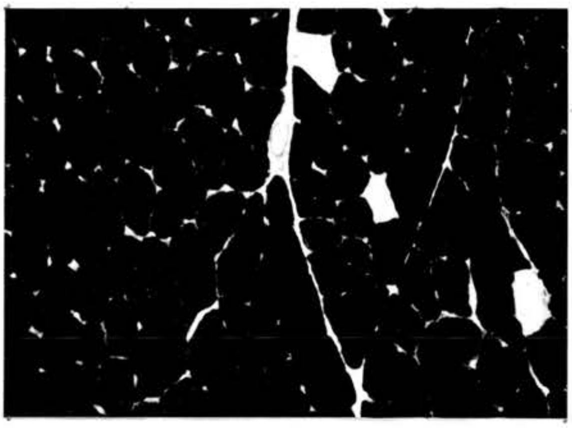
Figs. 106, 108 and 110.

Fresh frozen transverse sections from the caudal superficial region of m. semitendinosus (Fig. 106), m. diaphragma (Fig. 108) and m.pectoralis transversus (Fig. 110) of a 337 kg yearling Thoroughbred female demonstrating myosin ATPase activity.

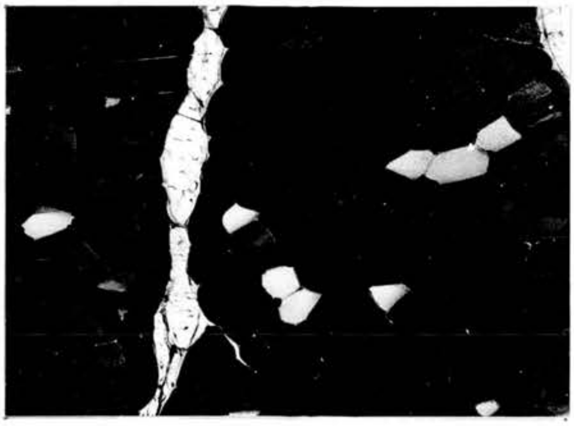
Figs. 107, 109 and 111.

Fresh frozen transverse sections from the caudal superficial region of m. semitendinosus (Fig. 107), m. diaphragma (Fig. 109) and m. pectoralis transversus (Fig. 111) of a 115 kg, yearling female Welsh Mountain pony demonstrating myosin ATPase activity.

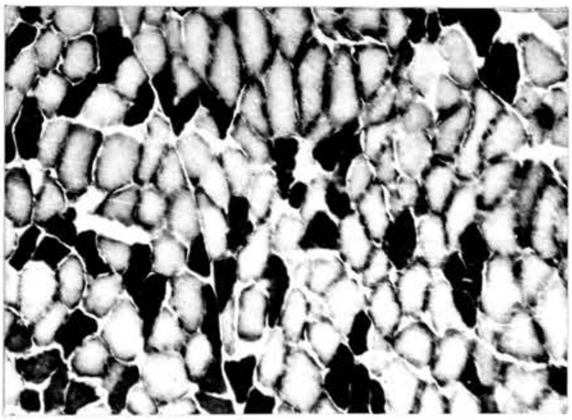
An "intermediate" reaction for myosin ATPase may be seen in some fibres.



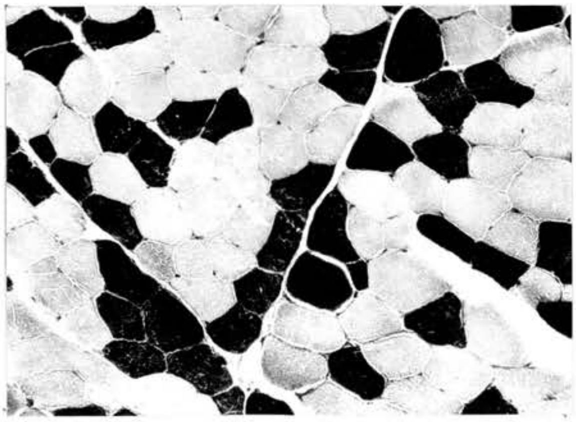
106.



107

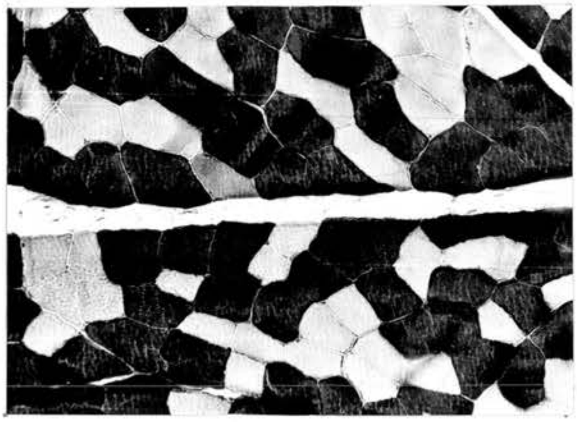


108



109

110



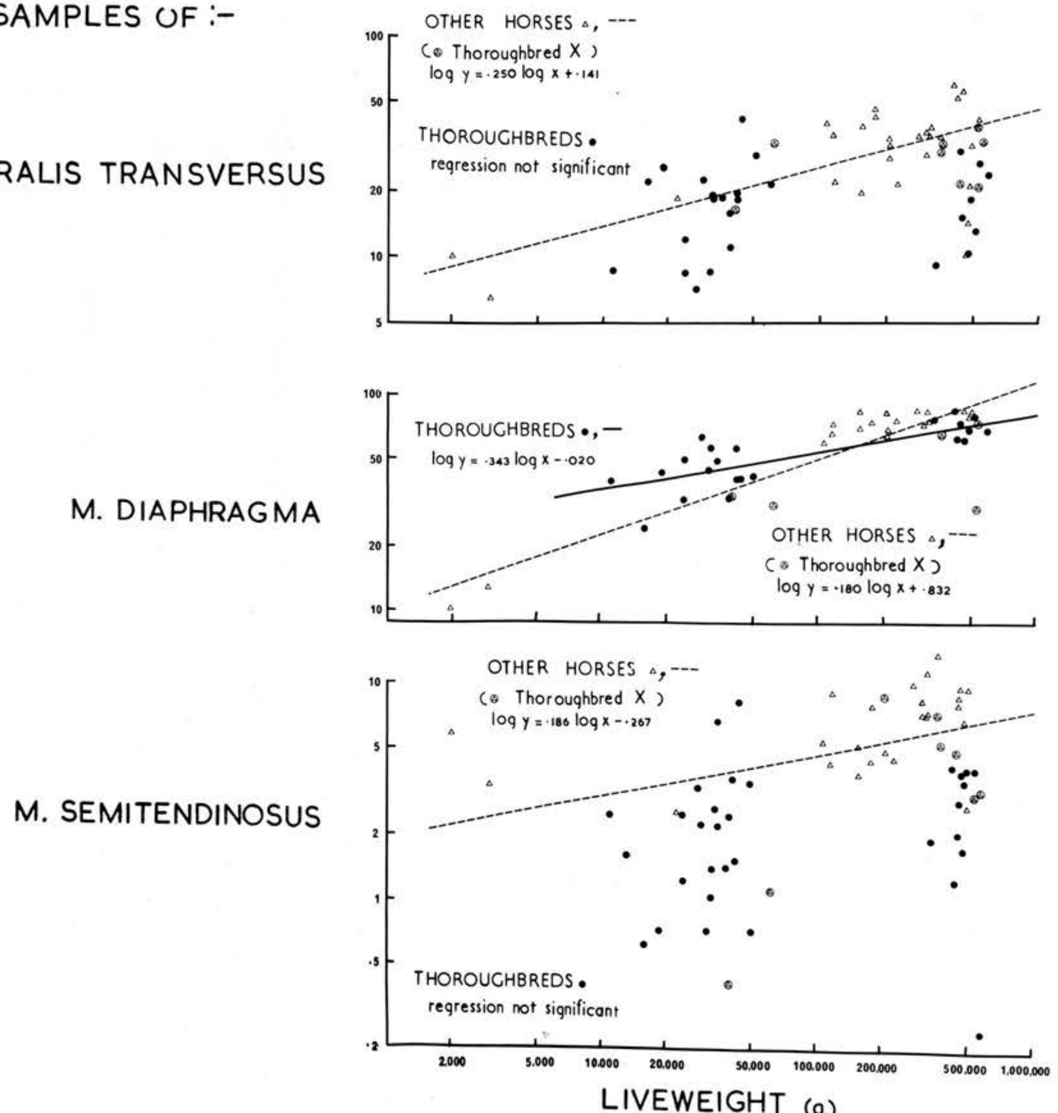
111

100 µm

Fig. 112.

Growth changes in the proportion of myosin ATPase low-reacting fibres in m. semitendinosus, m. diaphragma and m. pectoralis transversus of Thoroughbreds and other horses.

PERCENTAGE AREA OCCUPIED BY MYOSIN ATPase LOW-REACTING FIBRES IN SAMPLES OF :-



M. PECTORALIS TRANSVERSUS

M. DIAPHRAGMA

M. SEMITENDINOSUS

Table 52 Total numbers of fibres, and of myosin ATPase low-reacting (AL) fibres in m. semitendinosus of the dog.

	Age status of Greyhounds	Live-weight (g)	Sex	Total number of fibres (x 1000)	Total number of AL fibres	Type of dog	Live-weight (g)	Sex	Total number of fibres (x 1000)	Total number of AL fibres
	Young	222	♂	185	5,477	Young Labrador	464	♂	143	5,775
	Young	260	♂	230	4,133	Young Collie X	527	♀	120	4,766
	Young	377	♀	280	5,197	Young Labrador	573	♀	141	5,006
	Young	927	♀	219	4,304	Young Collie X	785	♀	132	8,212
	Young	1,056	♀	289	4,498	Young Collie X	931	♂	141	9,901
	Young	1,174	♀	300	4,407	Young Collie	976	♂	99	28,901
	Young	2,280	♂	173	37,522	Young Labrador	1,010	♂	151	4,584
	Young	5,712	♀	208	41,366	Young Collie X	1,235	♂	114	18,518
	Young	11,000	♀	270	42,170	Young Collie X	3,180	♂	126	55,254
	Young	15,250	♀	274	23,920	Young Collie X	3,843	♀	186	48,678
	Young	19,750	♂	331	26,705	Young Collie X	6,000	♂	114	41,563
	Young	23,500	♀	337	26,513	Young Boxer X	6,585	♀	183	34,002
	Adult	19,000	♀	280	4,949	Young Terrier	7,960	♂	120	33,268
	Adult	22,300	♀	295	3,749	Young Boxer X	8,500	♂	167	44,269
D*	Adult	24,150	♀	230	22,355	Young Collie	9,023	♀	166	57,332
	Adult	24,884	♂	348	11,802	Young Boxer X	9,900	♀	222	37,331
	Adult	25,000	♀	322	5,405	Adult Collie	7,742	♀	132	29,333
	Adult	25,200	♂	209	5,228	Adult Collie X	10,400	♀	184	36,433
D*	Adult	25,300	♂	529	11,166	Adult Collie	11,000	♀	139	38,480
	Adult	27,200	♂	313	13,605	Adult Collie	12,000	♀	188	63,242
	Adult	27,500	♂	282	5,934	Adult Collie	14,100	♂	136	25,841
	Adult	28,000	♂	232	6,064	Adult Collie	22,000	♀	155	18,435
D*	Adult	28,500	♀	329	8,903	Adult Afghan	25,100	♂	214	31,482
	Adult	28,864	♂	328	3,175	Adult Afghan	31,900	♂	194	18,308
	Adult	29,750	♀	404	2,083	Adult Labrador	33,000	♀	175	21,533
	Adult	30,000	♂	352	1,165	Adult Great Dane	46,500	♂	248	22,144
D*	Adult	30,000	♂	319	7,950					
	Adult	31,200	♂	348	18,317					
	Adult	31,400	♂	346	8,647					
	Adult	33,523	♀	306	14,591					
	Adult	33,608	♀	260	8,022					
	Adult	34,091	♂	320	14,397					
	Adult	37,000	♂	355	16,973					

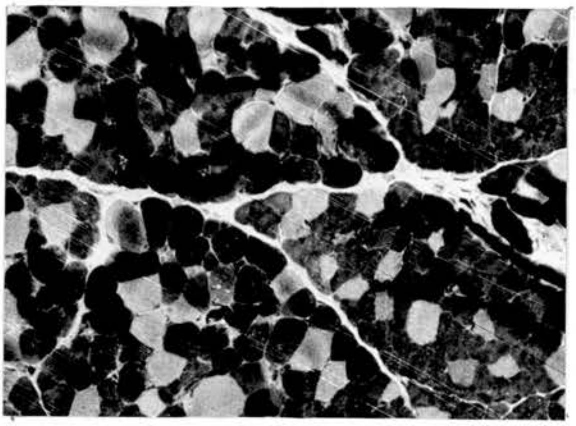
D* Detrained Greyhounds.

Figs. 113, 115 and 117.

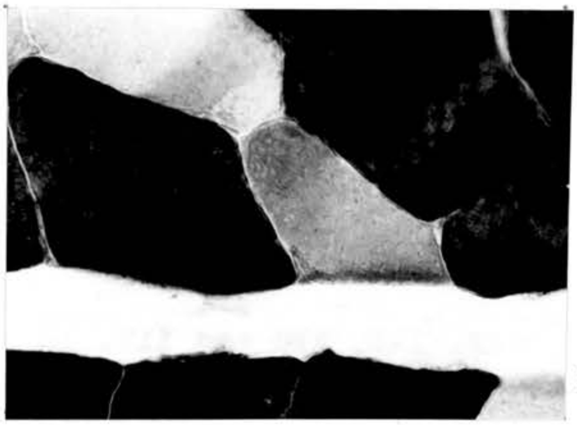
Fresh frozen transverse serial sections from the superficial region of m. pectoralis transversus of a 2·3 kg six week old male Greyhound demonstrating myosin ATPase (Fig. 113), SDHase (Fig. 115) and GPase (Fig. 117) activity. Fibres with an "intermediate" reaction for myosin ATPase are apparent.

Figs. 114, 116 and 118.

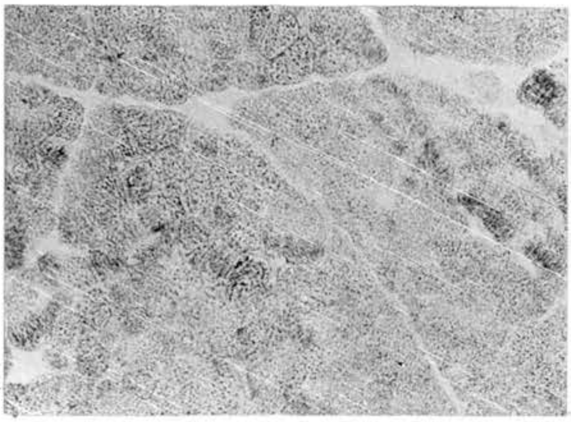
Fresh frozen transverse serial sections from m. pectoralis transversus of a 115 kg, yearling female Welsh Mountain pony demonstrating myosin ATPase (Fig. 114), SDHase (Fig. 116) and GPase (Fig. 118) activity. A fibre with an "intermediate" reaction for myosin ATPase is apparent.



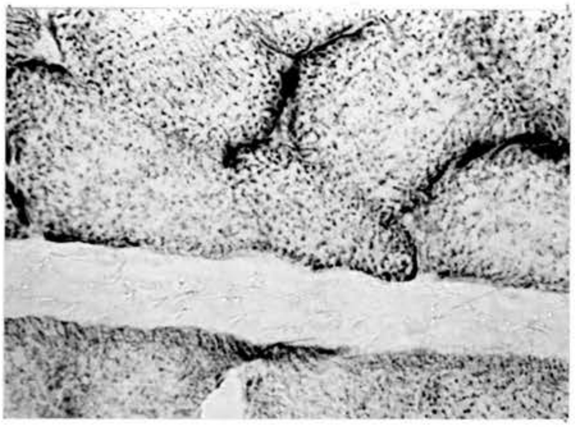
113



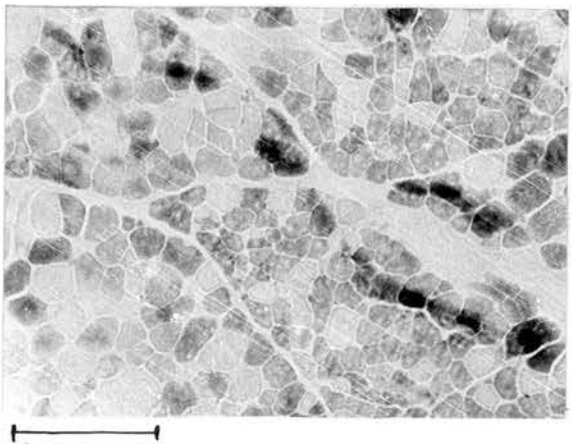
114



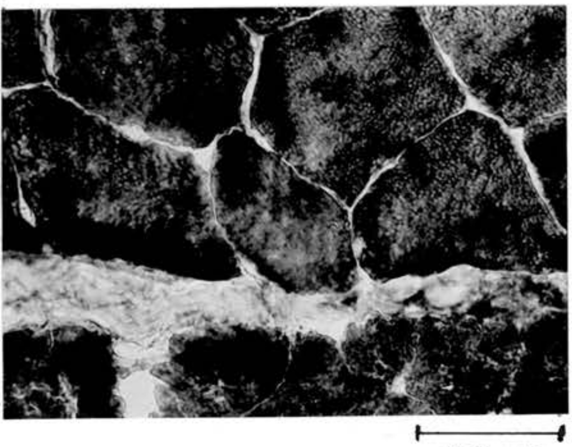
115



116



117



118

Fig. 119.

Growth changes in the total numbers of fibres and total number of myosin ATPase low-reacting fibres in m. semitendinosus of Greyhounds and other dogs.

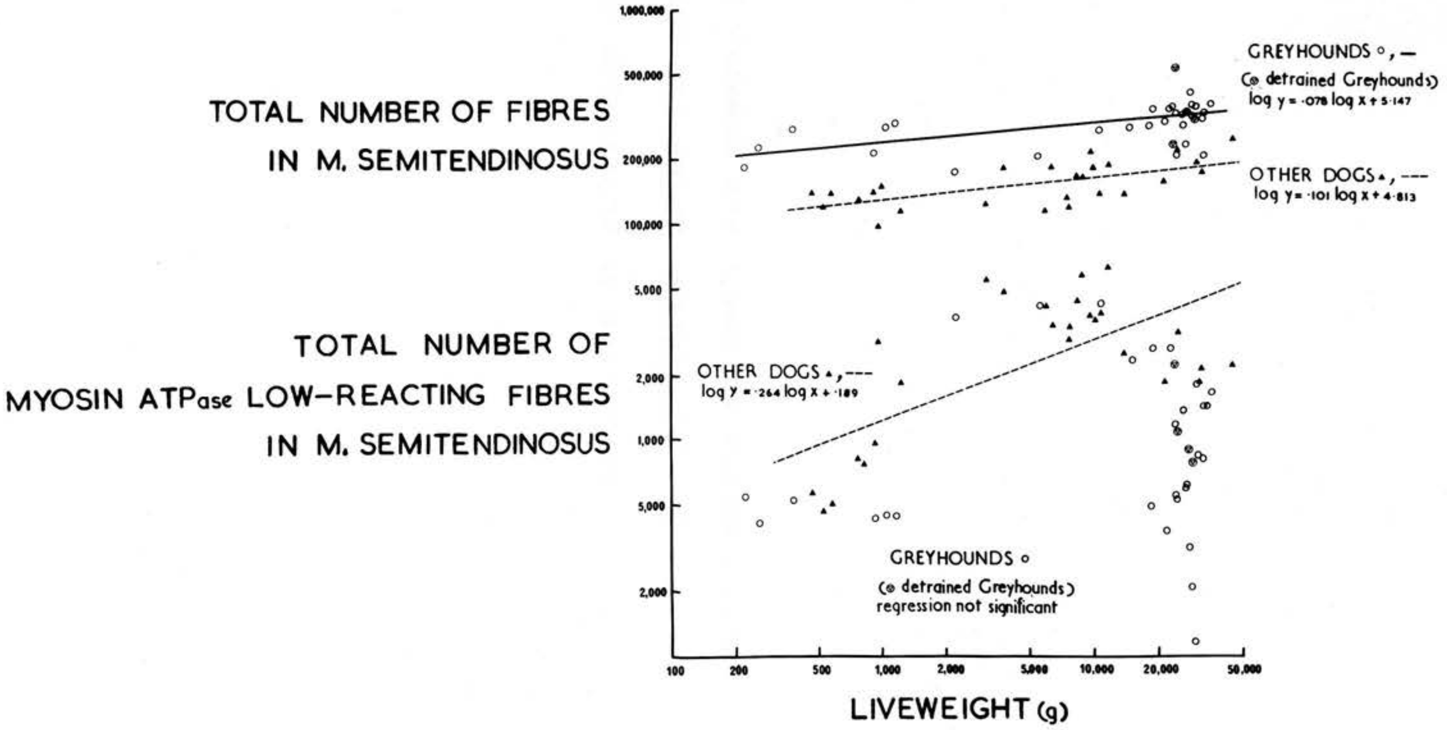

TOTAL NUMBER OF FIBRES
IN M. SEMITENDINOSUS
TOTAL NUMBER OF
MYOSIN ATPase LOW-REACTING FIBRES
IN M. SEMITENDINOSUS
1,000,000
500,000
200,000
100,000
5,000
2,000
1,000
5,000
2,000
GREYHOUNDS ○, —
(⊗ detrained Greyhounds)
log y = ·078 log x + 5·147
OTHER DOGS ▲, ---
log y = ·101 log x + 4·813
OTHER DOGS ▲, ---
log y = ·264 log x + ·189
GREYHOUNDS ○
(⊗ detrained Greyhounds)
regression not significant
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
LIVEWEIGHT (g)

Table 53 Mean areas in μm^2 of myosin ATPase low-reacting (AL) and high-reacing (AH) fibres, in m. semitendinosus, m. diaphragma and m. pectoralis transversus of dogs.

Type of animal	Live-weight (g)	Sex	M. Semitendinosus			M. Diaphragma			M. Pectoralis transversus		
			AL	AH	(N*)	AL	AH	(N*)	AL	AH	(N*)
Young Greyhounds											
	222	♂	163	114		328	244		163	238	
	260	♂	250	126		409	250		189	129	
	377	♀	337	137		364	156		160	154	
	927	♀	181	157		250	336		339	345	
	1,056	♀	471	260		450	407		321	433	
	1,174	♀	535	178		775	281		294	548	
	2,280	♂	489	469		461	397		361	430	
	5,712	♀	641	983		718	858		710	582	
	11,000	♀	1,024	1,588		693	1,408		1,250	773	
	15,250	♀	2,315	2,474		981	1,171		1,684	1,659	
	19,750	♂	1,778	2,188		1,338	1,568		1,569	1,432	
	23,500	♀	1,872	2,657		1,355	2,733		2,604	1,474	
3 Smallest Greyhounds											
	Mean		250	126		367	217		171	174	
	SD		87	12		41	53		16	57	
Adult Greyhounds											
All adults											
	Mean		2,358	3,212	(21)	1,602	1,972	(10)	1,992	3,727	(9)
	SD		571	577		373	470		478	745	
Males											
	Mean		2,476	3,226	(13)	1,732	2,037	(5)	2,543	3,576	(4)
	SD		577	540		354	547		237	337	
Females											
	Mean		2,167	3,189	(8)	1,472	1,886	(5)	2,151	3,848	(5)
	SD		540	672		380	446		223	991	
Detrained adults											
	Mean		2,174	3,402	(4)	1,521	2,330	(4)	2,361	3,974	(4)
	SD		121	908		526	435		221	959	
Trained adults											
	Mean		2,401	3,167	(17)	1,655	1,716	(6)	2,297	3,529	(5)
	SD		628	501		275	340		374	557	
Young Other dogs											
	464	♂	310	287		570	460		-	-	
	527	♀	295	251		688	659		615	568	
	573	♀	361	333		489	453		-	-	
	785	♀	277	230		360	334		296	362	
	931	♂	339	301		594	544		632	365	
	976	♂	268	425		408	520		386	339	
	1,010	♂	307	230		371	451		638	592	
	1,235	♂	499	466		525	675		471	725	
	3,180	♂	646	1,167		-	-		-	-	
	3,843	♀	645	742		605	627		924	740	
	6,000	♂	1,450	1,823		871	713		1,142	724	
	6,585	♀	815	1,327		935	1,587		969	1,978	
	7,960	♂	1,424	2,041		-	-		-	-	
	8,500	♂	1,148	2,090		1,420	1,678		1,506	1,714	
	9,023	♀	2,106	2,508		856	1,281		1,317	1,762	
	9,900	♀	1,692	1,979		1,918	1,949		1,523	2,350	
3 Smallest other dogs											
	Mean		322	290		582	524		615	568	
	SD		35	41		100	117		-	-	
Adult other dogs											
All adults	Mean		1,930	2,526	(10)	1,380	1,456	(7)	2,963	3,240	(8)
	SD		350	754		330	365		1,400	1,777	
Males											
	Mean		1,880	2,860	(3)	1,375	1,718	(2)	3,334	4,184	(3)
	SD		462	419		586	961		1,300	1,200	
Females											
	Mean		2,100	2,668	(7)	1,381	1,352	(5)	2,740	2,674	(5)
	SD		442	696		279	386		1,557	1,935	

*N = number of adult samples.

Table 54 Allometric equations comparing the growth of myosin ATPase high-reacting (AH) fibres with myosin ATPase low-reacting (AL) fibres in m. semitendinosus, m. diaphragma and m. pectoralis transversus of the dog and horse.

Muscle	Type of animal	Number of observ-ations	Growth ratio b*	Se b	log a	r **
M. semitendinosus						
	Greyhounds	33	1·299 c	0·078	-0·882	0·9485
	Other dogs	26	1·153 c	0·062	-0·371	0·9671
	Thoroughbreds	32	1·039	0·064	0·072	0·9467
	Other horses	32	1·004	0·090	0·315	0·8982
M. diaphragma						
	Greyhounds	22	1·235	0·154	-0·666	0·8734
	Other dogs	21	0·929	0·128	0·237	0·8583
	Thoroughbreds	23	0·981	0·069	-0·042	0·9510
	Other horses	23	0·916	0·071	0·204	0·9416
M. pectoralis transversus						
	Greyhounds	21	1·066	0·084	-0·118	0·9459
	Other dogs	20	1·024	0·108	-0·055	0·9131
	Thoroughbreds	30	1·288 cd	0·061	-0·687	0·9697
	Other horses	34	0·938 d	0·054	0·387	0·9512

* Regression coefficient b, standard error Se b.

c Values of b bearing this superscript are significantly different ($P < 0{\cdot}025$) from 1.

d Values of b bearing this superscript are significantly different ($P < 0{\cdot}001$) from one another.

** Correlation coefficient r.

Table 55 Mean areas in μm^2 of myosin ATPase low-reacting (AL) and high-reacting (AH) fibres, in m. semitendinosus, m. diaphragma and m. pectoralis transversus of horses.

Type of animal	Live-weight (kg)	Sex	M. Semitend-inosus			M. Diaphragma			M. Pectoralis transversus		
			AL	AH	(N*)	AL	AH	(N*)	AL	AH	(N*)
Young Thoroughbred											
	11·0	♀	290	280		247	242		187	159	
	13.4	♀	107	115		-	-		-	-	
	16.0	♂	211	194		289	268		384	320	
	19.0	♀	233	255		474	332		375	304	
	23.9	♂	341	537		636	286		394	408	
	24.0	♀	317	516		461	321		428	451	
	28.0	♂	362	421		-	-		387	410	
	29.0	♂	266	321		661	211		448	362	
	31.0	♀	330	391		443	304		347	422	
	31.5	♂	318	443		-	-		545	677	
	32.0	♀	336	502		444	232		370	499	
	33·5	♂	320	558		312	231		246	317	
	34·5	♀	222	374		-	-		-	-	
	34·8	♀	410	437		-	-		-	-	
	38·6	♂	442	1,192		378	761		948	1,170	
	39·0	♂	429	587		-	-		321	307	
	40·5	♀	599	1,166		784	747		613	929	
	42·0	♂	310	428		370	363		364	433	
	43·0	♀	795	862		477	548		1,191	1,220	
	50·0	♀	293	441		330	313		465	621	
	58·7	♀	663	718		-	-		720	1,189	
	337·0	♀	1,555	3,021		2,190	1,506		874	2,792	
	420·0	⚦	1,834	3,638		3,911	2,856		-	-	
	432·7	♂	1,444	2,853		2,254	2,671		2,426	4,443	
3 Smallest Thoroughbreds											
	Mean		203	196		268	255		286	240	
	SD		92	83		30	18		139	114	
Adult Thoroughbreds											
All adults											
	Mean		3,373	4,827	(9)	4,529	3,678	(6)	2,665	5,417	(10)
	SD		2,190	1,420		1,396	1,225		816	1,344	
Entire males											
	Mean		2,223	4,605	(2)	-	-		2,927	4,218	(2)
	SD		271	361		-	-		266	929	
Castrated males											
	Mean		-	-		3,633	3,021	(2)	2,290	5,288	(2)
	SD		-	-		738	346		791	985	
Females											
	Mean		3,699	4,891	(7)	4,977	4,007	(4)	2,703	5,859	(6)
	SD		2,416	1,633		1,505	143		987	1,438	
Horses in training											
	Mean		2,370	4,229	(5)	-	-		2,725	5,400	(8)
	SD		1,816	946		-	-		778	1,415	
Horses out of training											
	Mean		4,627	5,575	(4)	-	-		2,426	5,483	(2)
	SD		2,150	1,686		-	-		1,273	1,492	
Young other horses											
	2·15	♂	336	513		310	279		322	436	
	2·98	♂	306	374		350	232		336	451	
	22·00	♀	265	393		-	-		471	607	
Thoroughbred X	39·0	♂	470	920		307	443		404	637	
Thoroughbred X	62·0	♂	398	1,028		-	-		761	954	
	109·1	♂	630	2,145		1,229	1,015		1,750	2,383	
	114·5	♀	873	2,025		2,422	1,924		1,555	2,041	
	118·2	♂	788	2,670		1,518	1,370		1,243	4,431	
	153·7	♂	1,386	2,774		2,202	1,790		1,130	1,952	
	178·2	♀	1,006	3,186		-	-		4,199	6,305	
Thoroughbred X	207·3	♂	1,402	3,232		2,567	2,239		857	1,354	
	203·6	♂	815	1,331		1,335	1,255		1,336	2,834	
Adult other horses											
All adults											
	Mean		1,705	3,569	(20)	3,126	2,688	(14)	3,516	4,959	(22)
	SD		422	891		797	117		1,813	1,883	
Thoroughbred crosses											
	Mean		1,460	3,579	(5)	3,444	2,979	(3)	2,649	4,639	(6)
	SD		424	963		1,199	1,064		752	1,162	
Others											
	Mean		1,787	3,566	(15)	3,039	2,609	(11)	3,841	5,079	(16)
	SD		402	902		707	1,228		2,000	2,111	
Entire males											
	Mean		1,827	4,034	(4)	2,817	3,679	(3)	3,739	4,849	(2)
	SD		624	1,629		643	204		291	168	
Castrated males											
	Mean		1,616	3,618	(7)	3,339	2,385	(5)	5,605	5,160	(9)
	SD		477	548		983	908		1,768	2,352	
Females											
	Mean		1,723	3,324	(9)	3,103	2,446	(6)	3,584	4,814	(11)
	SD		303	698		781	673		2,064	1,719	

*N = Number of adult samples.

Fig. 120.

Change in area of myosin ATPase high-reacting (AH) relative to myosin ATPase low-reacting (AL) fibres during growth in the dog and horse.

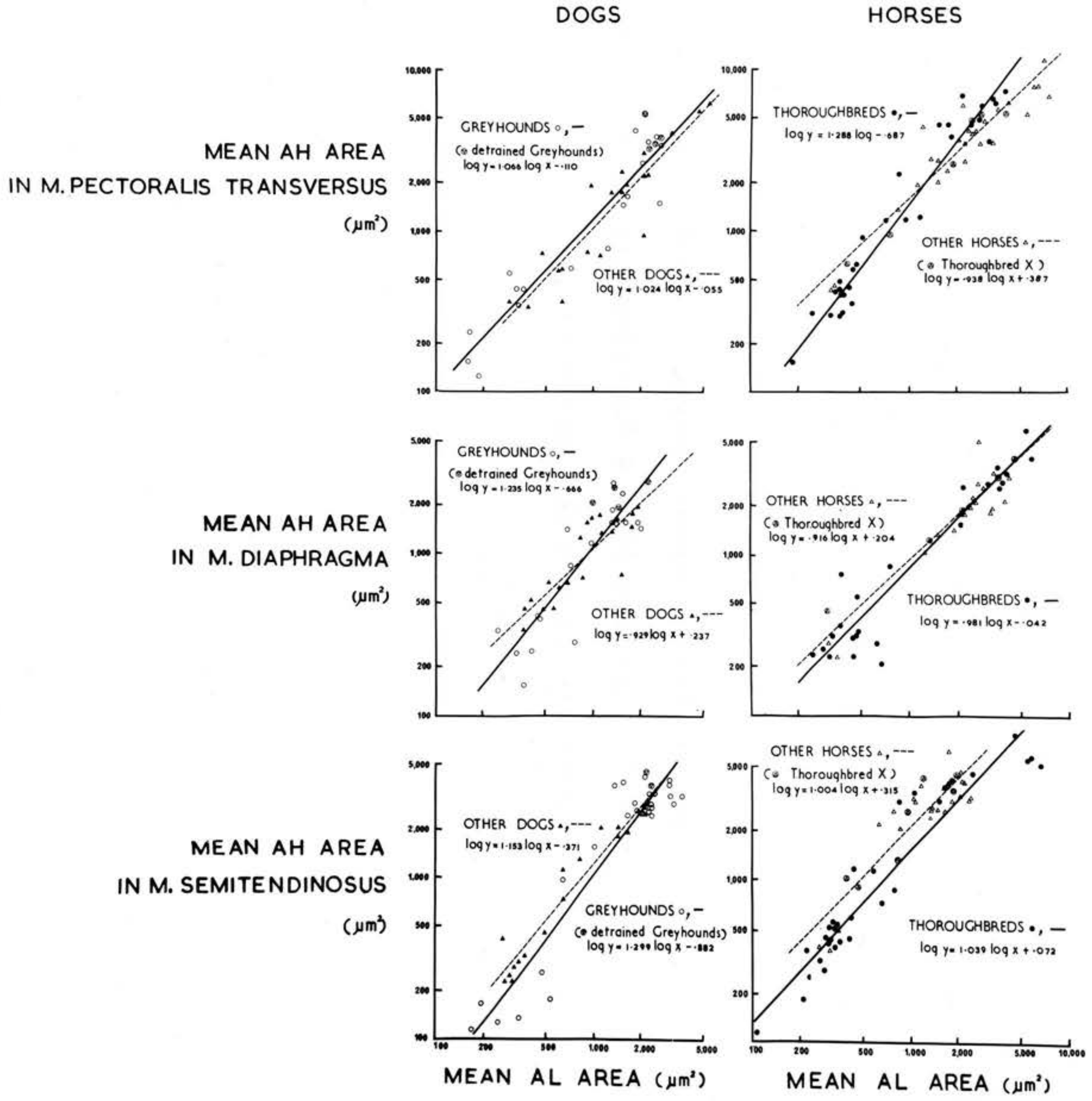

DOGS
HORSES
MEAN AH AREA IN M. PECTORALIS TRANSVERSUS (μm²)
GREYHOUNDS ○, —
(⊙ detrained Greyhounds)
log y = 1·066 log x − ·110
OTHER DOGS ▴, ---
log y = 1·024 log x − ·055
THOROUGHBREDS ●, —
log y = 1·288 log − ·687
OTHER HORSES ▵, ---
(⊙ Thoroughbred X)
log y = ·938 log x + ·387
MEAN AH AREA IN M. DIAPHRAGMA (μm²)
GREYHOUNDS ○, —
(⊙ detrained Greyhounds)
log y = 1·235 log x − ·666
OTHER DOGS ▴, ---
log y = ·929 log x + ·237
OTHER HORSES ▵, ---
(⊙ Thoroughbred X)
log y = ·916 log x + ·204
THOROUGHBREDS ●, —
log y = ·981 log x − ·042
MEAN AH AREA IN M. SEMITENDINOSUS (μm²)
OTHER DOGS ▴, ---
log y = 1·153 log x − ·371
GREYHOUNDS ○, —
(⊙ detrained Greyhounds)
log y = 1·299 log x − ·882
OTHER HORSES ▵, ---
(⊙ Thoroughbred X)
log y = 1·004 log x + ·315
THOROUGHBREDS ●, —
log y = 1·039 log x + ·072
10,000
5,000
2,000
1,000
500
200
100
MEAN AL AREA (μm²)
MEAN AL AREA (μm²)

Table 56 Capillary - fibre ratios and mean area per capillary (in μm^2) in m. semitendinosus, m. diaphragma and m. pectoralis transversus of dogs.

Type of animal	Live-weight (g)	Sex	M. Semitendinosus			M. Diaphragma			M. Pectoralis transversus		
			Capillary/ fibre ratio	Area/ capillary	(N*)	Capillary/ fibre ratio	Area/ capillary	(N*)	Capillary fibre ratio	Area/ capillary	(N*)
Young Greyhounds											
	222	♂	-	-		0·09	3,333		0·09	3,378	
	260	♂	-	-		0·07	3,827		0·01	9,146	
	377	♀	-	-		0·06	2,569		0·07	2,329	
	1,056	♀	-	-		0·14	3,024		0·06	5,000	
	1,174	♀	0.07	2,660		0·34	1,065		0·13	2,206	
	2,280	♂	0.73	659		0·44	964		0·35	1,027	
	5,712	♀	0.75	1,214		0·72	1,147		0·59	1,198	
	11,000	♀	1.06	1,410		0·91	1,298		0·86	1,448	
	15,250	♀	1.19	2,068		0·89	1,253		1·31	1,276	
	19,750	♂	1.46	1,480		1.20	1,242		1·82	1,234	
	23,500	♀	1.65	1,569		1.19	1,850		1·56	2,168	
Young Greyhounds	Mean		0.99	1,581	(7)	0·55	1,961	(11)	0·62	2,765	(11)
	SD		0.53	636		0·45	1,039		0·67	2,423	
Adult Greyhounds											
All adults	Mean		2·22	1,435	(13)	1·78	1,075	(8)	2·14	1,556	(8)
	SD		0·17	248		0·32	195		0·18	207	
Males											
	Mean		2·22	1,468	(7)	1·75	1,084	(4)	2·08	1,554	(4)
	SD		0·20	260		0·31	238		0·20	186	
Females											
	Mean		2·22	1,397	(6)	1·81	999	(4)	2·20	1,559	(4)
	SD		0·15	252		0·36	141		0·16	255	
Detrained adults	Mean		2·17	1,514	(4)	1·81	1,194	(4)	2·05	1,708	(4)
	SD		0·22	234		0·47	209		0·19	88	
Trained adults	Mean		2·23	1,399	(9)	1·74	956	(4)	2·23	1,405	(4)
	SD		0·16	259		0·11	85		0·14	176	
Young other dogs											
	464	♂	0.02	38,462		0.03	15,615		-	-	
	527	♀	0.15	1,689		0.45	1,493		-	-	
	573	♀	0·05	6,173		0·10	4,464		-	-	
	785	♀	0·30	765		0·50	688		0·36	952	
	931	♂	-	-		-	-		0·20	2,083	
	976	♂	0·63	604		0·57	817		0·47	765	
	1,010	♂	0·68	340		-	-		0·47	1,284	
	1,235	♂	0·68	691		0·54	1,152		0·58	1,087	
	3,180	♂	0·91	1,029		-	-		-	-	
	3,843	♀	-	-		0·71	874		0·97	819	
	6,000	♂	1·04	1,618		0·87	896		0·97	995	
	6,585	♀	1·17	1,053		1·06	1,170		1·08	1,341	
	7,960	♂	1·95	962		-	-		-	-	
	8,500	♂	1·41	1,309		1·21	1,279		1·15	1,409	
	9,023	♀	1·10	161		0·83	1,289		1·00	1,539	
	9,900	♀ +	1·88	1,030		1·57	1,230		1·53	1,249	
Young other dogs	Mean		0·86	3,992	(14)	0·70	2,581	(12)	0·80	1,229	(11)
	SD		0·62	10,028		0·44	422		0·41	375	
Adult other dogs											
All adults	Mean		1·88	1,372	(9)	1·48	1,190	(6)	2·17	1,486	(7)
	SD		0·27	244		0·25	401		0·90	397	
Males	Mean		2·12	1,355	(2)	1·67	1,949	(1)	3·00	1,692	(2)
	SD		0·10	175		-	-		1·27	436	
Females	Mean		1·82	1,377	(7)	1·44	1,038	(5)	1·83	1,403	(5)
	SD		0·27	272		0·26	169		0·57	399	

D* Detrained Greyhounds.

N* Number of observations.

\+ Absence of visible reaction for capillaries.

Table 57 Capillary - fibre ratios and mean area per capillary (in μm^2) in m. semitendinosus, m. diaphragma and m. pectoralis transversus of horses.

Type of animal	Live-weight (kg)	Sex	M. Semitendinosus		M. Diaphragma		M. Pectoralis transversus	
			Capillary/ fibre ratio	Area/ capillary (N*)	Capillary/ fibre ratio	Area/ capillary (N*)	Capillary/ fibre ratio	Area/ capillary (N*)
Young Thoroughbreds								
	23·9	♂	0·98	541	0·98	411	1·01	402
	28·0	♂	0·98	426	-	-	0·71	596
	31·0	♀	0·84	464	0·76	464	0·88	424
	32·0	♀	0·67	740	-	-	-	-
	34·5	♀	0·40	907	-	-	-	-
	34·8	♀	0·57	758	-	-	-	-
	38·6	♂	1·46	1,046	1·08	530	1·10	1,055
	39·0	♂	-	-	-	-	0·54	309
	40·5	♀	0·80	1,433	0·98	779	0·64	849
	42·0	♂	1·10	398	0·77	474	0·79	530
	43·0	♀	0·45	1,901	-	-	0·85	1,420
	50·0	♀	0·86	504	0·49	654	-	-
	58·7	♀	0·94	701	-	-	0·99	1,055
	337·0	♀	1·66	1,784	1·73	1,142	-	-
	432·7	♀	1·77	1,592	1·90	1,259	2·29	1,560
Young Thoroughbreds	Mean		0·96	943 (14)	1·08	714 (8)	0·98	820 (10)
	SD		0·42	523	0·49	323	0·49	440
Adult Thoroughbreds								
All adults	Mean		2·83	1,711 (4)	2·49	1,886 (3)	3·01	1,707 (4)
	SD		0·78	213	0·42	506	0·39	218
Detrained adults								
	Mean		3·81	2,006 (1)	2·44	1,475 (1)	2·75	1,770 (2)
	SD		-	-	-	-	0·37	351
Trained adults								
	Mean		2·50	1,613 (3)	2·52	2,092 (2)	3·27	1,644 (2)
	SD		0·52	103	0·59	508	0·19	55
Young other horses								
	2·15	♂	0·19	2,632	0·13	2,193	-	-
	2·98	♂	0·49	761	0·45	529	0·59	761
	22·0	♀	0·72	563	-	-	0·85	680
Thoroughbred X	39·0	♂	1·18	776	0·86	449	0·92	623
Thoroughbred X	62·0	♂	-	-	-	-	2·38	370
	109·1	♂	1·27	1,490	1·15	989	1·64	1,275
	114·5	♀	1·42	1,359	1·28	1,732	1·33	1,389
	118·2	♂	1·45	1,518	1·02	1,442	1·85	1,518
	153·7	♂	1·06	2,532	1·53	1,351	1·36	1,259
	178·2	♂	-	-	-	-	2·83	1 842
Thoroughbred X	203·6	♂	0·87	1,450	1·42	921	1·32	862
	207·3	♂	-	-	1·35	1,821	1·78	1,280
Young other horses								
All young other horses	Mean		0·96	1,453 (9)	1·02	1,270 (9)	1·53	1,078 (3)
	SD		0·43	733	0·47	595	0·66	246
Thoroughbred crosses	Mean		1·03	1,113 (2)	1·14	685 (2)	1·54	618 (3)
	SD		0·22	477	0·40	334	0·75	246
Other young horses	Mean		0·94	1,551 (7)	0·99	1,437 (7)	1·53	1,251 (8)
	SD		0·49	793	0·51	554	0·68	379
Adult other hoses								
All adults	Mean		1·98	1,582 (13)	1·88	1,600 (11)	2·10	1,749 (12)
	SD		0·30	202	0·45	450	0·35	369
Thoroughbred crosses	Mean		1·88	1,749 (5)	1·95	1,676 (3)	2·09	1,848 (5)
	SD		0·38	182	0·58	422	0·30	272
Other adults	Mean		2·05	1,478 (8)	1·85	1,572 (8)	2·11	1,677 (7)
	SD		0·26	137	0·44	485	0·41	432
Entire males			-	-	2·82	1,220 (1)	-	-
Castrated males	Mean		1·93	1,674 (6)	1·61	1,793 (5)	2·16	1,719 (6)
	SD		0·34	179	0·28	469	0·21	389
Females	Mean		2·03	1,503 (7)	1·96	1,484 (5)	2·04	1,778 (6)
	SD		0·30	198	0·32	433	0·47	383

N* = Number of observations.

Table **58** Logarithmic regression equations comparing the growth of capillary-fibre ratios with liveweight in m. semitendinosus, m. diaphragma and m. pectoralis transversus in dogs and horses.

Muscle	Type of animal	Number of observations	Growth ratio b*	Se b	log a	r **
M. semitendinosus						
	Greyhounds	20	0·815	0·084	-3·276	0·9155
	Other dogs	32	0·718	0·718	-2·742	0·8415
	Thoroughbreds	18	0·431	0·431	-2·070	0·8422
	Other horses	22	0·359	0·359	-1·707	0·9102
M. diaphragma						
	Greyhounds	19	0·659	0·036	-2·702	0·9760
	Other dogs	18	0·600	0·106	-2·336	0·8160
	Thoroughbreds	11	0·376	0·068	-1·794	0·8785
	Other horses	20	0·408	0·038	-1·991	0·9305
M. pectoralis transversus						
	Greyhounds	19	0·880 c	0·061	-3·583	0·9612
	Other dogs	18	0·537 c	0·050	-2·010	0·9361
	Thoroughbreds	14	0·422 c	0·050	-2·241	0·9383
	Other horses	23	0·215 c	0·051	-0·871	0·6774

* Regression coefficient b, standard error Se b.

c Values of b within a species followed by this superscript are significantly different ($p < 0{\cdot}01$) from one another.

** Correlation coefficient.

Figs. 121 - 126.

Fresh frozen transverse sections from:

m. diaphragma of a 2·2 kg, 160 day "in utero" male Connemara cross pony (Fig. 121);

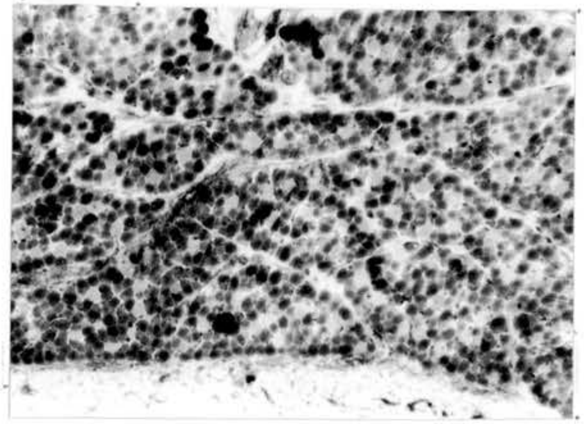
the superficial region of m. pectoralis transversus of a 0·38 kg, one week old female Greyhound (Fig. 122);

m. diaphragma of a 25 kg, four year old female Afghan (Fig. 123);

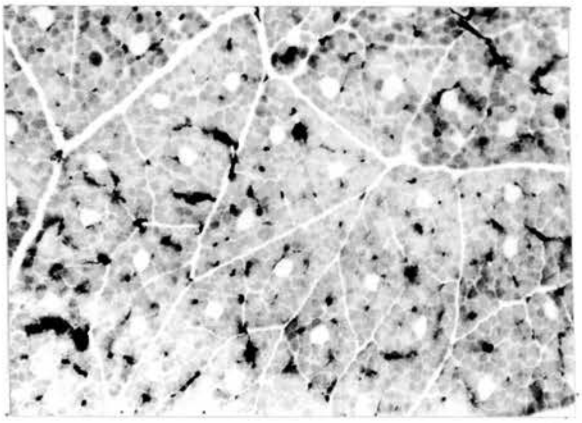
the superficial caudal region of a 28 kg three year old male Greyhound (Fig. 124);

m. diaphragma of a 318 kg, six year old Piebald pony mare (Fig. 125);

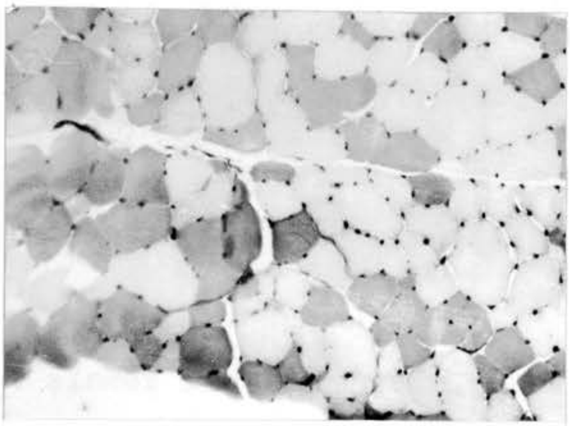
and the superficial region of m. pectoralis transversus of a 445 kg, six year old Connemara cross mare (Fig. 126); all treated to demonstrate capillaries.



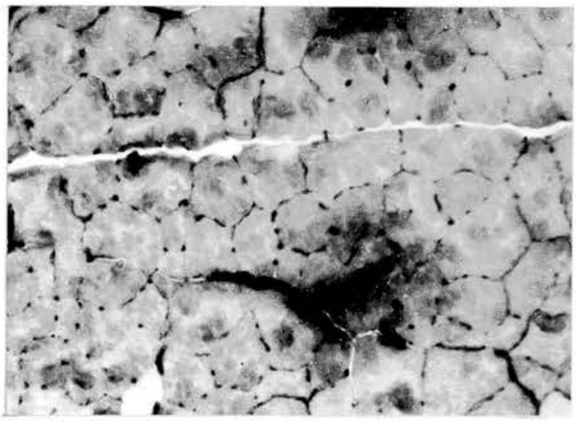
121.



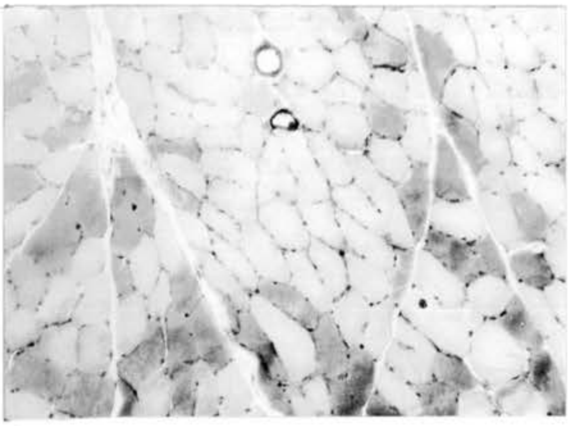
122



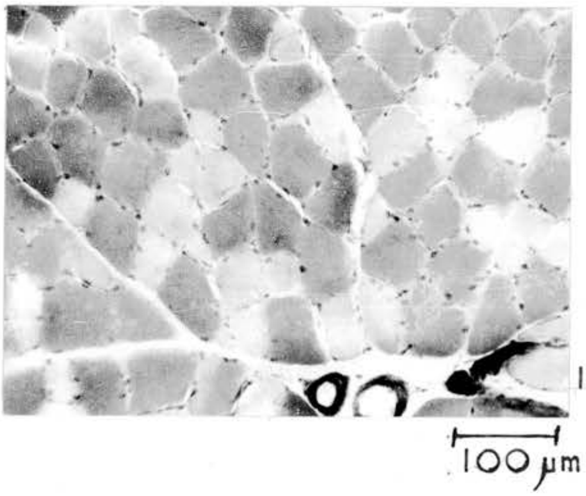
123.



124



125



126

Table 59 Biochemical estimation of succinate dehydrogenase activity (SDHase) in m. semitendinosus, m. diaphragma and m. pectoralis transversus of dogs and horses expressed as mg of INT formazan produced per g of muscle per 15 minutes.

DOGS

Type of animal	Live-weight (kg)	Sex	M. semi-tendin-osus	M. dia-phragma	M. pector-alis tran-sversus
Greyhound pups					
	260	♂	0·38	0·88	0·66
	377	♀	0·42	0·96	-
	1,056	♀	1·45	1·52	1·26
	1,174	♀	0·62	1·39	0·60
	2,280	♂	0·80	1·49	1·09
	5,712	♀	1·09	-	-
	11,000	♀	1·04	1·92	0·90
	15,250	♀	1·94	2·69	1·20
	19,750	♂	1·65	1·95	0·98
	23,500	♀	2·26	2·15	1·43
Greyhound adults					
	D* 24,150	♀	2·36	-	-
	(inside		2·74)		
	25,000	♀	3·54	2·91	-
	D* 25,300	♂	3·65	2·91	-
	D* 28,500	♀	2·23	2·50	-
	(inside		2·50)		
	D* 30,000	♂	2·06	2·23	-
	(inside		2·76)		
	37,000	♂	2·29	3·14	-
Other pups					
	6,585	♀	1·49	1·62	-
	8,500	♂	1·13	1·25	0·83
	9,900	♀	1·13	1·73	1·06
Other adults					
	-		-	-	-

HORSES

Type of animal	Live-weight (kg)	Sex	M. semi-tendin osus	M. dia-phragma	M. pector-alis tran-sversus
Thoroughbred foals					
	16,000	♂	1·01	-	0·61
	19,000	♀	0·84	-	-
	24,000	♀	0·78	3·16	1·41
	29,000	♂	1·04	-	-
	31,500	♂	0·86	-	0·84
	50,000	♀	-	1·94	-
Thoroughbred adults	458,186	♀	1·78	-	0·61
	470,909	♀	1·25	-	2·23
	483,636	♂	1·32	-	1·26
Other foals Thoroughbred X	39,000	♂	1·34	-	1·00
	114,546	♀	1·81	3·37	2·12
	118,182	♂	0·67	1·11	1·17
Other adults					
	-		-	-	-

D* Detrained Greyhounds.

Table 60 <u>Classification of fibre types in mammalian muscle</u>.

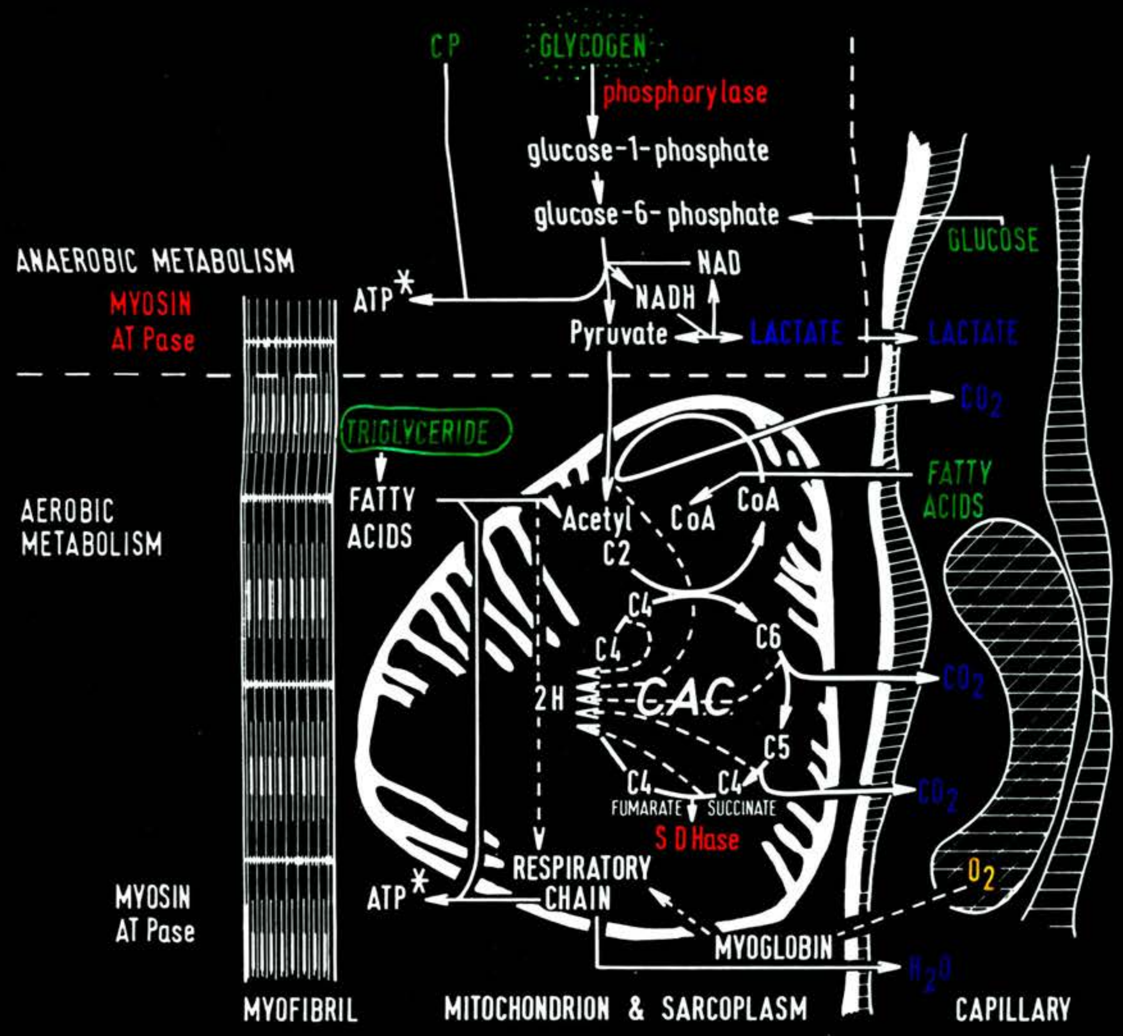
Gunn and Davies (1971)	SLOW-TWITCH AEROBIC	FAST-TWITCH ANAEROBIC	FAST-TWITCH COMBINED	FAST-TWITCH AEROBIC	SLOW-TWITCH COMBINED
Peter et al. (1972)	SLOW-TWITCH OXIDATIVE	FAST-TWITCH	FAST-TWITCH OXIDATIVE GLYCOLYTIC	-	-
Dubowitz and Pearse (1960)	1	11	-	-	-
Stein and Padykula (1962)	B	A	C	-	-
Engel (1962)	1	11	-	-	-
Romanul (1964)	111	1	11	-	-
Padykula and Gauthier (1966)	Intermediate	White	Red	-	-
Moody and Cassens (1968)	Red	White	Intermediate	-	-
Hall-Craggs (1968)	Slow-red	Fast-White	Fast-red	-	-
Edgerton and Simpson (1969)	Intermediate	White	Red	-	-
Brooke and Kaiser (1970)	1	11B	11A	-	-
Yellin and Guth (1970)	β	$\alpha\beta$	α	-	-
Ashmore and Doerr (1971)	β-red	α-white	α-red	-	-
Burke et al. (1971)	Slow	Fast-fatiguable	Fast-fatigue resistant	-	-
Johnson and Pearse (1971)	1	11	111	-	-

Fig. 127.

Outline of anaerobic and aerobic metabolism in muscle. The hatched line separates the metabolic processes which may take place without oxygen from those which need oxygen. (Modified from Davies, 1973).

Key: Energy sources. Marker enzymes. Products.

SUMMARY OF ANAEROBIC AND AEROBIC METABOLISM IN SKELETAL MUSCLE



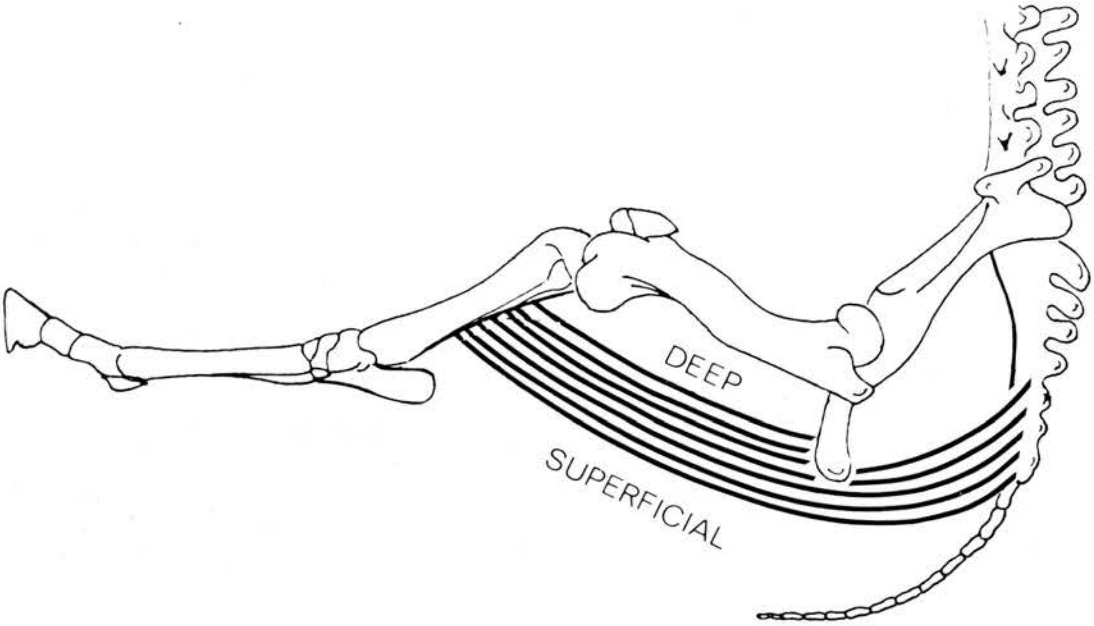
* ATP is produced most rapidly by anaerobic metabolism, but more ATP is formed per mole of glucose using aerobic metabolism.

Fig. 128.

Diagrammatic representation of m. semitendinosus in the dog.

Fig. 129.

Diagrammatic representation of m. semitendinosus in the horse.


DEEP
SUPERFICIAL

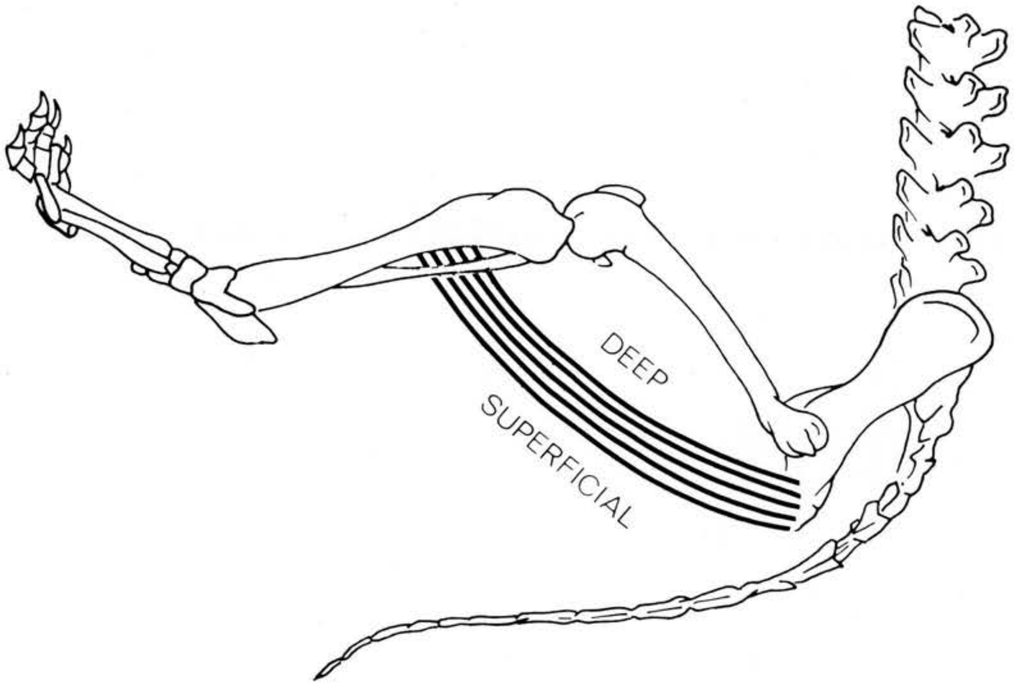
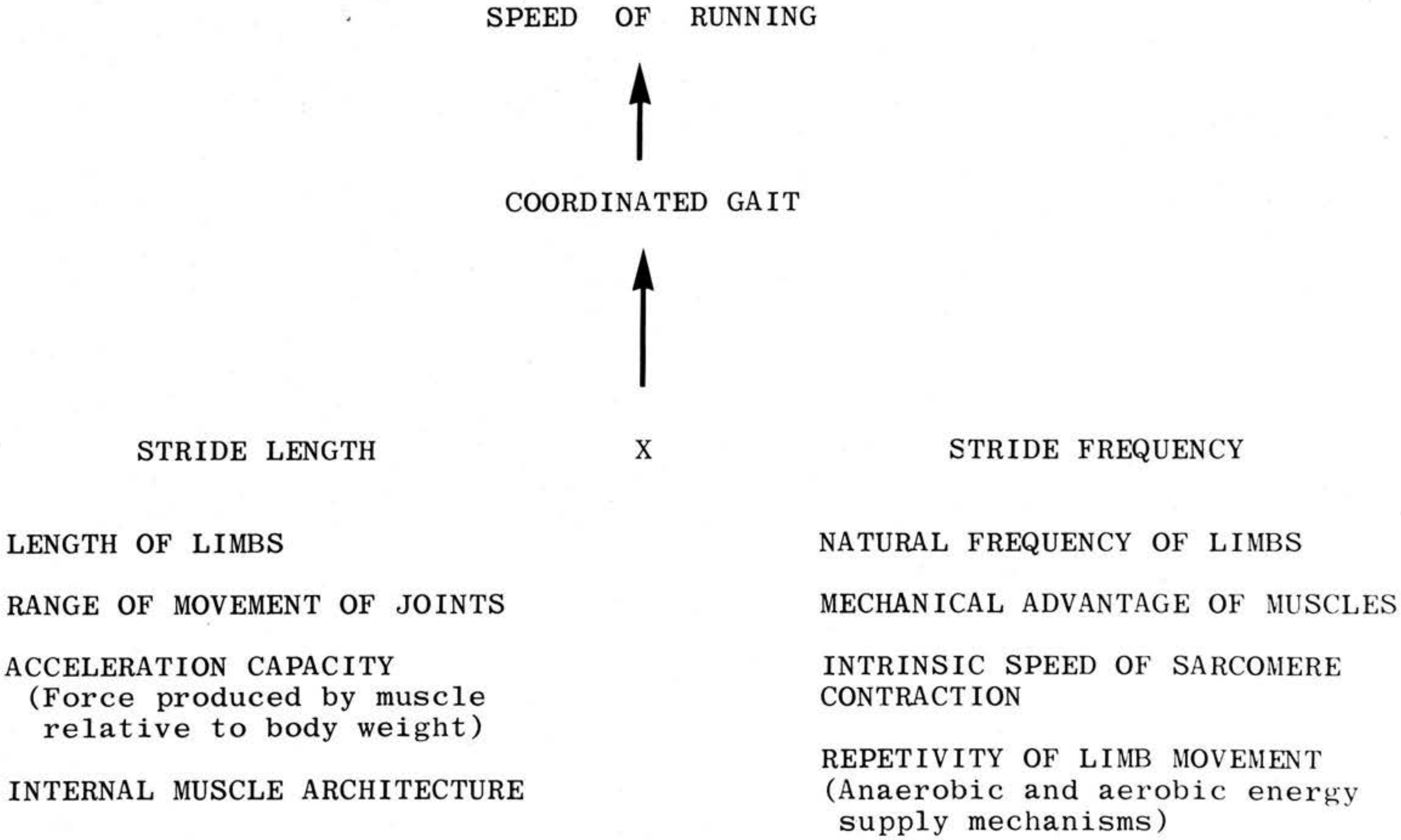

DEEP
SUPERFICIAL

Fig. 130.

Interrelationships of factors dictating the speed of running animals.



SPEED OF RUNNING

COORDINATED GAIT

STRIDE LENGTH X STRIDE FREQUENCY

LENGTH OF LIMBS

RANGE OF MOVEMENT OF JOINTS

ACCELERATION CAPACITY
(Force produced by muscle
relative to body weight)

INTERNAL MUSCLE ARCHITECTURE

NATURAL FREQUENCY OF LIMBS

MECHANICAL ADVANTAGE OF MUSCLES

INTRINSIC SPEED OF SARCOMERE
CONTRACTION

REPETIVITY OF LIMB MOVEMENT
(Anaerobic and aerobic energy
supply mechanisms)

APPENDIX 1

List for recording data obtained from total or partial muscle dissection of the horse. All weights are recorded in grammes, all linear measurements are made in centimetres and all volumes recorded in cubic centimetres.

Breed	Welsh Mountain
Sex	Male
Identification number	E4373
Age (postnatal age plus 338 days)	855 days
Weight	109,000
Respiratory system	1,190
Heart	695
Abdominal viscera including the digestive system, spleen, and urinogenital system.	30,453
Spinal cord	146
Head	8,182
Integument comprised of skin, tail, hooves, and where present mammary glands, penis, sheath, testicles and scrotum.	8,332

DATA FROM HALF CARCASS

Fat	1,984
Fascia, ligaments and scrap (blood vessels, nerves and lymph nodes)	527
Fore limb tendons	110
Hind limb tendons	200

MUSCLES AND CONSTITUENTS OF MUSCLE GROUPS

Cutaneus	399
Cutaneus colli	
Cutaneus trunci	
Attaching fore limb to the body	2,666
Sternocephalicus	
Brachiocephalicus	
Trapezius cervicalis	
" thoracalis	
Rhomboideus cervicalis	
" thoracalis	
Latissimus dorsi	
Pectorales superficiales	
" profundi	
Serratus dorsalis (cranialis and caudalis)	
" ventralis (cervicis and thoracis)	
Upper fore limb	2,018
Deltoideus	
Supraspinatus	
Infraspinatus	
Teres major	
" minor	
Subscapularis	
Coracobrachialis	
Articularis humeri	
Biceps brachii	
Brachialis	
Tensor fascia antebrachii	
Triceps brachii	

Lower fore limb	542
Anconeus	
Extensor carpi radialis	
Extensor digitorum communis	
" " lateralis	
Extensor carpi obliquus	
Flexor carpi radialis	
" " ulnaris	
Ulnaris lateralis	
Flexor digitorum superficialis	
" " profundus	
Costal muscles	848
Levatores costarum	
External intercostals	
Internal intercostals	
Retractor costae	
Transversus thoracis	
Abdominal muscles	1,430
Obliquus externus abdominis	
Obliquus internus abdominis	
Rectus abdominis	
Transversus abdominis	
Axial muscles	2,010
Omohyoideus	
Sternothyroideus	
Scalenus dorsalis	
" ventralis	
Cervicalis ascendens	

- Axial muscles continued
  - Rectus capitis ventralis major
  - " " " minor
  - Rectus capitis lateralis
  - Spinalis
  - Longissimus costarum
  - Longus colli
  - Intertransversales colli
  - Splenius
  - Longissimus capitis et atlantis
  - Complexus
  - Multifidis cervicis
  - Obliquus capitis anterior
  - " " posterior
  - Rectus capitis dorsalis major
  - " " " minor
  - Multifidis dorsi
  - Intertransversales lumborum
  - Coccygeus
  - Sacro-coccygeus dorsalis
  - " " lateralis
  - " " ventralis
  - Intertransversalis caudae
  - Retractor ani
- Iliopsoas group 638
  - Psoas major
  - " minor
  - Iliacus
  - Quadratus lumborum

Longissimus (dorsi and cervicis)		856
Upper hind limb		6,423
Semitendinosus	504	
Semimembranosus	590	
Adductor	421	
Biceps femoris	1268	
Sartorius	85	
Gracilis	250	
Pectineus	71	
Quadratus femoris	24	
Quadriceps femoris	1,040	
Tensor fasciae latae	207	
Glutei	1,885	
Obturator internus externus and gemelli	78	
Lower hind limb		798
Extensor digitorum longus		
" " lateralis		
" " brevis		
Tibialis cranialis		
Peroneus tertius		
Gastrocnemius		
Soleus		
Popliteus		
Flexor digitorum superficialis		
" " profundus		
Muscle subtotal		18,628

Diaphragm	548	
Total muscle (subtotal x 2, plus diaphragm)	37,803	
BONES		
Fore limb	1,531	
Hind limb	1,834	
Ribs and costal cartilages	941	
Bone subtotal	4,306	
Sternum	246	
Vertebrae and pelvis	4,428	
Total bone (subtotal x 2, plus sternum, vertebrae and pelvis)	13,286	
REST plus TOTAL MUSCLE plus TOTAL BONE	105,729	(97% of total body weight)

BONE LENGTHS, WEIGHTS and VOLUMES

	Length	Weight	Volume
Humerus	22·5	490	473
Radius and ulna	32·9	405	397
Femur	30·7	736	712
Tibia and fibula	28·7	473	420

APPENDIX 2

List for recording data obtained from total or partial muscle dissection of the dog. All weights are recorded in grammes, all linear measurements are made in centimetres and all volumes recorded in cubic centimetres.

Breed	Collie x Terrier
Sex	Female
Identification number	C6472
Age	1095 days
Weight	10,400
Respiratory system	165
Heart	108
Abdominal viscera including the digestive system, spleen, and urinogenital system.	1,557
Spinal cord	18
Head	890
Integument comprised of skin, tail, claws, and where present mammary glands, penis, sheath, testicles and scrotum.	1,234

DATA FROM HALF CARCASS

Fat	116
Fascia, ligaments and scrap (blood vessels, nerves and lymph nodes)	10
Fore limb tendons	7
Hind limb tendons	14

MUSCLES AND CONSTITUENTS OF MUSCLE GROUPS

Cutaneus trunci	-
Attaching fore limb to the body	354
Sternocephalicus	
Branchiocephalicus	
Latissimus dorsi	
Trapezius cervicalis	
" thoracalis	
Rhomboideus cervicalis	
" thoracalis	
" capitis	
Pectoralis superficialis	
" profundus	
Serratus dorsalis (cranialis and caudalis)	
" ventralis (cervicis and thoracis)	
Omotransversarius	
Upper fore limb	240
Deltoideus	
Supraspinatus	
Infraspinatus	
Teres major	
" minor	
Subscapularis	
Coracobrachialis	
Biceps brachii	
Brachialis	
Tensor fascia antebrachii	
Triceps brachii	

Lower fore limb

- Anconeus
- Extensor carpi radialis
- Extensor digitorum communis
  - " " lateralis
  - pollicis longus et indicus proprius
- Flexor carpi radialis
  - " " ulnaris
  - " digiti quinti
  - " digitorum brevis
  - " " superficialis
  - " " profundus
- Ulnaris lateralis
- Brachioradialis
- Pronator teres
- Pronator quadratus
- Supinator
- Abductor digiti quinti
  - " pollicis brevis et opponens pollicis
  - " pollicus longus
  - " digiti quinti
  - " digiti secundi
- Adductor pollicis
- Interossei
- Lumbricales
- Flexor pollicis brevis

Lower fore limb continued	
Interflexorii	
Palmaris brevis accessorius	
Costal muscles	106
Levantores costarum	
External intercostals	
Internal intercostals	
Retractor costae	
Transversus thoracis	
Abdominal muscles	170
Obliquus externus abdominis	
" internus abdominis	
Rectus abdominis	
Transversus abdominis	
Axial muscles	332
Sternothyroideus	
Sternohyoideus	
Scalenus	
Rectus capitis dorsalis	
" " lateralis	
" " ventralis	
Spinalis et semispinalis thoracis et cervicis	
Semispinalis capitis	
Iliocostales	
Longus colli	
Intertransversarii	
Rotatores	
Splenius	

Axial muscles continued		
Longus capitis		
Longissimus cervicis		
" capitis		
Multifidus		
Transversus costarum		
Obliquus capitis caudalis		
" " cranialis		
Coccygeus		
Sacrococcygei		
Ischiococcygeus		
Levator ani		
Intertransversarius dorsalis coccygeus		
Intertransversarius ventralis coccygeus		
Iliopsoas group		45
Psoas major		
" minor		
Illacus		
Quadratus lumborum		
Longissimus (thoracis and lumborum)		205
Upper hind limb		594
Semitendinosus	40	
Semimembranosus	63	
Adductor	90	
Biceps femoris and abductor cruris caudalis	100	

Upper hind limb continued		
Sartorius	30	
Gracilis	31	
Pectineus	5	
Quadratus femoris	4	
Quadriceps femoris (including articularis genus)	125	
Tensor fasciae latae	24	
Glutei, piriformis and capsularis coxae	65	
Obturator internus, externus and gamelli	17	
Lower hind limb		85
Extensor digitorum longus		
" " lateralis		
" " brevis		
" hallucis longus		
Tibialis cranialis		
Peroneus brevis		
Peroneus longus		
Abductor digiti I, II and V		
Adductor digiti I, II and V		
Flexor digitorum superficialis		
" " profundus		
" hallucis brevis		
Gastrocnemius		
Popliteus		
Tibialis caudalis		

Lower hind limb continued	
Interflexorii	
Lumbricales	
Muscle subtotal	2199
Diaphragm	55
Total muscle (subtotal x 2, plus diaphragm)	4453

BONES

Fore limb	101
Hind limb	112
Ribs and costal cartilages	77
Bone subtotal	290
Sternum	18
Vertebrae and pelvis	433
Total bone (subtotal x 2, plus sternum, vertebrae and pelvis)	1031
REST plus TOTAL MUSCLE plus TOTAL BONE	9750 (94% of total body weight)

BONE LENGTHS, WEIGHTS and VOLUMES

	Length	Weight	Volume
Humerus	13·5	39	30
Radius and ulna	15·5	35	22
Femur	14·2	40	30·5
Tibia and fibula	14·8	35	25

Appendix 3.

DISSECTION DATA – DOGS

Identification	Sex	Training	Liveweight (g)	Age (days)	M. Semitendinosus (g)	Femur (g)	Femoral Muscle (g)	Distal Hindlimb Muscle (g)	Proximal Forelimb Muscle (g)	Humerus	Total Muscle (g)	Total Bone (g)	M. Longissimus (g)	Total Hindlimb bones (g)	Total forelimb bones (g)	Distal Forelimb Muscle (g)	Heart (g)	M. Cutaneous (g)	Pectoral Girdle (g)	Cervical Muscles (g)	Abdominal Muscles (g)	Axial Muscles (g)	Hypomeres X5 (g)	Respiratory System (g X 10)	Abdominal Viscera (g X 10)	Spinal Cord (g)	Integument (g X 10)	Fat (g)	Head (g X 10)	Forelimb Tendons (g)	Hindlimb Tendons (g)	Humerus Length (cm)	Humerus Volume (cm³)	Radius + Ulna (g)	Radius + Ulna length (cm)	Radius + Ulna Vol (cm³)	Femur Length (cm)	Femur Volume (cm³)	Tibia + Fibula Weight (g)	Tibia + Fibula Length (cm)	Tibia + Fibula Volume (cm³)
Young Greyhounds																																									
C54 72	F	–	377	7	.46	1.98	8.26	1.84	6.27	2.72	97.42	60.75	2.37	4.78	7.77	1.74	8.17	0.067	9.90	3.13	4.20	8.44	0.887	0.102	6.98	–	4.94	0.243	5.61	0.23	0.27	4.1	2.3	2.01	4.6	1.8	4.1	1.8	1.3	8.6	1.1
C11 73	F	–	927	0	1.20	5.71	20.7	4.34	17.7	7.30	260.4	148.6	8.67	14.7	21.3	6.35	12.2	0.79	25.96	8.70	9.48	21.07	2.64	2.80	11.2	–	11.4	2.19	15.4	0.84	1.67	5.7	5.0	6.1	6.1	4.5	5.5	4.5	3.93	5.2	3.0
C9 73	F	–	1,056	14	1.32	5.70	25.0	4.81	21.98	7.67	327.5	156.2	11.69	14.9	21.9	6.03	9.86	0.00	41.9	9.63	10.5	24.3	3.43	3.28	12.6	–	16.1	8.53	14.5	0.78	1.4	5.6	6.0	6.3	6.0	4.4	5.5	4.8	3.90	5.0	3.1
C57 72	F	–	1,174	21	1.33	4.95	26.4	5.9	18.0	6.4	296.0	156.0	7.74	15.2	18.5	6.52	16.5	0.12	34.6	5.9	13.3	28.8	3.31	4.51	19.5	–	10.2	15.6	14.6	0.48	0.55	5.3	4.0	5.4	5.7	3.2	5.1	3.4	4.0	5.1	2.8
C4 73	M	–	1,423	42	1.65	12.1	28.5	4.48	22.2	13.4	300.4	266.3	10.2	10.02	37.8	2.9	20.3	0.359	26.3	10.6	10.18	25.9	3.89	4.45	29.8	–	12.7	000	34.6	0.99	1.79	9.4	10.5	11.2	8.3	9	7.6	10	9.9	9.2	7.0
C61 72	M	–	2,280	42	3.45	16.9	52.5	11.4	46	19	607	436.4	24	46.6	56	16	24	0.71	64.0	16.2	23.1	38.2	4.96	6.60	53.4	–	35.8	19.8	31.2	4.21	4.75	8.1	13	16	9.3	11.8	8.3	14	12.8	9.9	10.1
C16 73	F	–	5,712	77	15	44	266	41	135	41	2080	958	114	127	127	38	59	4.0	170	52	568	125.0	28.0	10.7	95.7	12	48.8	9.0	52.2	8.0	10.0	12.1	33	40	14.1	30	13.6	36	34	13	26
C19 73	F	–	11,000	119	37	69	595	89	268	64	4338	1561	235	191	205	73	89	6.0	268	113	116	258.0	60	29.0	235	18	831	24	74.6	11.0	14.8	15.3	47	62	18.5	44	16.8	56	54	17.2	31
C23 73	F	–	15,250	168	63	85	980	147	455	76	7,206	1,920	465	244	241	106	158	13.0	543	142	195	434.0	73	40.4	296	23	101	99	96.1	23.0	24.0	17.4	50	95	21.4	52	18.8	62	74	20.3	52
C25 73	M	–	17,750	175	80	107	1280	189	590	102	9,563	2,531	606	307	317	132	185	33.0	810	202	265	495	131	49.5	264	30	136	19	121	23.0	25	19.1	74	100	23.4	72	20.8	75	94	22.2	65
C29 73	F	–	23,500	365	124	90	1764	250	758	86	12,455	2,272	821	245	248	154	305	78.0	930	290	345	652	150	46.9	366	30	136	196	129	20.0	21	20	57	69	23.9	43	21.6	65	75	22.2	50
Adult Greyhounds																																									
168 71	F	+	19,000	1460	103	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
190 71	F	+	21,520	–	107	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
140 71	F	+	22,300	639	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48 71	M	+	23,300	–	102	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C34 72	F	D	26,150	1,825	110	103	1,661	223	855	101	13,397	2,550	685	293	302	193	334	50	1,190	255	357	968	162	33	312	–	161	310	126	16	33	19.5	68	–	–	–	21.0	90	–	–	–
164 71	M	+	24,884	1825	134	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C45 72	F	+	25,000	730	124	121	1,832	249	850	113	14,088	2,919	818	338	342	187	419	30	1,285	265	379	932	172	29	266	–	169	000	122	13	35	19.7	70	95	24.1	60	21.8	82	114	25.2	65
C30 72	M	+	25,200	1460	113	137	1,901	266	956	135	14,692	3,306	973	340	406	194	365	53	1,125	283	413	1,003	134	40	161	–	113	000	127	–	–	21.8	90	–	–	–	23.2	100	110	–	99.5
C41 72	M	D	25,300	1,825	127	126	1,953	244	900	116	16,422	3,123	719	350	363	173	326	15	1,366	261	490	992	142	47	275	–	168	65	127	8	35	19.9	90	–	–	–	21.8	90	105	22.5	80
95 71	M	+	25,540	–	127	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
219 71	M	+	26,500	–	140	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	24.7	–	–	–	–
175 71	M	+	27,200	1,825	136	137	2041	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	23.1	–	–	–	–
180 71	M	+	27,500	1460	133	135	2321	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	23.9	–	–	–	–
C20 72	M	+	28,000	1,095	177	137	2530	260	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	23.6	100	119	23.9	80
117 71	M	+	28,409	–	152	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C44 72	F	D	28,500	2,555	130	141	2,148	290	1,041	126	15,742	3,259	815	386	305	201	422	32	1,295	325	417	1,074	176	95	322	–	182	195	138	30	46	21.2	95	105	25.4	90	21.0	110	117	24.2	85
193 71	M	+	28,864	–	140	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
171 71	M	+	29,100	–	145	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
252 70	M	+	29,500	–	145	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
136 71	M	+	29,545	–	140	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C35 72	F	+	29,750	1,095	150	172	2,267	310	1,120	162	17,983	4,310	1,422	492	486	230	460	50	1,522	310	488	993	215	38	197	–	153	0.00	156	18	37	23.1	113	–	–	–	26.5	110	–	–	–
144 71	M	+	30,000	1,460	149	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
179 71	M	+	30,000	1,460	142	139	2,135	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C48 72	M	D	30,000	1643	151	149	2,287	299	1,152	142	19,213	3,684	863	405	439	203	449	25	1605	391	580	1,000	170	95	317	–	180	70	148	36	63	22.5	100	125	25.4	83	22.3 23.5	80	126	24.3	110
149 71	M	+	31,200	1,278	162	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
176 91	M	+	31,400	730	171	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	22.2	–	–	–	–
118 71	M	+	32,500	–	152	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
172 71	F	+	33,523	–	163	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C16 72	F	+	33,608	730	158	157	2,475	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	23.6	–	–	–	–
255 70	M	+	34,800	–	180	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
165 71	M	+	34,000		170	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32 71	M	+	34,091	730	147	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C18 72	M	+	37,000	1,825	176	165	2,924	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	23.2	120	–	–	–
Young Other Dogs																																									
Collie X 27 71	M	–	400	1	.129	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Labrador 182 71	M	–	464	2	.60	1.86	8.97	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X C2 72	F	–	527	14	.53	1.74	8.24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Labrador 181 71	F	–	573	4	.67	2.50	10.96	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X C8 73	F	–	785	23	.66	3.85	10.68	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X C6 72	M	–	931	21	.94	4.06	12.91	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie C12 72	M	–	976	42	1.05	6.5	16.33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Labrador 200 71	M	–	1,010	14	.96	4.22	17.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X C10 72	M	–	1,285	35	1.58	5.5	23.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cairn Terrier C10 73	F	–	1,256	56	2.20	6.77	34.5	6.99	23	6.39	329.5	151.9	11.97	18.3	16.2	6.53	12	1.0	21	7.64	4.1	21.5	3.57	2.9	24.8	50	10.0	48	4.2	147	1.80	6.55	5	5.46	7.3	4.5	6.9	5.5	4.85	6.8	4
Collie X 212 71	M	–	3,180	106	4.27	17.9	74.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X 208 71	F	–	3,843	106	6.47	19.3	106.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X 251 71	M	–	6,000	183	11.4	34.8	181	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Boxer X C17 73	F	–	6,585	91	15	33	232	48.5	143	34	3,120	823	45	96.3	119	48	63	6	170	58	85	182	21	16.5	108	15	850	158	67.5	7	8	11.3	25	30	17.0	22	11.8	24	25	11.9	19
Terrier 49 71	M	–	7,960	152	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Boxer X C21 73	M	–	8,500	133	34	40	344	68	201	40	3,024	999	142	117	122	55	66	18	279	80	110	164	26	22.4	117	17	123	223	80.6	9	10	13.1	30	35	15.8	26	13.1	30	35	14.2	27
Collie 249 71	F	–	9,023	183	23	43.4	362	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Boxer X C27 73	F	–	9,900	161	36	46	523	100	274	44	4,183	1120	222	136	143	77	85	20	303	96	134	259	54	28.2	151	20	120	92	99.0	10	14	13.6	29	40	16.6	26	15.0	33	41	15.5	28
Adult Other Dogs																																									
Collie X 207 71	F	–	7,762	4,700	24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Labrador x Terrier 26 71	M	–	10,185	–	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie x Terrier C64 72	F	–	10,400	1,095	40	40	594	85	240	39	4,453	1031	205	112	101	68	108	000	354	106	170	332	45	17	149	18	123	116	89	7	14	13.5	30	35	15.5	22	14.2	31	35	14.8	25
Collie 215 71	F	–	11,000	1100	31	39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	150	–	–	–	–
Collie x Terrier 24 71	F	–	11,230	–	27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X 203 70	M	–	11,360	–	46	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Collie X 241 71	F	–	12,000	548	42	45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15.7	–	–	–	–
Collie 238 71	M	–	14,100	2,190	39	65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17.6	–	–	–	–
Collie 213 71	F	–	22,000	3650	55	75	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17.3	–	–	–	–
Afghan C2 73	F	–	25,100	1,460	106	137	1,743	270	947	129	12,639	3,276	685	372	401	820	258	40	947	277	197	818	135	13	223	28	219	407	178	31	58	29.2	94	112	28	68	25.6	91	116	29.0	77
Afghan C4 73	M	–	31,900	1,460	114	146	1,924	278	1,021	148	14,509	3,698	920	385	453	199	330	34	1,065	412	429	775	165	62	346	32	275	111	804	43	75	24	102	123	27	78	25.7	104	118	26.0	79
Labrador C37 72	F	–	33,000	2548	68	119	1,312	261	804	135	11,250	3,470	458	346	399	229	292	3	861	268	390	914	48	89	538	–	332	183	251	80	160	18.1	87	–	–	–	19.8	82	–	–	–
Great Dane C59 72	M	–	46,500	2,920	120	276	2,339	434	1,438	298	20,895	7,396	910	793	892	393	414	4	2,165	585	598	1,287	205	109	183	39	711	478	303	34	85	26.5	256	243	309	162	29.1	286	276	29.9	198

M = Male F = Female + = In training D = Detained

Appendix 4.

DISSECTION DATA – HORSES

Identification	Sex	Training	Liveweight (g)	Age (Estimated age or days ÷ 358 days)	M. Semitendinosus (g)	Femur (g)	Femoral Muscle (g)	Distal Hindlimb Muscle (g)	Proximal Extensor Muscle (g)	Humerus (g)	Total Muscle (g)	Total Bone (g)	M. Longissimus (g)	Total Hindlimb Bones (g)	Total Forelimb Bones (g)	Distal Forelimb Muscle (g)	Heart (g)	M. Cutaneous (g)	Pectoral Girdle (g)	Costal Muscles (g)	Abdominal Muscles (g)	Axial Muscles (g)	M. Gluteus (g)	Respiratory System (x10 g)	Abdominal Viscera (g)	Spinal Cord (g)	Integument (g)	Fat (g)	Head (x100 g)	Femoral Tissues (g)	Humerus Tissues (g)	Humerus Length (cm)	Humerus Volume (x10 cm³)	Radius + Ulna Weight (x10 g)	Radius + Ulna Length (cm)	Radius + Ulna Volume (x10 cm³)	Femur Length (cm)	Femur Volume (x10 cm³)	Tibia + Fibula Weight (x10 g)	Tibia + Fibula Length (cm)	Tibia + Fibula Volume (x10 cm³)
Young Thoroughbreds																																									
E13172	M	—	691	154	1.3	4.7	30.8	3.6	13.5	3.7	274.6	111.73	9.6	13.9	14.3	4.3	7.3	000	19.5	6.8	6.3	30.8	5.1	3.12	67	3.8	7.1	0.1	1.0	1.0	0.5	4.2	0.3	0.3	6.3	0.3	5.5	1.0	0.3	5.3	0.3
E2872	F	—	11,000	338	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E173	F	—	13,429	274	30.3	178	415	80.3	162.7	100.6	2,806	3004	123.5	459.1	341	53.8	178.2	53.2	1327	63.6	72.4	170.7	41.8	55.8	3544	68	991.2	0.1	15.1	—	—	14.1	8.0	9.2	20.2	7.2	17.6	16	12	18.1	9.0
E4072	M	—	16,000	337	45	205	543	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E6272	F	—	19,000	326	50	280	585	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	24	20	21.3	20
E373	F	—	23,872	314	117.5	407	1451	250.8	510	210.8	8,909	5,747	352.3	1,134	791	230	300	13.5	577	169	163	4730	1498	102	2,343	58	2635	16	22	87	192	16.8	18.2	24.0	26.0	18	22.6	32	28	23.5	23
E2672	F	—	26,000	318	85	372	1,109	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E4272	M	—	28,000	285	112	340	1,323	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E6072	M	—	29,000	326	101	465	1,093	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	22.9	41	33	24.2	28
E573	F	—	30,965	311	144	487	1,751	370	—	—	—	—	—	—	—	—	441	16.4	—	—	—	—	119.1	126	4,821	—	—	—	36	—	—	—	—	—	—	—	22.4	41	34	23.5	28
E1272	M	—	31,500	321	125	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E5372	M	—	33,500	330	133	503	1,714	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	24	49	35	26	38
E2572	M	—	34,500	274	145	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E2072	F	—	34,800	341	147	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E1772	M	—	39,000	338	189	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E2173	F	—	40,500	340	220	730	2366	423	940	410	16,257	11,497	123	1,998	1,594	352	425	64	1,125	308	260	1,155	555	124	2,595	110	3,335	0.1	27	49	116	21.1	35.5	41.0	31.2	37	27	56	47	27.7	41
E6872	M	—	42,000	338	180	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E1773	F	—	42,962	338	215	685	2,475	546	1,198	410	16,759	10,896	506	1,963	1,594	433	482	000	1,305	320	347	972	258	153	3,565	85	3,860	0.1	33	150	190	20.6	38.4	44.0	31.2	63	26.4	59	46	27.3	68
E3172	F	—	50,000	338	250	765	2,997	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E1673	F	—	58,664	346	284	992	3,577	532	1,418	595	23,699	15,295	1,729	2,651	2,013	454	625	1.5	1,616	411	326	1,467	184	159	6,188	85	2,958	0.1	37	184	38.3	22.1	47.1	48.2	33.8	47	28.4	74	58	29.1	53
E5072	F	—	337,880	903	2,485	2,325	29,210	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	41.7	—	—	—	—
24970	CH	—	420,000	890	3,024	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E4673	M	—	432,427	886	3,105	2,880	34,392	3,792	9,965	1,844	191,883	53,855	5,400	7,023	5,961	2,378	3,699	2,312	13,080	3,901	5,547	10,398	3,306	718	120,700	212	16,654	6,306	153	315	595	36.2	165	166	50.9	127	47.6	229	179	43.4	149
Adult Thoroughbreds																																									
22771	F	+	445,455	1068	2,670		—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E4672	F	+	458,182	1,433	2,895	2,650			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	45	—	—	—	—
E7272	F	+	470,909	1,068	3,715	2,272	39,498		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E7272	F	D	470,909	1,433	3,298	2,414	33,388		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E6472	F	+	483,636	1,433	4,040	2,360	41,649		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15871	CH	+	509,091	3,258	3,870	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E2272	F	D	560,000	2,528	3,870	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Young Other Horses																																									
Connemara X Pony 23571	F	—	2,150	160	8.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Welsh Mountain Pony E12772	M	—	2,977	158	12.99	21	158	26.5	60.0	12.5	1,272	384	138	52.6	44.2	18.4	29.97	18.4	99	18	300	29.5	14.4	108	274	11.4	21.4	7.23	4.99	6.27	8.98	6.8	0.9	1.2	9.1	0.8	8.7	2.0	1.4	7.9	1.1
Dartmoor Pony E9472	F	—	22,000	339	105	400	1,620	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	32.4	38	—	—	—
Welsh Mountain Pony E4373	M	—	109,091	855	504	736	6,423	798	2,018	480	37,803	13,286	856	1,843	1,531	542	695	399	2,666	848	1,430	2,010	638	119	30,483	146	8,132	1,984	81	110	200	22.5	47	41	32.9	40	30.7	71	47	28.7	42
Welsh Mountain Pony E3073	F	—	114,546	703	507	618	6,517	791	1,617	394	39,051	11,373	980	1,545	1,254	499	590	520	2,408	1,657	1,155	2,631	583	102	—	135	8,068	630	50	60	132	22.6	34	35	32.5	32	29.7	49	41	29.3	40
Welsh Mountain Pony E9772	M	—	118,182	703	625	782	7,523	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30.8	67	51	29	52
Welsh Mountain Pony E12072	M	—	153,727	886	828	815	9,137	1,138	2,907	560	—	—	—	2,961	1,731	712	695	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	40	47	32.6	41	31.2	67	55	28.4	56
Welsh Mountain Pony E9072	M	—	178,182	703	925	1,042	10,706	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	33.5	89	—	—	—
Fell x Palomino Pony 24971	M	—	207,273	521	1,300	—	13,811	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arab x Thoroughbred E5972	M	—	39,000	326	192	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
[illegible] x Thoroughbred 1872	M	—	62,000	348	482	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arab X Thoroughbred 9871	M	—	203,636	460	1,070	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Adult Other Horses																																									
Shetland Pony E172	M	+	153,727	1,798	590	510	7,305	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	24.5	—	—	—	—
Welsh Mountain Pony E1273	M	—	178,182	1,433	958	1,132	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Shetland Pony E3673	CM	+	203,636	3,258	1,254	1,127	12,236	1,604	4,790	770	35,054	29,402	2,024	2,712	2,442	1,165	1,471	1,376	4,561	1,685	2,963	5,852	1,926	233	32,799	100	15,502	5,149	114	107	243	26.3	57	62	36.1	40	35.2	98	68	30.9	48
Welsh Mountain E12872	F	+	229,091	2,528	1,082	965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	34.1	84	—	—	—
Shetland Pony E8172	M	+	280,000	1,798	1,200	925	11,320	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	31.4	73	56	27.5	44
Connemara X 12271	F	—	305,455	4,918	1,260	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arab E3373	F	—	305,455	2,528	1,795	—	—	—	—	—	—	—	—	—	—	—	2,170	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Connemara X 23371	F	—	318,182	1,433	1,245	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Piebald E773	F	—	318,182	2,528	1,690	—	—	—	—	—	—	—	—	—	—	—	2,405	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exmoor X 12471	M	+	356,364	3,258	1,605	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Connemara X E8872	F	+	445,455		2,335	1,955	26,724	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	41.9	153	116	37	93
Welsh Mountain Pony 4471	M	+	458,182	2,528	1,968	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exmoor X Pony 24570	M	—	480,000	3,258	2,200	—	—	—	—	—	—	—	—	—	—	—	3,850	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Connemara X E10572	CM	+	490,000	2,893	2,304	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Clydesdale E3973	F	—	494,364	2,528	2,910	3,680	33,064	3,957	11,490	2,300	223,997	70,420	5,482	8,652	7,892	4,922	3,510	2,138	16,510	4,080	6,410	17,504	4,342	838	79,418	354	48,497	873	238	570	689	36.5	194	209	49.8	171	47.4	288	217	36.4	163
Cob E12372	CM	—	547,273		3,670	—	—	—	—	—	—	—	—	—	—	—	4,440	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thoroughbred X E5672	F	—	356,364	1,068	1,260	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thoroughbred X E4073	M	—	369,091	1,433	2,472	3,135	28,594	3,311	—	—	—	—	—	7,518	—	—	3,310	—	—	—	—	—	2,914	489	—	—	—	—	182	—	537	—	—	—	—	—	47.1	275	193	42.5	179
Thoroughbred X E2673	M	—	432,727	1,250	2,340	2,032	30,473	2,975	8,504	1,380	170,880	34,564	4,133	4,843	4,231	2,058	—	2,379	12,465	2,831	5,814	9,855	2,663	—	—	200	19,816	1,902	160	290	415	31.9	113	108	42.6	79	42.5	162	122	37.4	92
Thoroughbred X E11572	M	+	521,818	3,258	3,362	2,576	37,218	3,611	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	44.5	297	153	39.3	109
Thoroughbred X E11172	F	+	536,545	2,893	3,362	1,360	41,253	3,608	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	40.5	181	132	38.5	99

M = Male　CH = Castrated Male　F = Female　+ = In training　- = Never trained　D = Out of training

Appendix 5.

HISTOMETRIC DATA – DOGS

						M. Semitendinosus													M. Diaphragma							M. Pectoralis transversus						
	Identification	Sex	Training	Age (days)	Liveweight (g)	T.S.A. (x 1,000,000 µm²)	Total Nos. of fibres (x 1000)	Mean fibre area (µm²)	Total No. of AL fibres	% AL Nos.	Total AL area (x1000 µm²)	Mean AL area (µm²)	% Area AL	Total Nos. of AH fibres (x 1000)	Mean AH area (µm²)	% AHSH Nos.	Capillary to fibre ratio	Area per capillary (µm²)	Mean fibre area (µm²)	% AL Nos	Mean AL area (µm²)	% Area AL	Mean AH area (µm²)	Capillary to fibre ratio	Area per capillary (µm²)	Mean fibre area µm²	% AL Nos	Mean AL area (µm²)	% Area AL	Mean AH area (µm²)	Capillary to fibre ratio	Area per capillary (µm²)
Young Greyhounds																																
	C5072	M	–	0	222	21.4	185	116	5,477	3.0	893	163	4.0	180	114	97	—	—	253	8.0	328	10	244	0.09	3,333	233	6.0	163	4.0	238	0.09	3,378
	C5272	M	–	1	260	29.5	230	128	4,133	2.0	1,033	250	4.0	226	126	98	—	—	257	4.0	419	8.0	250	0.07	3,827	180	2.0	189	3.0	129	0.01	4,146
	C5472	F	–	7	377	39.4	280	141	5,197	2.0	1,751	337	4.0	275	137	98	—	—	163	3.0	344	8.0	156	0.06	2,569	160	2.0	391	6.0	154	0.07	2,329
	C1173	F	–	0	927	34.5	219	158	4,304	2.0	779	181	2.0	214	157	98	—	—	328	8.0	260	6.0	336	—	—	339	4.0	206	3.0	345	—	—
	C973	F	–	14	1,056	76.0	289	263	4,448	2.0	2,119	471	3.0	285	260	98	—	—	410	8.0	450	9.0	407	0.14	3,024	321	2.0	433	3.0	318	0.06	5,000
	C5772	F	–	21	1,174	95.8	300	183	4,407	2.0	2,358	535	4.0	296	178	98	0.07	2,660	360	16	975	34	281	0.34	1,005	294	20	548	5.0	288	0.13	2,206
	C6172	M	–	42	2,280	83.0	173	479	37,522	22	18,348	489	22	136	469	78	0.73	659	420	36	461	40	397	0.44	964	361	23	480	28	340	0.35	1,027
	C1673	F	–	77	5,712	190.0	208	915	41,366	20	26,516	641	14	166	983	80	0.75	1,214	821	27	718	24	858	0.72	1,147	710	28	582	23	759	0.59	1,198
	C1973	F	–	119	11,000	405.0	270	1,500	42,170	16	43,182	1,024	11	228	1,588	84	1.06	1,410	1,179	32	693	16	1,408	0.91	1,298	1,250	29	973	17	1,442	0.86	1,448
	C2373	F	–	168	15,250	674	274	2,460	23,910	9.0	55,375	2,315	8.0	250	2,474	91	1.19	2,066	1,109	33	981	23	1,191	0.87	1,253	1,684	23	1,659	22	1,690	1.31	1,296
	C2573	M	–	175	19,750	714	331	2,155	26,705	8.0	47,481	1,778	7.0	305	2,188	92	1.46	1,480	1,488	35	1,338	31	1,568	1.20	1,242	1,569	30	1,432	27	1,628	1.82	1,234
	C2973	F	–	365	23,500	875	337	2,595	26,513	9.0	49,632	1,872	6.0	311	2,657	92	1.65	1,569	2,193	39	1,255	24	2,733	1.19	1,850	2,604	23	1,494	13	2,936	1.56	2,168
Adult Greyhounds																																
	14871	F	+	1,460	19,000	711.0	280	2,543	4,947	18	11,101	2,243	1.6	275	2,548	98	2.08	1,226	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	14071	F	+	439	22,300	980.0	295	3,326	3,941	13	9,054	2,415	0.92	291	3,338	99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C3972	F	D	1,825	24,150	985.0	230	4,280	22,355	9.7	49,114	2,197	5.0	208	4,506	90	2.48	1,927	1,485	34	1,355	25	2,571	2.34	897	4,006	42	2,130	22	5,366	2.21	1,814
	16471	M	+	1,825	24,884	843.0	348	2,425	11,802	3.4	29,534	2,333	3.3	336	2,425	97	2.40	1,631	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C4572	F	+	730	25,000	800.0	322	2,481	5,405	1.7	8,879	1,643	1.1	317	2,495	98	2.28	1,089	1,680	29	1,353	23	1,814	1.69	995	2,609	14	2,098	12	2,898	2.10	1,205
	C3072	M	+	1,460	25,200	833.0	209	3,184	5,228	2.5	14,040	3,068	1.9	204	4,008	97	2.31	1,726	1,657	27	1,952	31	1,529	1.91	869	3,304	16	2,799	13	3,340	2.19	1,509
	C4172	M	D	1,825	25,300	1,339.0	529	2,530	11,146	2.1	22,940	2,055	1.7	518	2,540	98	1.97	1,286	1,834	16	1,482	13	1,901	1.35	1,363	3,112	12	2,226	9.0	3,235	1.98	1,966
	17571	M	+	1,825	27,200	907	313	2,899	13,605	4.3	29,169	2,144	3.2	299	2,933	96	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	18071	M	+	1,460	27,500	1,090	282	3,876	5,934	2.1	18,081	3,047	1.6	276	3,888	98	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C2072	M	+	1,095	28,000	900	232	3,882	6,064	2.6	9,684	1,597	1.1	226	3,923	97	2.50	1,553	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C4472	F	D	2,555	28,500	911	329	2,771	8,903	2.7	18,803	2,112	2.1	321	2,784	98	2.09	1,339	1,792	23	1,000	13	2,031	1.49	1,200	3,363	13	2,481	9.0	3,466	2.07	1,625
	17371	M	+	1,095	25,864	915	528	2,773	3,175	0.97	7,515	2,367	0.82	324	2,797	99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C3572	F	+	1,095	29,950	1,178	464	2,918	2,083	0.52	6,474	3,214	1.56	402	2,916	99	2.20	1,327	1,543	20	2,022	27	1,622	1.71	903	3,869	12	1,856	6.0	4,144	2.43	1,590
	14471	M	+	1,460	30,000	984	352	2,798	1,165	0.35	2,747	2,361	0.32	301	2,900	99	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C4872	M	D	1,643	30,000	1,193	319	3,737	7,950	2.5	19,547	2,333	1.4	311	3,775	97	2.19	1,965	2,708	19	2,228	16	2,816	2.06	1,315	3,538	17	2,666	17	3,852	2.15	1,648
	14971	M	+	1,278	31,200	1,121	348	3,223	13,317	5.3	54,801	3,161	5.1	329	3,230	95	1.96	1,645	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	17671	M	+	731	31,461	1,123	346	3,250	8,667	4.5	31,536	3,647	2.8	337	3,260	97	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	17271	F	+	639	33,523	965	306	3,151	14,591	4.8	31,254	2,142	3.3	292	3,202	95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C1672	F	+	730	33,608	947	260	3,647	9,022	3.1	11,052	1,378	1.2	252	3,719	97	2.18	1,672	1,604	29	1,630	30	1,593	—	—	3,538	19	2,212	11	3,568	—	—
	3271	M	+	730	34,081	941	320	2,961	16,399	4.5	26,571	1,847	2.8	306	2,993	95	2.20	1,325	1,627	30	1,628	29	1,582	—	—	—	—	—	—	—	—	—
	C1872	M	+	1825	37,000	1,194	355	3,311	16,993	4.8	38,967	2,283	3.3	335	3,363	95		—	2,083	34	1,547	29	2,358	1.66	1,056	3,897	25	2,543	20	3,897	2.18	1,316
Young Other Dogs																																
Labrador	18271	M	–	2	464	41.1	143	288	5,775	4.0	1790	310	4.0	137	289	96	0.02	38,462	470	9.0	590	11	460	0.03	15,615	—	—	—	—	—	—	—
Collie X	C272	F	–	14	527	20.2	120	262	4,766	4.0	1,406	295	5.0	115	251	96	0.15	1,689	675	9.0	688	10	659	0.45	1,493	571	6	615	6	568	—	—
Labrador	18171	F	–	2	573	47.0	141	335	5,006	4.0	1,807	361	4.0	136	333	96	0.06	6,173	455	6.0	489	0.6	453	0.10	4,464	—	—	—	—	—	—	—
Collie X	C872	F	–	23	785	30.7	132	233	9,212	6.0	2,275	277	7.0	124	230	94	0.30	765	344	38	360	40	334	0.50	688	339	24	296	21	362	0.36	952
Collie X	C572	M	–	21	931	42.7	141	303	9,901	7.0	3,356	339	8.0	131	301	93	—	—	562	36	594	38	549	—	—	423	22	632	33	365	0.20	2083
Collie	C1272	M	–	42	976	37.5	99	279	28,901	29	7,746	268	21	70	425	71	0.63	606	469	45	408	39	520	0.57	817	358	41	386	44	339	0.47	765
Labrador	20071	M	–	14	1,010	35.0	151	232	4,584	3.0	1,407	307	4.0	146	230	96	0.68	340	438	16	371	14	451	—	—	598	13	638	14	592	0.41	1,286
Collie X	C1072	M	–	35	1,235	54.0	114	472	18,518	16	4,241	499	17	96	466	84	0.68	691	617	39	525	33	675	0.54	1152	623	40	471	30	925	0.58	1,087
Collie X	21271	M	–	106	3,180	118.0	126	938	55,254	44	35,694	646	30	71	1,167	56	0.91	1,029	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Collie X	20971	F	–	106	3,843	133.0	186	716	40,678	26	31,397	645	24	137	942	74	—	—	617	49	605	48	627	0.71	874	778	32	924	37	740	0.97	819
Collie X	25171	M	–	183	6,000	192.0	114	1,687	41,563	37	60,366	1,450	31	72	1,823	63	1.04	1,618	781	43	871	52	713	0.87	896	967	58	1142	38	726	0.97	995
Boxer X	C1772	F	–	91	6,585	225.0	183	1,222	34,002	19	27,712	815	12	149	1,329	81	1.17	1,053	1,237	54	935	41	1,587	1.06	1,170	1,450	52	969	35	1,978	1.08	1,341
Terrier	4971	M	–	152	7,960	225.0	120	1,870	53,268	28	47,360	1,424	21	87	2,041	92	1.95	962	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Boxer X	C2173	M	–	132	8,500	307.0	167	1,841	44,209	27	50,821	1,148	17	123	2,080	93	1.41	1,309	1,542	53	1,620	49	1,678	1.21	1,279	1,618	46	1,506	43	1,714	1.15	1,409
Collie	24971	F	–	183	9,023	394.0	166	2,370	67,332	35	120,968	2,106	31	109	2,508	70	1.10	161	1,077	49	856	40	1,281	0.83	1,289	1,532	52	1,317	44	1,762	1.00	1,539
Boxer X	C2773	F	–	161	9,900	429.0	222	1,934	37,331	17	63,164	1,692	15	185	1,999	85	1.88	1030	1,933	51	1,918	51	1,949	1.57	1,210	1,913	53	1,523	42	2,350	1.53	1,249
Adult Other Dogs																																
Collie	20771	F	–	670	7,742	226.0	132	1,712	29,333	22	49,466	1,686	22	103	1,719	78	1.46	1,177	1344	46	1310	47	1,389	1.70	929	2207	56	2209	56	2,206	1.90	1,185
Collie x Terrier	C6472	F	–	1,095	10,400	493.0	184	2,674	36,433	20	69,984	1,921	14	148	2,859	80	1.90	1,410	1,183	55	1,551	72	733	1.22	971	1,686	60	2,186	78	936	1.27	1,333
Collie	21571	F	–	1,100	11,000	370.0	139	2,662	38,480	28	65,301	1,697	18	101	3,032	72	1.75	1,525	1,453	52	1,166	42	1,259	1.13	1,211	2,198	56	2,176	56	2,226	1.46	1,539
Collie	24171	F	–	548	12,000	448.0	188	2,379	63,242	34	119,118	1,884	27	125	2,630	66	1.48	1,609	1,453	52	1,166	42	1,359	1.13	1,211	2,198	56	2,176	56	2,226	1.46	1,539
Collie	23871	M	–	2390	14,100	346.0	136	2,540	25,841	19	44,550	1,724	13	111	2,730	81	—	—	1,278	54	960	41	1,650	—	—	2,633	47	2,125	38	3,083	—	—
Collie	21371	F	–	3,650	22,800	371	155	2,390	18,435	12	37,846	2,052	10	137	2,436	88	2.10	1,005	1,390	59	1,103	48	1,785	1.44	855	2,015	56	1,639	48	1,998	1.78	953
Afghan	C273	F	–	1,460	25,100	895	214	3,722	31,482	15	87,456	2,778	11	182	3,885	85	2.13	1,952	1,554	42	1,174	49	1,475	1.90	1,223	5,492	42	5,492	36	6,003	2.75	2,006
Afghan	C473	M	–	1,460	31,900	627	194	3,240	18,308	10	43,939	2,400	7.0	175	3,328	90	2.19	1,472	1,789	60	1,789	59	1,786	1.67	1,749	5,090	51	4,902	48	5,655	3.90	1,383
Labrador	C3772	F	–	2,548	33,000	382	175	2,193	21,533	12	57,035	2,649	15	153	3,118	88	1.88	1,159	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Great Dane	C5972	M	–	2,920	46,500	625	248	2,521	22,144	8.9	33,590	1,616	5.4	226	2,521	91	2.05	1,231	—	—	—	—	—	—	—	3,585	50	3,196	44	4,013	2.10	2,000

M = Male F = Female + = In training D = Detrained.

Appendix 6.

HISTOMETRIC DATA – HORSES

	Identification	Sex	Training	Age (Postnatal age in days + 280 days)	Liveweight (g)	M. Semitendinosus													M. Diaphragma							M. Pectoralis transversus						
						T.S.A. ($\times 10^6\ \mu m^2$)	Total no. of fibres ($\times$ 1,000)	Mean fibre area (μm^2)	Total no. of AL fibres	% AL No.	Total AL area ($\times$ 1,000 μm^2)	Mean AL area (μm^2)	% Area AL	Total no. AH fibres ($\times$ 1,000)	Mean AH fibre area (μm^2)	% AHSH No.	Capillary to fibre ratio	Area per capillary (μm^2)	Mean fibre area (μm^2)	% AL No.	Mean AL area (μm^2)	% Area AL	Mean AH area (μm^2)	Capillary to fibre ratio	Area per capillary (μm^2)	Mean fibre area (μm^2)	% AL No.	Mean AL area (μm^2)	% Area AL	Mean AH area (μm^2)	Capillary to fibre ratio	Area per capillary (μm^2)
Young Thoroughbreds																																
	E2872	F	–	338	11,000	174	657	265	44,718	2·2	12,968	290	2·4	662	280	98	–	–	244	41	247	41	242	–	–	161	8	187	9	159	–	–
	E173	F	–	274	13,429	91	992	115	13,728	1·7	1,473	107	1·6	778	115	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	E4072	M	–	337	16,000	224	1,155	194	12,544	0·6	2,647	211	0·70	1,142	194	43	–	–	273	23	289	24	268	–	–	332	19	384	22	320	–	–
	E6272	F	–	326	19,000	153	605	253	35,673	0·8	8,312	233	0·71	569	255	52	–	–	382	35	474	43	332	–	–	319	21	395	25	304	–	–
	E373	M	–	314	23,872	475	898	529	36,100	3·4	12,310	341	2·5	862	537	13	0·98	541	398	32	636	51	286	0·98	411	407	9	394	9	408	1·01	402
	E2672	F	–	318	24,000	415	811	512	15,480	1·9	4,907	317	1·2	795	516	66	–	–	357	26	461	33	321	–	–	468	13	428	12	451	–	–
	E4272	M	–	285	28,000	419	999	420	36,815	2·3	13,327	362	3·2	962	421	26	0·98	426	–	–	–	–	–	–	–	408	8	387	7	410	0·71	596
	E6072	M	–	326	29,000	401	1,253	320	33,083	1·7	8,900	266	2·2	1,220	321	52	–	–	372	36	661	64	211	–	–	378	18	448	22	362	–	–
	E573	F	–	311	30,965	569	1,459	390	49,559	0·87	16,354	330	0·71	1,409	391	33	0·84	464	354	36	443	45	304	0·76	464	414	10	347	9	422	0·88	424
	E1272	M	–	321	31,500	544	1,234	442	46,751	1·4	14,867	318	1·0	1,187	443	37	–	–	–	–	–	–	–	–	–	648	22	545	18	677	–	–
	E2372	F	–	317	32,000	596	1,209	493	63,260	2·0	21,255	336	1·6	1,146	502	34	0·67	740	318	41	444	57	232	–	–	468	24	370	19	499	–	–
	E5372	M	–	330	33,500	516	985	524	58,674	4·2	19,096	320	2·6	925	558	42	–	–	264	41	312	49	231	–	–	302	22	246	18	317	–	–
	E2572	F	–	274	34,500	469	1,274	368	64,711	3·7	14,377	222	2·2	1,206	374	46	0·40	907	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	E2072	F	–	341	34,800	386	887	435	64,846	2·4	26,588	410	6·8	823	437	36	0·57	758	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	E2373	M	–	339	38,636	1,005	877	1,146	87,373	6·1	38,619	442	2·4	790	1,192	56	1·46	1,046	572	49	398	33	761	1·08	530	1,149	14	948	11	1,170	1·10	1,055
	E1772	M	–	338	39,000	569	976	583	22,169	1·9	9,508	429	1·4	954	587	63	–	–								309	15	221	16	307	0·54	309
	E2173	F	–	340	40,500	646	587	1,101	67,137	6·6	40,215	599	3·6	520	1,166	96	0·50	1,433	763	43	784	56	747	0·98	779	852	24	613	18	929	0·64	849
	E6872	M	–	338	42,000	320	757	426	38,400	1·7	11,904	310	1·5	713	428	–	1·10	398	366	40	390	41	363	0·77	474	418	21	364	19	433	0·79	530
	E1773	F	–	338	42,762	782	914	856	81,482	7·4	64,778	795	8·0	832	862	29	0·45	1,901	516	45	477	41	548	–	–	1,208	42	1,191	41	1,220	0·85	1,420
	E3172	F	–	338	50,000	460	1,060	434	48,897	1·3	14,630	293	0·70	1,010	441	47	0·86	504	320	41	330	42	313	0·49	654	568	34	465	28	621	–	–
	E1673	F	–	346	58,664	674	941	716	34,250	3·6	22,769	663	3·4	907	718	–	0·94	761	–	–	–	–	–	–	–	1,044	31	920	21	1,189	0·99	1,055
	E5072	F	–	703	337,000	3,222	1,086	2,967	–	3·7	–	1,555	1·9	–	3,021	50	1·66	1,984	1,978	69	2,190	76	1,506	1·73	1,142	2,328	24	894	9	2,792	–	–
	24970	CH	–	890	426,000	–	–	3,513	–	7·2	–	1,834	3·7	–	3,638	42	–	–	3,670	79	3,911	84	2,856	–	–	–	–	–	–	–	–	–
	E4673	M	–	886	432,727	4,832	1,713	2,821	–	2·3	–	1,444	1·2	–	2,853	49	1·77	1,592	2,392	67	2,254	63	2,671	1·90	1,259	3,584	43	2,426	29	4,443	2·29	1,580
Adult Thoroughbreds																																
	22771	F	+	1,068	465,455	3,431	1,140	3,009	–	4·4	–	878	2·0	–	3,085	–	–	–	3357	73	3,747	73	2620	–	–	2,245	27	1,856	15	3,746	–	–
	E4672	F	+	1,433	458,182	–	–	5,398	–	2·8	–	5,417	2·7	–	5,403	97	2·56	1,676	6,344	58	6,599	61	5,982	2·44	1,733	5,194	25	3,406	16	6,192	3·40	1,653
	E7272	F	+	1,068	470,909	7,456	2,242	3,322	–	5·3	–	1,091	1·7	–	3,447	58	1·96	1,669	5,141	61	5,915	70	3,930	2·10	2,451	5,602	29	2,146	10	6,986	–	–
	E9272	F	D	1,433	470,909	4,543	1,245	3,650	–	6·2	–	1,639	2·8	–	3,783	–	–	–	–	–	–	–	–	–	–	3,711	25	1,525	10	4,428	2·48	1,522
	E1172	M	+	1,068	483,636	–	–	4,357	–	10	–	2,407	5·5	–	4,579	48	–	–	–	–	–	–	–	–	–	4,492	29	2,739	18	4,895	–	–
	E6472	F	+	1,433	483,636	7,151	1,598	4,474	–	7·8	–	2,038	3·6	–	4,680	–	2·99	1,695	–	–	–	–	–	–	–	5,013	30	3,115	21	3,561	3·13	1,605
	10671	CH	D	2,528	496,364	–	–	–	–	–	–	–	–	–	–	–	–	–	3,109	67	3,112	69	2,976	–	–	4,210	36	2,850	21	5,985	–	–
	18871	CH	+	3,258	509,091	8,963	2,836	4,197	–	–	–	–	–	–	–	–	–	–	3,926	96	4,155	78	3,266	–	–	3,980	29	1,930	13	4,591	–	–
	E1472	F	D	3,623	534,545	–	–	5,655	–	3·8	–	5,758	3·8	–	5,657	38	–	–	–	–	–	–	–	–	–	4,709	37	3,326	26	6,538	–	–
	E2272	F	D	2,528	560,000	–	–	5,053	–	0·15	–	6,540	0·25	–	5,050	99	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	E9672	F	D	5,448	585,455	–	–	–	–	–	–	–	–	–	–	–	–	–	3,597	68	3,446	69	3,495	2·44	1,475	6,099	36	3,958	23	7,267	3·01	2,018
	25771	F	D	5,448	598,182	–	–	7,634	–	5·9	–	4,590	3·4	–	7,819	68	3·81	2,006	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Young Other Horses																																
Connemara X Pony	23571	M	–	160	2,150	92	183	503	10,451	5·7	3,515	336	5·8	193	513	94	0·19	2,632	282	10	310	10	279	0·13	2,193	425	10	322	10	436	–	–
Welsh Mountain Pony	E12771	M	–	158	2,977	160	431	392	15,912	3·7	4,808	306	3·4	415	374	96	0·49	961	243	9	350	13	232	0·46	529	442	8	336	60	457	0·59	761
Dartmoor Pony	E9472	F	–	339	22,000	242	601	403	35,152	3·5	12,996	265	2·5	115	393	96	0·92	563	–	–	–	–	–	–	–	581	22	471	18	607	0·85	680
Welsh Mountain Pony	E4373	M	–	855	109,091	860	449	1,916	–	15	–	630	5·8	–	2,145	22	1·29	1,490	1,135	56	1,229	61	1,015	1·15	989	2,090	46	1,750	39	2,383	1·64	1,275
Welsh Mountain Pony	E3073	F	–	703	114,546	1,267	658	1,925	–	8·7	–	873	4·2	–	2,025	42	1·42	1,359	2,222	60	2,422	65	1,924	1·28	1,932	1,842	41	1,555	35	2,041	1·33	1,389
Welsh Mountain Pony	E7772	M	–	903	118,182	1,653	753	2,196	–	25	–	788	9·0	–	2,690	25	1·45	1,518	1,473	90	1,518	92	1,370	1·02	1,442	2,808	51	1,283	23	4,431	1·85	1,518
Welsh Mountain Pony	E12072	M	–	886	153,727	1,666	623	2,674	–	7·2	–	1,386	3·7	–	2,774	42	1·06	2,582	2,061	66	2,202	70	1,990	1·53	1,351	1,715	29	1,130	19	1,952	1·36	1,259
Welsh Mountain Pony	E9072	M	–	703	178,182	1,530	517	2,959	–	10	–	1,006	4·3	–	3,186	–	–	–	–	–	–	–	–	–	–	5,208	52	4,199	42	6,305	2·83	1,842
Fell x Palomino Pony	24771	M	–	521	209,273	1,874	617	3,040	–	11	–	1,402	4·8	–	3,232	44	–	–	2,451	65	2,567	68	2,239	1·35	1,821	2,278	37	1,336	27	2,834	1·78	1,280
Arab x Thoroughbred	E5972	M	–	326	39,000	840	917	916	37,789	0·98	12,761	470	0·40	879	920	37	1·18	776	386	42	307	33	443	0·86	449	582	24	404	16	639	0·92	623
Hunter x Thoroughbred	E1872	M	–	248	62,000	1,073	1,062	1,010	30,151	1·8	12,600	398	1·10	1,032	1,028	31	–	–								882	37	761	32	954	2·38	370
Arab x Thoroughbred	19871	M	–	460	203,636	1,900	1,504	1,263	–	13	–	815	8·5	–	1,331	23	0·87	1,450	1,305	62	1,335	64	1,255	1·42	921	1,136	44	857	33	1,354	1·32	862
Adult Other Horses																																
Shetland Pony	E172	CH	+	1,798	153,727	1,900	548	3,101	–	13	–	1,167	5·4	–	3,841	41	–	–	2,959	73	3,339	83	1,926	–	–	2,907	49	2,235	38	3,555	–	–
Welsh Mountain Pony	E273	CH		1,433	178,182	1,650	610	2,906	–	19	–	1,091	7·7	–	3,087	36	1·61	1,684	2,031	68	2,166	73	1,938	1·68	1,209	3,221	50	2,890	45	3,553	1·90	1,699
Shetland Pony	E3673	CH	+	3,258	203,636	2,270	783	2,899	–	12	–	1,894	7·8	–	3,049	22	1·93	1,504	2,522	99	2,621	82	2,155	1·52	1,663	2,597	37	2,265	32	2,790	2·47	1,053
Welsh Mountain Pony	E12872	F	+	2,528	229,091	3,128	798	2,667	–	8·4	–	1,388	4·4	–	2,784	38	2·15	1,268	2755	63	3,282	75	1,858	1·82	1,515	3,636	30	2,541	21	4,101	2·41	1,054
Shetland Pony	E8172	CH	+	1,798	280,000	3,990	1,127	3,540	–	20	–	1,924	9·6	–	3,988	31	2·29	1,543	3,503	74	3,999	84	2,126	1·47	2,384	3,454	43	2,647	34	4,063	2·25	1,535
Connemara X	12271	F	–	4,718	305,455	2,125	838	2,535	–	12	–	1,625	7·9	–	2,663	34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pony	16171	F	–	3,258	305,455	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4,960	38	3,482	28	5,733	–	–
Arab	E3373	F	+	2,528	305,455	3,148	899	3,503	–	15	–	1,679	7·0	–	3,812	43	2·32	1,509	3,781	62	4,234	90	3,030	1·87	2,020	5,952	38	5,599	36	6,171	2·55	2,334
Connemara X	23371	F	–	1,433	318,182	2,327	610	3,737	–	12	–	2,199	11	–	3,974	–	–	–	2,729	76	2,906	81	2,542	–	–	4,246	47	3,367	39	3,545	–	–
Piebald	E773	F	–	2,528	318,182	2,525	971	2,601	–	13	–	1,477	7·1	–	2,763	49	1·79	1,460	1,776	69	1,940	75	1,411	2·06	862	2,334	54	1,502	35	2,721	1·58	1,481
Exmoor	12471	CM	+	3,258	356,364	2,995	1,029	2,911	–	15	–	2,384	13	–	3,006	67	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pony	E271	CH	–	3,258	356,364	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9,239	46	7,071	34	11,145	–	–
Pony	15971	F	–	3,258	407,293	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7,135	55	9,557	58	6,625	–	–
Pony	16071	F	+	3,258	420,000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7,135	54	6,565	50	7,805	–	–
Connemara X	E5872	F	+	2,528	445,455	2,691	987	3,035	–	13	–	1,819	8·0	–	3,644	67	2·28	1,329	–	–	–	–	–	–	–	2,685	60	2,060	54	3,622	–	–
Welsh Mountain	4471	M	+	2,528	458,182	–	–	3,110	–	12	–	2,371	9·1	–	3,151	88	–	–	2,545	83	2,771	84	5,089	–	–	–	–	–	–	–	–	–
Exmoor	24570	M	–	3,258	480,000	–	–	3,974	–	5	–	2,188	2·5	–	4,066	39	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Connemara X	E10572	CH	+	2,873	480,000	3,476	636	5,465	–	19	–	1,981	6·1	–	6,306	64	–	–	3,436	77	3,482	78	3,286	2·82	1,220	4,525	22	2,944	14	4,968		
Clydesdale	E3973	F	–	2,528	496,364	3,673	1,168	3,148	–	14	–	2,038	9·3	–	3,330	51	2·03	1,553	2,716	76	2,712	76	2,722	1·59	1,704	3,413	42	2,517	31	4,057	1·60	2,134
Percheron X	15871	CH	–	3,258	534,545	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7,015	47	6,017	40	7,951	–	–
Thoroughbred X	E5772	F	–	1,065	356,364	1,718	739	2,326	–	11	–	1,323	6·5	–	2,456	41	1·48	1,569	–	–	–	–	–	–	–	2,345	39	1,898	27	2,613	1·66	1,412
Thoroughbred X	E4073	CH	–	1,433	369,091	3,671	1,516	2,421	–	12	–	966	5·0	–	2,614	26	1·49	1,630	2,066	61	2,198	64	1,863	1·32	1,568	3,704	47	2,533	32	4,730	1·95	1,899
Thoroughbred X	E2673	CH	–	1,250	432,929	3,561	910	3,914	–	10	–	1,847	4·7	–	4,144	66	1·95	2,010	–	–	–	–	–	–	–	4,396	33	2,899	21	5,133	2·19	2,008
Thoroughbred X	E11572	CH	+	3,258	521,818	4,522	1,171	3,861	–	9·1	–	1,212	2·9	–	4,126	70	2·31	1,674	4,405	90	4,590	73	3,982	2·06	2,141	4,706	45	4,019	38	5,268	2·22	2,121
Thoroughbred X	E11172	F	+	2,893	534,545	4,940	1,149	4,361	–	6·6	–	1,955	3·0	–	4,467	44	2·17	1,861	3,396	67	3,544	30	3,092	2·46	1,381	4,396	41	2,158	20	5,958	2·44	1,802
Thoroughbred X	15771	CH	+	3,258	560,000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3,378	44	2,426	32	4,129	–	–

M= Male F= Female + = In training D= Out of training

9. Changes in organ weights in mice exposed to moderate or severe hypoxia. By E. J. Clegg. *Department of Human Biology and Anatomy, University of Sheffield*

Mice exposed to moderate or severe hypoxia show differing patterns of loss in body weight. At moderately reduced atmospheric pressures weight loss is small and ceases after a few days, but at very low pressures it is continuous (Clegg & Harrison, Proc. *3rd Int. Congr. Biometereol.* 1966).

In the present experiments groups of litter-mate pairs (experimental and control) of male C57BL mice were killed after periods of up to 7 days' exposure to atmospheric pressures of either 530 torr or 390 torr and changes in the weights of hearts, spleens, livers and kidneys were assessed after covariance adjustment to allow for differences in body weights between groups. At both levels of hypoxia adjusted mean heart and spleen weights were increased over control values, but surprisingly, in comparisons between the two hypoxic groups the responses were greater at the less severe level of hypoxia. Liver weights were significantly decreased only at 390 torr; kidney weights showed no particular trend. Morphometric examination of the spleen showed that in hypoxic animals the amounts of red pulp were increased, the response being generally greater at 530 torr.

Both heart and spleen have been shown to be of importance in adaptive responses to hypoxia and the paradoxical result of this investigation, that the response appears greater when the degree of hypoxia is less, is interpreted as meaning that while at 530 torr adaptive processes are successful, at least in the short term, at 390 torr they are not. At this pressure lack of overall homeostasis itself reduces the extent of specific adaptive responses.

10. The ultrastructure of synovial cells in vitro. By Mary Glen-Bott. *Department of Anatomy, St Thomas's Hospital Medical School, London and University of Hong Kong*

Electron microscopy of the synovial membrane reveals two cell types (Barland *et al.*, *J. Cell. Biol.* **14**, 1962). Type A cells have numerous filopodia and vacuoles but little endoplasmic reticulum and their functions are absorbtive while type B cells, with abundant endoplasmic reticulum, have a secretory role.

Synovial cells were washed from trypsinized rabbit knee joints using a modification of the method of Fraser & McCall (*Ann. rheum. Dis.* **24**, 1965). The ultrastructure of these cells was compared with those of the intact joint both before and after trypsinization and after the washing procedure was completed. The washed cells were also kept in conditions of culture for periods of 4, 24 and 48 h and examined by electron microscopy. They showed immediate changes in morphology which included increased electron density; more numerous filopodia and evidence of phagocytosis. The two cell types were not now clearly distinguishable. After 4 h in suspension culture all the cells had a similar morphology: with a more rounded outline, indented nucleus, free cytoplasmic ribosomes, Golgi complex and also packed filaments. After 24 and 48 h in culture the cells which attached to a flat surface contained numerous large vesicles and dense bodies.

These results indicate that the two major synovial cell types loose their characteristic morphology while adapting to the altered conditions of culture. The two cell types of the intact joint may represent different functional states of the same cell and some morphological features of the cultured cells indicate that the synovial cell belongs to the same class of cell as the macrophage.

11. A comparative histochemical study of the mammalian diaphragm and M. semitendinosus. By A. S. Davies and H. M. Gunn. *Department of Veterinary Anatomy, University of Edinburgh* (Fig. 3)

Histochemical methods for myosin adenosine triphosphatase (ATPase), succinic dehydrogenase (SDHase), phosphorylase and lipids were used on fresh-frozen diaphragm and M. semitendinosus samples from adult mice, rats, rabbits, cats, dogs and horses. Samples of diaphragm

Journal of Anatomy 110, 137-139 (1971).

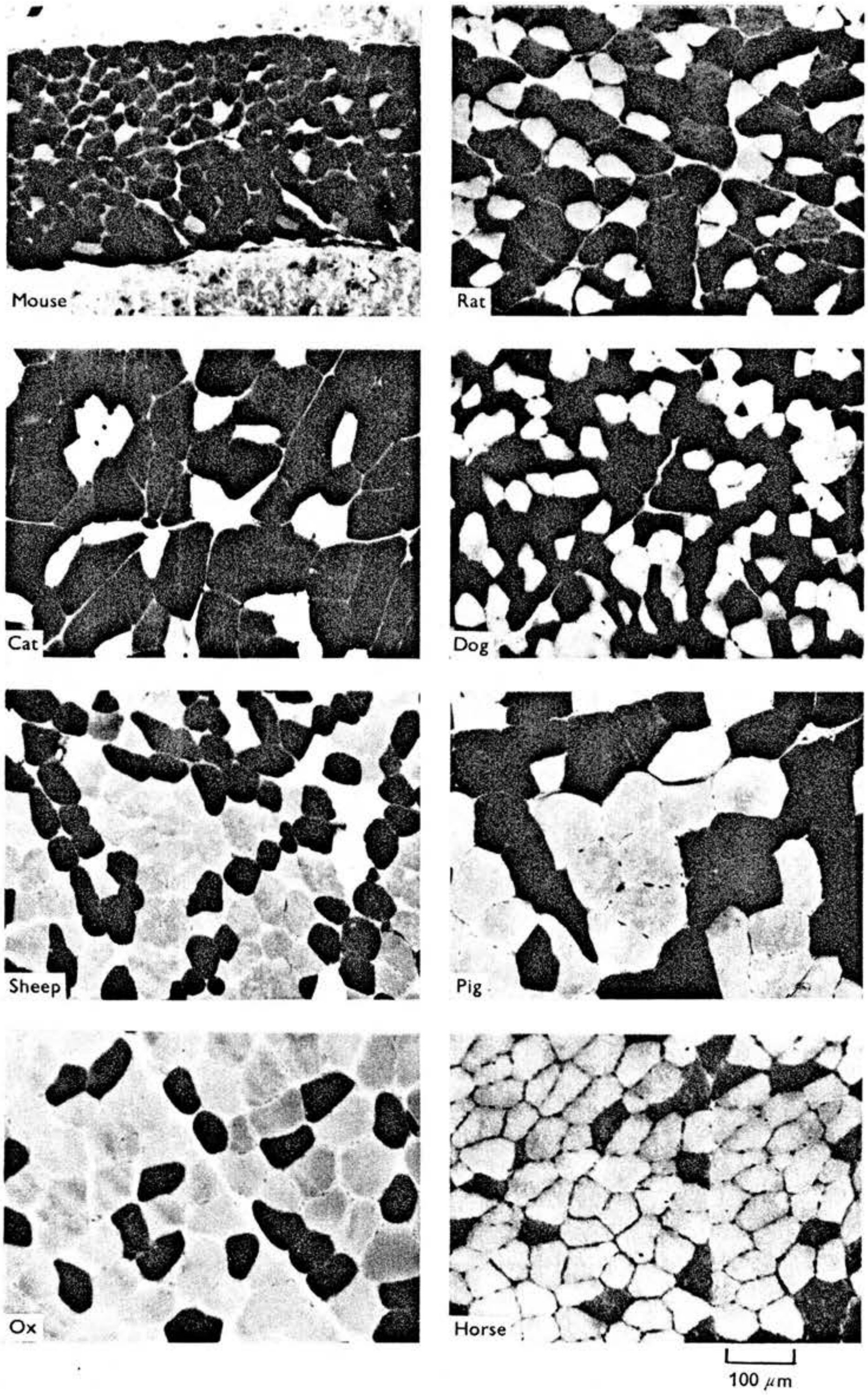


Fig. 3

only were obtained from adult pigs, sheep and cattle. Histochemical profiles of about 400 individual fibres for each sample were determined by tracing transverse serial sections.

In the diaphragm, the percentage of ATPase-high fibres tended to decrease with increasing body size (Fig. 3). The superficial region of M. semitendinosus of the smaller animals contained only ATPase-high fibres. With increasing body size, the deep region of mixed fibre population occupied a larger proportion of the muscle and the proportion of its fibres low in ATPase activity increased. The effect of body size on fibre type was much greater in the diaphragm than in M. semitendinosus.

The intensity of staining with Sudan Black B, with or without previous acetone extraction, corresponded to SDHase activity in individual fibres. Gauthier & Padykula (*J. Cell Biol.* **28**, 1966) reported decreased sudanophilia of fibres of the mammalian diaphragm with increasing body size. Although this trend was confirmed, the diaphragm of larger mammals was nevertheless composed of fibres of relatively high sudanophilia and SDHase activity. When the SDHase activity of fibres within the diaphragm of each animal was compared, the proportion of high to low activity fibres varied between species, but was not influenced by body size.

In general, the percentage of fibres in the diaphragm with high phosphorylase activity increased with increasing body size. ATPase-high fibres were high in phosphorylase, except in those animals with a lower percentage of phosphorylase-high than ATPase-high fibres. In M. semitendinosus, phosphorylase activity corresponded to ATPase activity.

The significance of these results will be discussed.

12. The sphincteric mechanism of the inguinal canal. By P. K. FITZGERALD. *University College, Cork*

Electromyography has now shown that the internal oblique and transversus muscle fibres that arise from the inguinal ligament are on constant guard over the inguinal canal and thereby act as a sphincter for it. These are the only muscle fibres in the abdominal wall that show constant activity. The inguinal sphincter is supplied by the first lumbar nerve. Paralysis of the sphincter may result from central or peripheral lesions of this nerve. Incompetence may result from a variety of conditions ranging from metabolic conditions such as hypovitaminosis to prolonged strain of the sphincteric muscles, e.g. abdominal distension, obesity, urinary obstruction, prolonged standing, chronic cough, etc. The surgical treatment of inguinal hernia resolves itself into (*a*) removal of the sac, (*b*) reconstruction of the inguinal canal. In infants since the external ring almost superimposes the internal ring it is often not necessary to open the canal. In adults the competence or incompetence of the inguinal sphincter will determine whether the reconstruction of the canal is advisable or not. If the sphincter is competent a Bassini type of repair is adequate. If the spincter is incompetent after appropriate means of producing tone in the sphincter fails, then either a mechanical support or a reconstruction of the abdominal wall is indicated. A reconstruction of the abdominal wall will vary with the age of the patient and condition of the musculature. In summary, therefore:

(1) The inguinal canal is controlled by sphincteric fibres.

(2) The course and distribution of LI nerve should be kept in mind in planning operations in the lumbar and low abdominal regions so as to prevent paralysis of the inguinal sphincter.

(3) The technique for repair of inguinal hernia should depend on the competence of LI myotome.

13. Sexual differentiation in the brain of the neonatal rat. By H. K. DARRAH, P. C. B. MACKINNON and A. W. ROGERS. *M.R.C. Neuroendocrinology Unit and Department of Human Anatomy, University of Oxford*

Sexual differentiation of the male rat brain occurs under the influence of the testis during the first week of life (Harris, *Endocrinology* **75**, 1964). Differentiation of the female rat brain into a male-type brain however can be simulated by transplanting testicular tissue or injecting androgenic hormones into the neonatal animal. Females treated in this way exhibit male-type behaviour and become acyclic and anovular in adult life. Recent evidence suggests that the

[*Reprinted from the Proceedings of the Biochemical Society*, 30 *September*–1 *October* 1971.
Biochem. J., 1971, Vol. 125, No. 4, 108–109P.]

Histochemical Characteristics of Muscle Fibres in the Diaphragm

By H. M. Gunn and A. S. Davies. (*Department of Veterinary Anatomy, University of Edinburgh, Edinburgh EH*9 1*QH, U.K.*)

This study attempts to define and explain histochemical variations in the muscle fibres of the diaphragm in mammals of various body sizes.

Fresh frozen transverse sections of muscle fibres were treated to demonstrate aerobic metabolism, anaerobic metabolism and lipid distribution. These properties were demonstrated by histochemical methods for succinate dehydrogenase activity, phosphorylase activity and the Sudan Black B method for lipids respectively. Incubation of sections with ATP and Ca^{2+} at pH 9.4 and subsequent treatment with Co^{2+} and ammonium sulphide demonstrated myosin adenosine triphosphatase activity. It may distinguish between fibres with a fast and a slow intrinsic speed of contraction due to the presence or absence of a deposit in the myofibrils.

By using serial frozen sections and back projection, histochemical profiles of about 400 individual muscle fibres were made on each sample taken from the diaphragms of shrews, mice, rats, rabbits, cats, dogs, sheep, humans, pigs, oxen and horses. From these profiles the following types of muscle fibres were found: fast-contracting, aerobic; fast-contracting, combined; fast-contracting, anaerobic; slow-contracting, aerobic; slow-contracting, combined.

Studies on myosin adenosine triphosphatase showed that the percentage of fast-contracting fibres increased with decreasing body size; this phenomenon can be related to the faster speed of contraction of the diaphragm in smaller mammals.

Biochemical studies have shown that the ability for aerobic metabolism is greater in the diaphragms of smaller mammals. Histochemically this trend was seen, but differences in succinate dehydrogenase activity between fibres were not as distinct as the differences in adenosine triphosphatase activity. The proportion of aerobic and anaerobic fibres varied between species, but was not influenced by body size. Phosphorylase activity tended to show an opposite trend to that of adenosine triphosphatase. The horse had nearly 100% of its fibres high in phosphorylase activity, but in the shrew diaphragm no fibres with phosphorylase activity were seen.

Fast-contracting muscle fibres were also high in phosphorylase activity, showing that faster-contracting fibres used mainly an anaerobic metabolism. In smaller animals the proportion of fibres with high adenosine triphosphatase activity exceeded that of fibres with high phosphorylase activity, so aerobic metabolism may be used by fast-contracting fibres.

PRINTED IN GREAT BRITAIN BY WILLIAM CLOWES AND SONS LIMITED, LONDON, COLCHESTER AND BECCLES

J. Anat. (1972), **112**, 1, pp. 41–60
With 20 *figures*
Printed in Great Britain

Histochemical fibre types in the mammalian diaphragm

A. S. DAVIES AND H. M. GUNN
Department of Anatomy, Royal (Dick) School of Veterinary Studies, Edinburgh

(*Accepted* 3 *March* 1972)

INTRODUCTION

In 1873, Ranvier showed that differences in the colour of femoral muscles of the rabbit could be related to differences in speed of contraction. This relationship has rarely been questioned, even though biochemical advances have shown that the redness is due to iron-containing pigments involved in oxygen and electron transport, and there is no reason to suppose that variations in the structure and function of the contractile myofilaments need be reflected in changes in the colour of the muscle. The advent of histochemical methods which reveal, in single fibres, the enzymes concerned with the release of energy and its connexion to a contractile force, has made the characterization of fibre types in muscle progressively more difficult.

Different levels of succinate dehydrogenase (SDHase) activity in individual muscle fibres were demonstrated by Padykula (1952), Rutenburg, Wohman & Seligman (1953) and Wachstein & Meisel (1955). The patterns obtained with other methods for enzymes of aerobic metabolism corresponded to those for SDHase (Dubowitz & Pearse, 1960*b*; Engel, 1962; Romanul, 1964). It has been claimed that the activity of the anaerobic metabolic enzyme phosphorylase is 'reciprocal' to that of enzymes of aerobic metabolism in skeletal muscle fibres of the rat and human (Dubowitz & Pearse, 1960*a*, *b*) and the cat (Jinnai, 1960). This concept has been supported by Engel (1962, 1965, 1970) and Suchenwirth & Bundschu (1970) in human muscles; Nishiyama (1966) in respiratory muscles of the rat and cat; Kugelberg & Edström (1968) in rat crural muscles; Moody & Cassens (1968) in the longissimus and trapezius muscles of the pig; and Jasmin, Bokdawala & Desrosiers (1971) in crural muscles of the hamster. However, fibres high in SDHase and moderate to high in phosphorylase activity have been demonstrated in rat crural muscles (Romanul, 1964), in rat femoral muscles and m. soleus of monkey and rat (Bocek & Beatty, 1966), in the thyroarytenoid and cricothyroid muscles of the rabbit (Hall-Craggs, 1968), in guinea-pig crural muscles (Edgerton & Simpson, 1969), in cat crural muscles (Prewitt & Salafsky, 1970), and in the gastrocnemius and soleus muscles of the mouse and the triceps brachii and rectus abdominis muscles of the pig and ox (Ashmore & Doerr, 1971). Using methods for SDHase, glycogen and myosin adenosine triphosphatase (myosin ATPase), Stein & Padykula (1962) established histochemical 'profiles' from transverse serial sections of fibres in rat crural muscles. They showed that some fibres are high in both myosin ATPase and SDHase activity. The existence of this type of fibre confounds the simple division of muscle fibres into two histochemical types as proposed by Engel (1962, 1965, 1970) for human muscles and applied to crural muscles of the guinea-pig by

Karpati & Engel (1967, 1968); their 'Type I' fibres have high activities for the enzymes of aerobic metabolism and show little phosphorylase or myosin ATPase activity, whereas their 'Type II' fibres have low activity for aerobic enzymes and high activity for phosphorylase and myosin ATPase. Edgerton & Simpson (1969) defined three basic fibre types in the crural muscles of the rat and guinea-pig; those with activities high for myosin ATPase, aerobic and anaerobic enzymes, those with activities high for myosin ATPase and anaerobic enzymes and low for aerobic enzymes, and those with activities low for myosin ATPase and anaerobic enzymes and showing 'intermediate' activity for aerobic enzymes. This 'intermediate' fibre frequently has, however, a higher SDHase activity than that of fibres high in myosin ATPase in muscles of the pig and ox (Ashmore & Doerr, 1971). Even this more complex classification does not seem to be generally applicable to all muscle fibres.

The present study was undertaken to resolve some of the apparently contradictory reports on the relationships between histochemical reactions in individual fibres. Patterns of fibre type profiles in one particular muscle have been established in mammals of different body size, using SDHase as an indicator of aerobic capacity, phosphorylase as an indicator of anaerobic capacity, and myosin ATPase as an indicator of the intrinsic speed of contraction of individual fibres. There has been no previous study comparing fibre type profiles in the same muscle of several different species. The diaphragm was chosen because this muscle has a similar function in all mammals and a comparable region, the costal diaphragm, can be sampled in each animal. The results have been briefly reported in a previous communication (Davies & Gunn, 1971).

MATERIAL AND METHODS

Preparation of material

Adult mice, rats, rabbits, cats, dogs and horses were killed by an overdose of anaesthetic. Adult sheep, pigs and cattle were killed by the usual abattoir procedures. The mice, rats and rabbits were laboratory strains reared in cages. The other animals used were from normal domestic and farm environments. The numbers and sex of the animals of each species are shown in Table 1. One sample of the costal diaphragm of each animal was removed within 45 minutes of death. Blocks of muscle, supported between blocks of liver tissue in the case of the smaller animals, were mounted on a cryostat chuck. A 5 mm thick cork sheet interposed between the chuck and the tissue prevented splitting of the tissue when chuck and tissue were rapidly frozen by plunging into dichlorodifluoromethane (Arcton 12, I.C.I.) cooled to its melting-point of −158 °C with liquid nitrogen. About ten adjacent serial transverse sections were cut 10 μm thick at −20 °C, mounted directly on to coverslips, and allowed to thaw and dry rapidly at room temperature.

Histochemical methods

Succinate dehydrogenase

Sections were incubated for 20 minutes at 37 °C in a medium composed of 10 ml of 0·2 M phosphate buffer at pH 7·6, 10 ml of 0·2 M sodium succinate, and 20 ml of nitro blue tetrazolium (1 mg/ml) (Nachlas *et al.* 1957). Gas bubbles frequently formed between the section and the coverslip; these were often eliminated by drying the section between washing and fixation in 4 % formaldehyde.

Table 1. *Mean transverse-sectional areas of diaphragm muscle fibres*

Species	No. of animals			Transverse-sectional area (μm^2)		
	Male	Female	Total	Mean	S.D.	Significance*
Mouse (*Mus musculus*)	4	0	4	1110	160	$P < 0{\cdot}05$
Rat (*Rattus rattus*)	3	1	4	1990	460	N.S.
Rabbit (*Oryctolagus cuniculus*)	3	0	3	3170	180	N.S.
Cat (*Felis catus*)	1	1	2	3590	1720	N.S.
Dog (*Canis familiaris*)	4	1	5	1690	150	N.S.
Sheep (*Ovis aries*)	0	3	3	1870	300	N.S.
Pig (*Sus scrofa*)	1	5	6	5680	1170	$P < 0{\cdot}001$
Ox (*Bos taurus*)	1	2	3	3790	460	N.S.
Horse (*Equus caballus*)	3	1	4	2420	560	N.S.
Total	20	14	34	2690	1370	—

* Significance of difference of mean for each species and mean for all species, tested at the 5% significance level by the test quotient t.

N.S. = not significant.

Lipids

Sections were fixed in 4% formaldehyde for 10 minutes and stained with a freshly filtered, saturated solution of Sudan black B in 70% ethanol for 20 minutes. Excess dye was removed by a brief wash in 50% ethanol. Some sections were immersed in acetone for 30 minutes between fixation and staining.

Phosphorylase

Takeuchi's (1956) modification of the method of Takeuchi & Kuriaki (1955) was used. Sections were incubated for three hours at 37 °C in a medium consisting of 75 mg glucose-1-phosphoric acid, 15 mg adenosine-5′-monophosphoric acid, 3 mg glycogen, 22·5 ml distilled water, 15 ml of 0·1 M acetate buffer at pH 5·8, one international unit of protamine zinc insulin and 7·5 ml of absolute ethanol. They were subsequently washed, dried, fixed in absolute ethanol, dried, and stained with dilute Lugol's iodine for three minutes. Because the colour faded, iodine staining was repeated immediately before subsequent use of the section.

Myosin ATPase

The calcium–cobalt method of Padykula & Herman (1955) was modified to improve the buffering capacity of the medium. Sections were fixed for exactly two minutes in cacodylate buffered 4% formaldehyde at pH 7·0. Without fixation, the sections floated off the coverslip, and prolonged fixation affected the characteristics of the enzyme (Stein & Padykula, 1962; Guth & Samaha, 1969). Sections were incubated for 20 minutes at 37 °C in a freshly made medium consisting of 8 ml of 1·0 M tris-(hydroxymethyl)-aminomethane, 4 ml of 0·18 M calcium chloride, and 60 mg ATP disodium salt made up to 30 ml with distilled water, which was then adjusted to a pH of 9·5 with 0·1 N-HCl and made up to a final volume of 40 ml. The final concentration of ATP was therefore 2·4 mM. With two washes in distilled water between treatments, the sections were immersed in 2% cobalt chloride for three minutes and developed in dilute ammonium sulphide for one minute.

Cell outlines

Sections were fixed for 10 minutes in 4% formaldehyde, washed, and stained for 20 minutes in Ehrlich's haematoxylin.

Methods for establishing fibre profiles and transverse-sectional areas

Profiles of about 400 individual fibres in each section were established by first back-projecting a haematoxylin stained section on to a glass screen, enabling a tracing of the fibre outlines to be made on transparent paper. Each serial section was then projected in turn. The histochemical reaction of each fibre was indicated on the tracing; Figs. 3–7 illustrate the type of material used. To estimate the level of activity of enzymes that showed a continuous spectrum of activity between fibres, a simple division into 'high' and 'low' was made for each fibre, relative to the overall level of activity of fibres in each section. It was not considered possible to compare one sample with another, because of difficulties of standardization of the preparation and processing of the material. This is considered to be a source of variation in the quantitative data between samples, and precludes the possibility of a comparison between species based on overall enzyme activity. Fibre transverse-sectional areas were estimated by counting the number of fibres projected within an area of known magnification on the screen.

RESULTS

Qualitative histochemistry

Succinate dehydrogenase

Diformazan deposition occurred as blue dots or irregular areas that appeared to form a network around the myofibrils (Figs. 13, 15, 17, 19). In fibres with a high level of activity, diformazan deposition was highest in the subsarcolemmal region. Diformazan was deposited in larger aggregations in the smaller animals. It was frequently observed that fibres shown in serial section to be myosin ATPase-low had a pattern of intense blue, punctate, clearly defined dots, moderately dense and evenly distributed, whereas the colour of the reaction in ATPase-high fibres was purplish, especially in freshly stained sections. This variation in reaction was not sufficiently consistent to use in identifying fibre types.

Lipids

The density of staining with Sudan black B, with or without previous treatment of the section with acetone, always corresponded to SDHase activity (Figs. 5, 6, 7). SDHase activity was therefore chosen to determine histochemical profiles.

Phosphorylase

Fibres varied in reaction from an intense blue network to a paler blue, to a diffuse pink, to fibres coloured only by the iodine. In all species except the mouse, fibres high in both phosphorylase and SDHase activity were seen (Figs. 4, 6, 17, 18).

Table 2. *Percentage of histochemical fibre types in the diaphragm of nine mammalian species*

		Percentage of fibre types*											
		Ah				Al							
	No. of fibres	Sh		Sl		Sh		Sl					Contraction times†
Species	counted	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl	Sh	Ph	Ah	ms ± S.D.
Mouse	1436	—	93	—	—	—	7	—	—	100	—	93	—
Rat	1337	7	25	27	2	1	38	—	—	71	35	61	18 ± 1
Rabbit	1605	21	—	36	—	—	43	—	—	64	57	57	32 ± 4
Cat	1612	16	—	45	—	—	39	—	—	55	61	61	39 ± 2
Dog	3573	64	—	—	—	—	36	—	—	100	64	64	65 ± 5
Sheep	2938	43	—	—	—	43	14	—	—	100	86	43	—
Pig	2548	17	3	32	3	4	41	—	—	65	53	55	—
Ox	1879	24	—	—	—	58	18	—	—	100	82	24	—
Horse	2559	21	—	—	—	77	2	—	—	100	98	21	—

* Key: Ah, Sh, Ph: high activity of myosin ATPase, SDHase or phosphorylase respectively. Al, Sl, Pl: low enzyme activity.

† Reference for contraction times: Sant'Ambrogio & Saibene (1970).

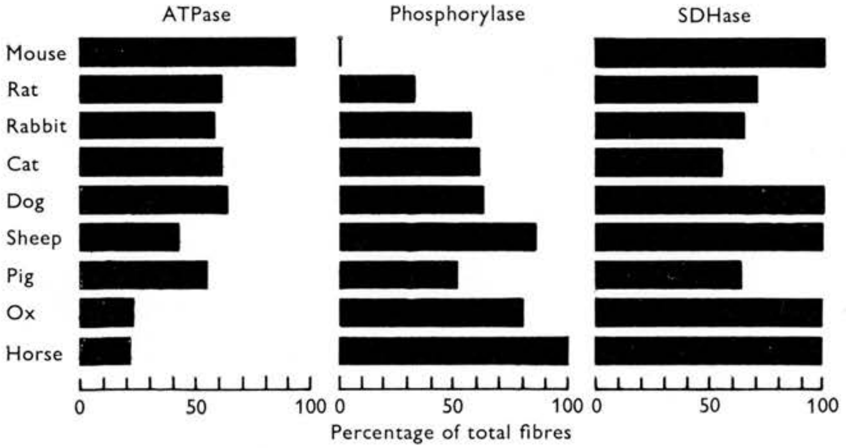


Fig. 1. Histogram showing the number of fibres of each species with high activity of myosin ATPase, phosphorylase and SDHase, as a percentage of total fibres sampled.

Myosin ATPase

Myosin ATPase-high fibres showed a dense brown reaction in which a brown network could usually be seen. These were always distinct from myosin ATPase-low fibres in which only the brown network was seen. Blood vessels were also stained; the reaction of capillary endothelia varied between species (Figs. 3, 9–12). Myosin ATPase-low fibres frequently had an activity of SDHase equal to or greater than adjacent myosin ATPase-high fibres (Figs. 3, 6, 13, 14, 15, 16, 19, 20); it was not therefore possible to grade the activity of SDHase from the myosin ATPase reaction.

Quantitative histochemistry

The data obtained on histochemical profiles of muscle fibres in the diaphragm are shown in Table 2 and Fig. 1. The proportion of myosin ATPase-high fibres decreases in the larger animals (Figs. 9–12). All myosin ATPase-low fibres are high in SDHase activity. A proportion of myosin ATPase-high fibres were classified as SDHase-low only in the rat, rabbit, cat and pig; hence the proportion of SDHase-high fibres is not dependent on body size. All fibres in the diaphragm of the dog (Fig. 8), for instance, are high in SDHase activity. The proportion of fibres high in phosphorylase activity increases in the larger animals. With the exception of all fibres in the mouse and a proportion of fibres in the rat and pig, all myosin ATPase-high fibres are high in phosphorylase activity. In the larger animals some myosin ATPase-low fibres are phosphorylase high. All species except the mouse have a significant proportion of fibres high in both phosphorylase and SDHase.

Mean transverse-sectional areas of diaphragm muscle fibres are shown in Table 1. Only two species are significantly different ($P < 0{\cdot}05$) from the mean of all the species; the mouse has small fibres and the pig large fibres relative to the other species.

DISCUSSION

Sources of variation

All samples were taken from the costal diaphragm of adult animals, which were of mixed sex and from different environments. There is no published work on the difference in the proportion of histochemical fibre types between sexes. Following artificial exercise in rats (Edgerton, Gerchman & Carrow, 1969) and guinea-pigs (Barnard, Edgerton & Peter, 1970), an increase was observed in the proportion of crural muscle fibres with high activity of enzymes of aerobic metabolism. There was, however, no significant difference in the proportion of myosin ATPase-high fibres. The effect of exercise on fibre types in the diaphragm has not been studied. The mice, rats and rabbits sampled in the present study had had very little exercise and the other species an unknown amount. With present evidence, it is possible that SDHase-low fibres in the diaphragm of the rat, rabbit, cat and pig are present because of lack of normal exercise. Since adult animals were used, the decrease reported in the proportion of myosin ATPase-high fibres in the developing soleus muscle of the guinea-pig, rat and cat (Karpati & Engel, 1967) and pectineus muscle of the dog (Cardinet *et al.* 1969) does not influence the results of this study. The variation in the proportion of myosin ATPase-high fibres between animals within a species is high, but does not obscure the overall effect of body size. We have observed large differences, which are not related to body size, in the proportion of myosin ATPase-high fibres in the diaphragm and limb muscles between breeds of dogs and horses (unpublished observations). The vertebral, sternal and costal regions of the rat diaphragm have been shown to vary in their lipase and SDHase activity (George & Susheela, 1961), respiratory quotient (Susheela & George, 1963) and butyrate oxidation (Susheela & George, 1964). However, Günther (1952, 1953) observed no differences in the proportion of fibres with 'Fibrillenstruktur' and 'Felderstruktur' in these regions of the diaphragm of the rat, mouse and dog, and Nishiyama (1966) stated that there was no variation between regions of the cat diaphragm in the proportion of fibre types demonstrated by histochemical methods for oxidative enzymes and phosphorylase.

The number of species, their range of body size, and the number of animals of each species used in the present study indicate a consistent pattern of fibre type distribution, but more detailed studies are needed to establish differences between breeds and the manner in which these differences develop.

Transverse-sectional areas of muscle fibres

The diaphragm samples used in our study were all removed before rigor and were therefore contracted. Freezing and section cutting were not considered to alter fibre size appreciably. Transverse-sectional areas were estimated only in regions in which fibres were cut transversely and where the amount of endomysium and perimysium was minimal. We therefore consider that the estimates of transverse-sectional area are comparable between samples and species.

The relation of body size to the transverse-sectional area of fibres in an equivalent muscle of different species has not been studied extensively. Joubert (1956) found that fibre diameters in the gastrocnemius muscle of two sheep, two rabbits, one pig and one ox were not related to body size. George & Naik (1959) studied the pectoralis muscle of 25 species of birds of varying body weight. The mean fibre diameter increased with increasing weight of the muscle, at a rate dependent on the mode of flight. Julian & Cardinet (1961) found that the mean transverse-sectional area of fibres of m. biceps brachii of a wide range of breeds of dogs (1·4 kg to 56 kg) was larger in heavier dogs. The dogs used in the present study were in the middle of this weight range. Gauthier & Padykula (1966) reported the results of fibre measurements in the diaphragm of 13 mammalian species, and claimed that there was a direct relationship between fibre diameter and body size. They gave no data for the horse and dog, which we found to have small fibres relative to several smaller species.

Our results suggest that there are large sources of variation in fibre transverse-sectional area apart from body size. The diaphragm of the mouse has a purely aerobic metabolism; small fibres would facilitate a high rate of oxygen diffusion. On this basis, Hill (1956) predicted that the diameter of muscle fibres should vary as the square root of linear body size. However, the fibres in the diaphragms of the species which we have studied do not fit this hypothesis.

Significance of the histochemical reactions used

Succinate dehydrogenase

Patterns of mitochondria, demonstrated by classical methods (Nachlas *et al.* 1957; Scarpelli & Pearse, 1958; Novikoff, Shin & Drucker, 1961) or by electron microscopy in skeletal muscle (Padykula & Gauthier, 1963; Ogata, 1964; Pieper, Feustel & Hubner, 1969) and kidney (Novikoff *et al.* 1961), have in each case been shown to follow the diformazan deposition caused by SDHase activity. Brooke & Engel (1966) provided evidence that nitro BT is selectively adsorbed on to mitochondria and sarcoplasmic reticulum of striated muscle fibres. Since, however, SDHase is believed to be entirely intramitochondrial (Roodyn, 1967), this should enhance the histochemical localization of this enzyme. A limited extent of diformazan deposition away from sites of SDHase activity, such as lipid droplets (Hitzeman, 1963), should have little effect on the comparison between individual fibres, but the report of a heterogeneous all-or-none deposition in individual mitochondria (Seligman *et al.* 1967) could have more serious implications. It is possible that the SDHase activity of mitochondria from different fibres may vary (Blanchaer, 1964), but the density of diformazan deposited histochemically in a particular fibre after incubation for as long as 20 minutes should depend primarily on mitochondrial density, rather than on the actual level of SDHase activity.

Paul & Sperling (1952) demonstrated a direct relationship between estimates of mitochondrial density, determined by phase microscopy of blendorized tissue, and the oxidative capacity of a variety of muscles from different species. This relationship is supported by observations on the effect of severe exercise on limb muscles, which can produce a twofold increase in the capacity of muscle to oxidize pyruvate (Holloszy, 1967), accompanied by a concomitant increase in mitochondrial density as seen electron microscopically (Gollnick & King, 1969). Similar findings were reported by Kraus, Kirsten & Wolff (1969).

The assumption that the histochemical SDHase reaction indicates the capacity of an individual fibre for aerobic metabolism appears reasonable, although it lacks direct proof.

Sudan black B

Padykula & Gauthier (1963) showed that this stain coloured both triglyceride droplets and phospholipid in muscle fibres of the rat diaphragm. Previous treatment with acetone removed triglyceride droplets but not phospholipid. They showed that the intracellular localization of the stain corresponded to the fat droplets and mitochondria seen electron microscopically. Since acetone extraction of our sections did not affect the density of the staining of an individual fibre relative to others surrounding it, triglyceride droplets appear to be associated with mitochondria in all fibres. The use of Sudan black B as a mitochondrial marker to estimate the dependence of a fibre on aerobic metabolism is as valid as the use of SDHase.

Phosphorylase

Takeuchi & Kuriaki (1955) showed that their method is specific for the enzyme catalysing the successive phosphorylation of the terminal glucose units of the glycogen chain, with the production of glucose-1-phosphate. The method uses the reversibility of this reaction to synthesize a polyglucose, staining blue with iodine, that is distinct from native glycogen, both by iodine staining and by electron microscopic appearance (Takeuchi & Sasaki, 1968). Differences in the colour of iodine staining have been attributed to the progressive increases in chain length during synthesis of the glucose polymer, blue indicating chains of over 30 glucose units, and red indicating chains of 7–13 glucose units (Swanson, 1948). Iodine colours have been used in this study to indicate different levels of phosphorylase activity in individual fibres.

It is accepted that glycogen is the major store of energy for muscular contraction in the absence of oxygen, and that phosphorylation is the first step in glycolysis. The phosphorylase activity of an individual fibre is therefore a measure of the rate at which it can derive energy for contraction anaerobically.

Myosin ATPase

Padykula & Herman (1955) and Padykula & Gauthier (1963) provided evidence that their histochemical technique was specific for myosin ATPase. This was given strong support by the work of Guth & Samaha (1969), who compared the effects of pre-incubation at pH values of 10·4 and 4·35 on the ATPase activity of both actomyosin extracted from fast and slow muscles of the cat, and individual fibres of these muscles examined histochemically. Their study also provided evidence that fibres shown histochemically to be ATPase-high are fast contracting, and that ATPase-low fibres are slow contracting, a concept supported by work showing that the activity of myosin ATPase is directly proportional to the intrinsic speed of shortening of normal muscles of widely varying speeds of contraction (Bárány, 1967), and of muscles in which the speed of contraction has been altered by cross-innervation (Bárány & Close, 1971). The distinct difference between the histochemical reactions of fast and slow contracting fibres is possibly related to the molecular difference between the myosin of fast and slow muscles demonstrated by Samaha, Guth & Albers (1970).

This evidence appears to justify the designation of ATPase-high mammalian extrafusal fibres as fast-twitch, and ATPase-low fibres as slow-twitch fibres.

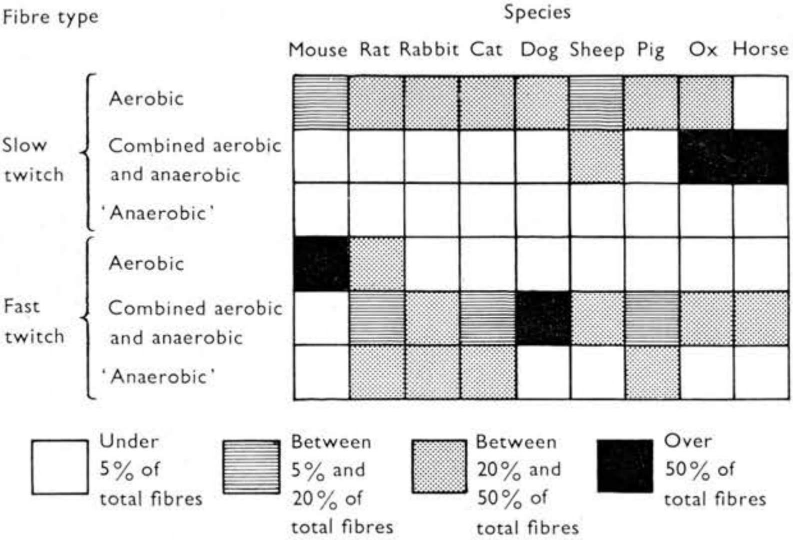
Classification of fibre types

The interpretation of histochemical fibre types should relate the reactions directly to the physiological and metabolic characteristics of each fibre. The evidence given above suggests that the profile obtained by determining the SDHase, phosphorylase and myosin ATPase reactions will classify an individual fibre by its capacity for aerobic and anaerobic metabolism, and by its intrinsic speed of contraction. Fig. 2 is an attempt to classify fibre types in the diaphragm by these criteria. Where the incidence of a fibre is less than 5 %, it probably plays an insignificant part in the function of the diaphragm, and it is appreciated that a fibre classified as 'anaerobic' or 'aerobic' will usually have a low level of the other type of metabolism. For both fast- and slow-twitch fibres, there are three theoretical possibilities for their metabolism; aerobic, combined aerobic and anaerobic, and anaerobic. Only five of these six possibilities occur in significant proportions. The following trends are observed:

(i) Slow-twitch fibres use aerobic metabolism to a greater extent than fast-twitch fibres, and consequently do not include an 'anaerobic' type.

(ii) The diaphragm of the smaller animals uses a predominantly aerobic metabolism. Although a capacity for aerobic metabolism is maintained in the larger animals, there is also an increasing capacity for anaerobic metabolism.

Our studies demonstrate that fibres may have a high activity of enzymes for both aerobic and anaerobic metabolism. They do not indicate what the absolute levels of the activities of these enzymes might be, but suggest that the relationship between aerobic and anaerobic metabolism in muscle fibres is not necessarily the simple 'reciprocal' one suggested by Dubowitz & Pearse (1960*a*, *b*). This contention is supported by Gillespie, Simpson & Edgerton (1970), who found greater stores of glycogen in the 'red' region of m. vastus lateralis of the guinea-pig, composed of 77 % SDHase high



Fibre type		Mouse	Rat	Rabbit	Cat	Dog	Sheep	Pig	Ox	Horse
Slow twitch	Aerobic	▤	▒	▒	▒	▒	▤	▒	▒	□
	Combined aerobic and anaerobic	□	□	□	□	□	▒	□	■	■
	'Anaerobic'	□	□	□	□	□	□	□	□	□
Fast twitch	Aerobic	■	▒	□	□	□	□	□	□	□
	Combined aerobic and anaerobic	□	▤	▒	▤	■	▒	▤	▒	▒
	'Anaerobic'	□	▒	▒	▒	□	□	▒	□	□

□ Under 5% of total fibres
▤ Between 5% and 20% of total fibres
▒ Between 20% and 50% of total fibres
■ Over 50% of total fibres

Fig. 2. Incidence of fibre types in the diaphragm.

fibres, than in the 'white' region, composed of 29 % SDHase high fibres. Edgerton & Simpson (1969) reviewed the various classifications that have been used since 1962 for histochemical fibre types in muscle. They favoured the descriptive terms 'red', 'intermediate' and 'white' in preference to letters or numbers. Fibres low in myosin ATPase activity were described as 'intermediate' in SDHase activity by Stein & Padykula (1962), Edgerton & Simpson (1969) and Jasmin *et al.* (1971) in their studies of crural muscles of rat, guinea-pig and rat, and hamster respectively. Our results, and those of Ashmore & Doerr (1971) for limb muscles of the pig and ox, and Burke *et al.* (1971) for the cat gastrocnemius, show that this type of fibre frequently has SDHase activity equal to or greater than surrounding myosin ATPase high fibres. The term 'intermediate' has, therefore, no general significance.

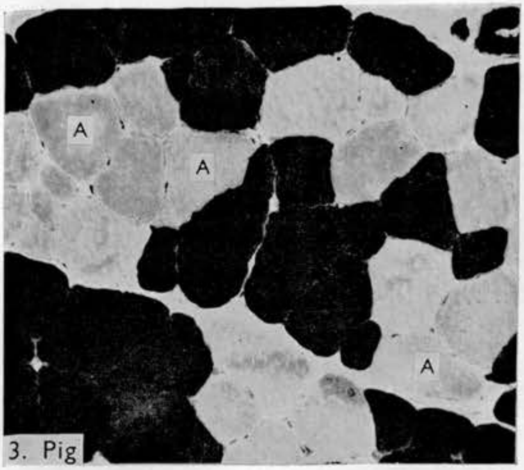
Muscle fibre types in the diaphragm

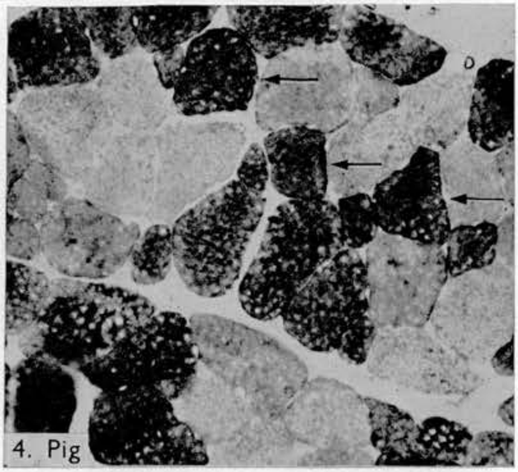
Bullard (1919) stained sections of the cat diaphragm with Sudan III and described equal numbers of 'dark' fibres with many lipid droplets and 'light' fibres of greater diameter and fewer lipid droplets, together with a small number of intermediate fibres. Günther (1952) also recognized the heterogeneity of muscle fibres in the diaphragm. By studying susa-fixed, paraffin embedded sections stained with Heidenhain's

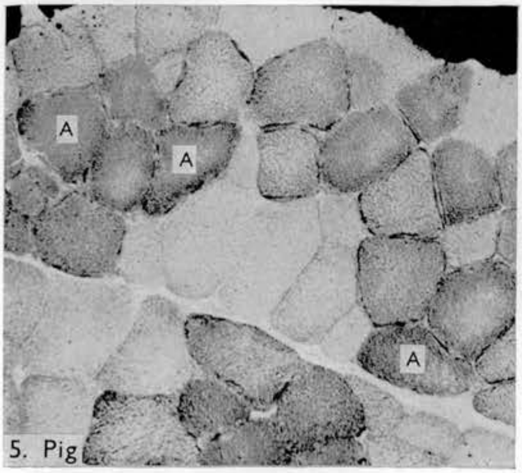
---

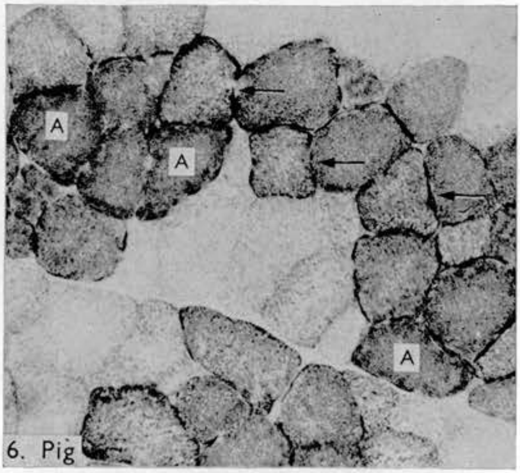
Figs. 3–7. Transverse serial sections of the pig diaphragm stained for myosin ATPase (Fig. 3), phosphorylase (Fig. 4), phospholipid and triglycerides (Sudan black B) (Fig. 5), SDHase (Fig. 6), and phospholipid (Sudan black B) after extraction of triglycerides with acetone (Fig. 7). Arrows indicate fibres high in both phosphorylase and SDHase activity. Fibres marked A have low myosin ATPase activity, but their SDHase activity and Sudanophilia are higher than any myosin ATPase high fibres.

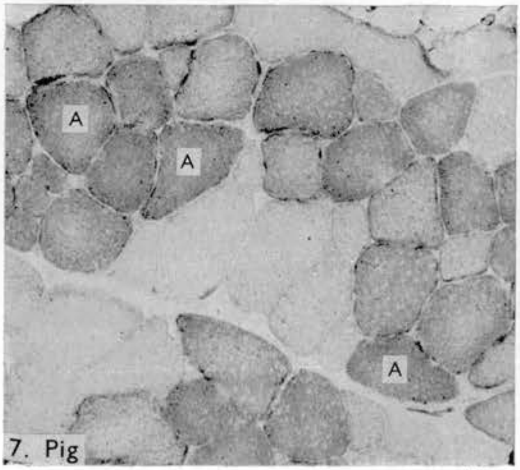
Fig. 8. Transverse section of diaphragm of dog: SDHase.

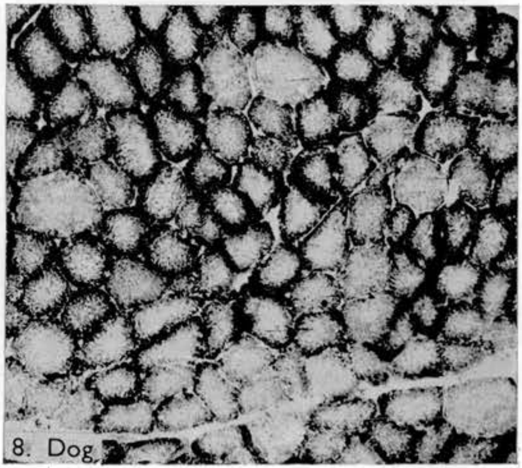

3. Pig


4. Pig

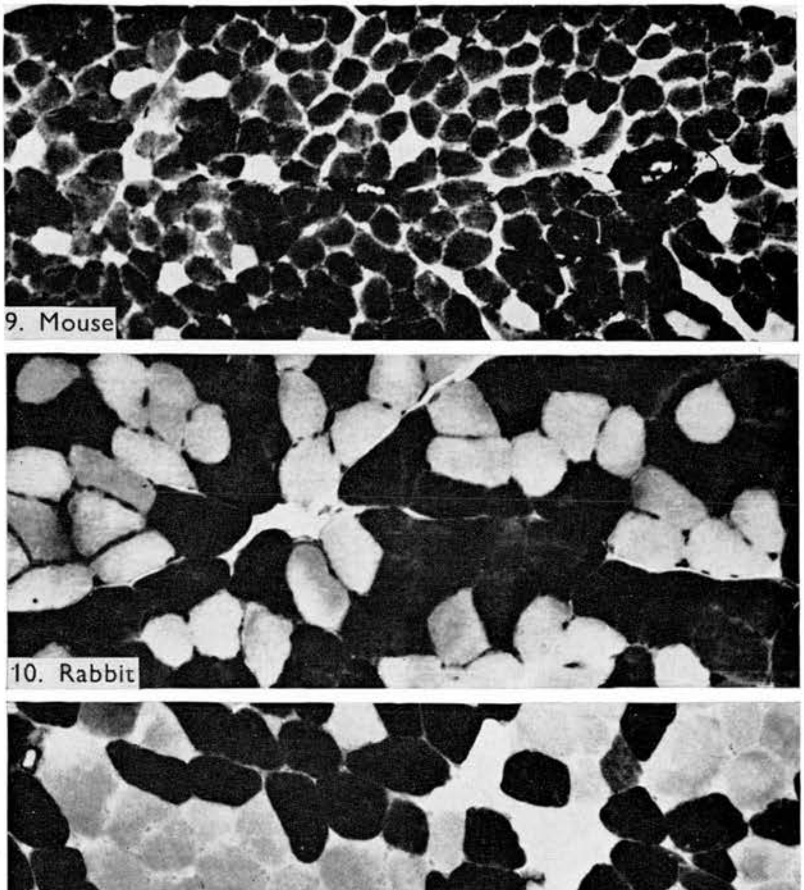

5. Pig


6. Pig


7. Pig


8. Dog

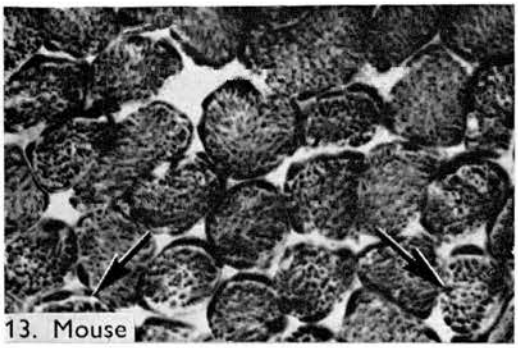
100 μm

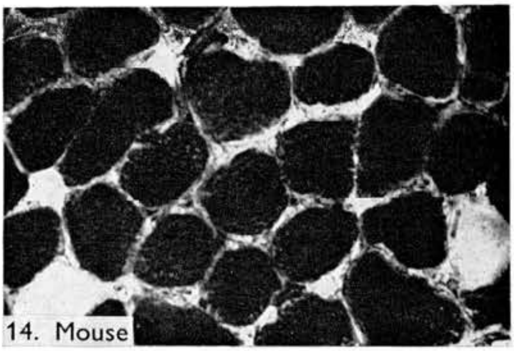


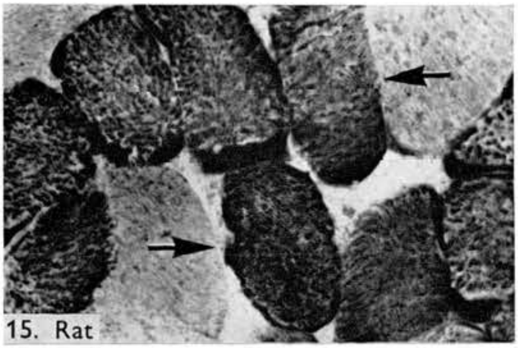
Figs. 9–12. Transverse sections of the diaphragm of the mouse (Fig. 9), rabbit (Fig. 10), sheep (Fig. 11), and horse (Fig. 12); myosin ATPase.

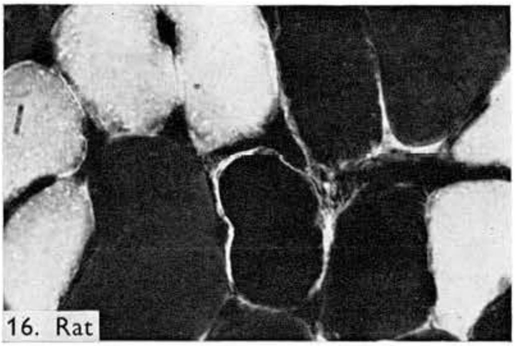
iron-alum haematoxylin, he reported the presence of two distinct populations of fibres in the diaphragm of the rat, mouse, rabbit and hedgehog, and later in the dog and human (Günther, 1953), corresponding in myofibrillar arrangement to the 'Fibrillenstruktur' and 'Felderstruktur' fibres described by Krüger (1952). This morphological difference was considered to be correlated with 'phasic' and 'tonic' contraction respectively; in the rat diaphragm 42% of fibres were classified as 'Felderstruktur', a proportion close to the 39% of ATPase-low fibres that we have observed. However, Günther (1953) found only 5% of the fibres of the diaphragm of the dog to be 'Felderstruktur', compared with our 36% myosin ATPase-low fibres in this species. In an electron microscopic study of the rat diaphragm, Bubenzer (1966) described two fibre types; thin, mitochondria-rich fibres were 'Felderstruktur', and thick fibres with fewer mitochondria, less glycogen and no lipid droplets were 'Fibrillenstruktur'. Muscle fibres in the diaphragm of the mouse, rat, guinea-pig and rabbit were found to vary in their phosphorylase activity by Takeuchi & Kuriaki (1955). Histochemical methods for enzymes of oxidative metabolism in the diaphragm of several mammals (Ogata, 1958) and in the diaphragm of the rat (George & Susheela, 1961; Padykula & Gauthier, 1963) showed a large variation in enzymic activity of individual fibres. Nishiyama (1966) distinguished three fibre types in the rat and cat diaphragm and concluded that phosphorylase was reciprocal to the activity of oxidative enzymes. However, we have observed a significant proportion of fibres in these muscles that contain high levels of both phosphorylase and SDHase activity (Figs. 17, 18).

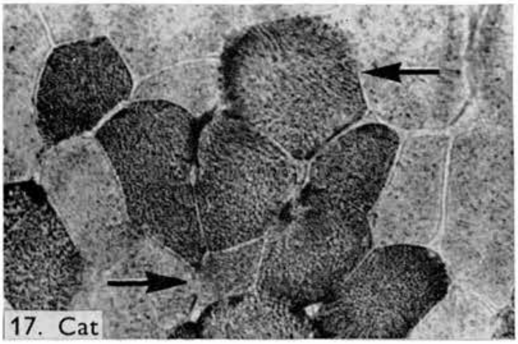
Padykula & Gauthier (1963) used the myosin ATPase reaction on the rat diaphragm but did not report a variation between fibres. In this muscle, they distinguished by electron microscopy 'red', 'intermediate' and 'white' fibres based on mitochondrial density, fibre diameter, width of Z line, and end-plate morphology (Padykula & Gauthier, 1963, 1970; Gauthier & Padykula, 1966). Gauthier & Padykula (1966) compared fibre types in the diaphragm of the rat, bat, shrew and ox with the electron microscope. They also studied the costal diaphragm of 36 mammalian species using Sudan black B staining of material either fresh frozen, or fixed in formalin or osmium tetroxide, and found that the level of Sudanophilia decreased with increasing body size. The diaphragm of small animals (species of mouse, bat and shrew) was stated to be composed of 'homogeneous red fibres', that of animals intermediate in size (including rat, cat, rabbit, dog and sheep) of 'mixtures of fibre types', and that of the pig and ox of 'homogeneous white fibres'. Our findings differ in that the diaphragms of the dog and sheep are composed more or less uniformly of fibres of high SDHase activity and Sudanophilia (Fig. 8). The diaphragm of the pig is clearly heterogeneous when stained with Sudan black B (Figs. 5, 7). Although they do not show the dense aggregations seen in fibres of smaller animals (Figs. 13, 15), the fibres of the ox and horse diaphragm have relatively high Sudanophilia and SDHase activity (Fig. 19).

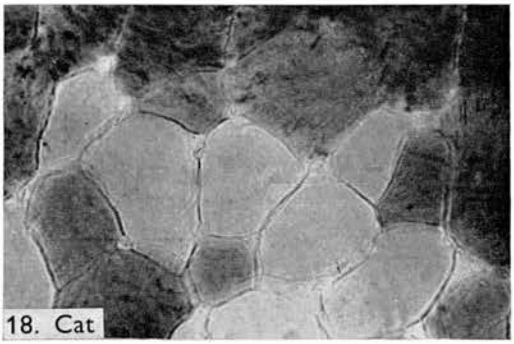

13. Mouse

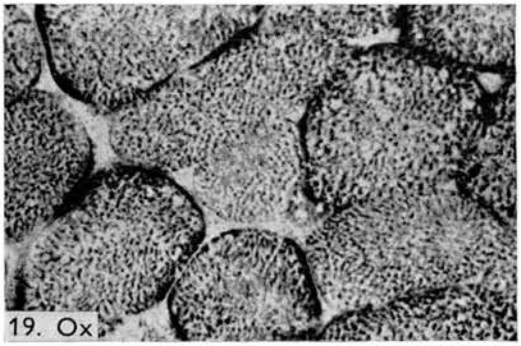

14. Mouse

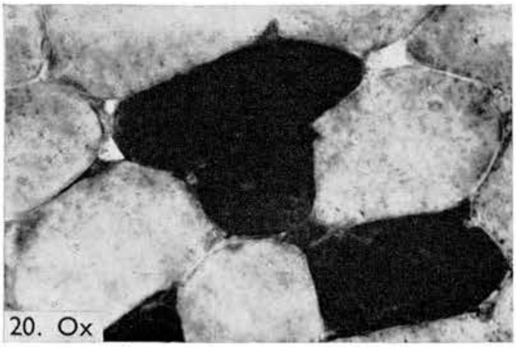

15. Rat


16. Rat


17. Cat


18. Cat


19. Ox


20. Ox

100 μm

Table 3. *Fibre types in muscles of known contraction times*

		Percentage of fibre type*											
		Ah				Al							
		Sh		Sl		Sh		Sl					Contraction time†
Species	Muscle	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl	Sh	Ph	Ah	(ms)
Rabbit	Thyroarytenoid	100	—	—	—	—	—	—	—	100	100	100	6
Rat	E.D.L.*	63	—	33	—	4	—	—	—	67	100	96	12
Cat	F.D.L.*	33	2	56	—	—	9	—	—	44	89	91	27
Rabbit	Cricothyroid	1	77	—	—	4	18	—	—	100	5	78	27
Rat	Soleus	14	1	—	—	1	84	—	—	100	15	15	36
Cat	Soleus	—	—	—	—	—	100	—	—	100	—	—	70

* Key: Ah, Sh, Ph: high activity of myosin ATPase, SDHase or phosphorylase respectively. Al, Sl, Pl: low enzyme activity. F.D.L.: m. flexor digitorum longus. E.D.L.: m. extensor digitorum longus.

† References for contraction times: Cat (Buller, Eccles & Eccles, 1960); rat (Close, 1964); rabbit (Hall-Craggs, 1968).

Comparative physiology

The presence of fast- and slow-twitch fibres in the diaphragm has been indicated by our histochemical demonstration of myosin ATPase-high and low fibres in all animals studied. Physiological evidence for this has been provided by studies on the action potentials in single diaphragmatic muscle fibres of the rabbit (Sant'Ambrogio, Decandia & Gantchev, 1969), and on the firing patterns of single phrenic motoneurons of the cat (Nail, Sterling & Widdicombe, 1969), which demonstrated the presence of two types of motor unit, differing in their threshold for stimulation and in firing frequency. For motor units of the cat gastrocnemius muscle these properties have been shown to be related to contraction times (Burke, 1968).

We have studied fibre types in muscles of known contraction times. The results are shown in Table 3, and confirm the postulation of Edgerton & Simpson (1969) that the proportion of myosin ATPase-high fibres in these muscles bears a reciprocal relationship to the contraction time. The histochemical findings of Barnard, Edgerton, Furukawa & Peter (1971) in guinea-pig hind limb muscles, and of Cardinet,

Figs. 13, 14. Transverse serial sections of the diaphragm of the mouse, stained for SDHase (Fig. 13), and myosin ATPase (Fig. 14). Arrows indicate myosin ATPase-low fibres with similar SDHase (Fig. 13), and myosin ATPase (Fig. 14). Arrows indicate myosin ATPase-low fibres with similar SDHase activity to myosin ATPase-high fibres.

Figs. 15, 16. Transverse serial sections of the diaphragm of the rat, stained for SDHase (Fig. 15) and myosin ATPase (Fig. 16). Arrows indicate fibres high in both SDHase and myosin ATPase activity.

Figs. 17, 18. Transverse serial sections of the diaphragm of the cat, stained for SDHase (Fig. 17) and phosphorylase (Fig. 18). Arrows indicate fibres high in both SDHase and phosphorylase activity.

Figs. 19, 20. Transverse serial sections of the diaphragm of the ox, stained for SDHase (Fig. 19) and myosin ATPase (Fig. 20). The myosin ATPase-low fibres have similar, or higher, SDHase activity compared with the myosin ATPase-high fibres.

Tunell & Fedde (1971) in m. pectineus of dogs, support this hypothesis. Table 2 shows the contraction times determined for the diaphragm of the rat, rabbit, cat and dog by Sant'Ambrogio & Saibene (1970). Although their results suggest that contraction time is related to body size, our data show little variation in the proportion of myosin ATPase-high fibres between these species. A histochemical study of the actual diaphragms for which contraction times have been determined will be necessary to resolve this inconsistency.

The proportion of myosin ATPase-high fibres in the semitendinosus muscle also appears to be inversely proportional to body size (Davies & Gunn, 1971), although the effect is not as marked as in the diaphragm. This property of m. semitendinosus would be expected by the requirements of dimensional theory (Hill, 1950), for which the limb muscles of larger animals must have lower intrinsic speeds of contraction.

Comparative metabolism

Crosfill & Widdicombe (1961) showed that in mice and rats the frequency of breathing could vary widely for constant alveolar ventilation with little increase in work, and that the rate of work of breathing per gram of body weight was high, compared with that in the larger guinea-pigs, rabbits, monkeys, cats and dogs. Since myosin ATPase activity is probably the rate-limiting step in the conversion of chemical to mechanical energy in muscle (Mommaerts, 1970), their results are consistent with the proportions of myosin ATPase-high fibres that we have seen in the diaphragm of the mouse, rat, rabbit, cat and dog. It is probable, then, that the diaphragms of the larger animals used in our study will have even lower rates of energy conversion than the larger animals studied by Crosfill & Widdicombe (1961).

Kunkel, Spalding, de Franciscis & Futrell (1956) showed that the cytochrome oxidase activity per gram of gracilis muscle of the rat, sheep, pig and ox varied as the $-0{\cdot}24$ power of body weight, and therefore directly with the metabolic rate (Kleiber, 1947). Although the respiration rate did not vary with body weight in other muscles, tissue slices from the diaphragm of a series of mice and rats respired at a rate proportional to the $-0{\cdot}15$ power of body weight (Bertalanffy & Estwick, 1953). While it is expected, therefore, that the capacity for oxidative metabolism of the diaphragm in our series of animals will also be less with increasing body size, fibres of the diaphragm of the larger animals appear histochemically to be dependent on aerobic metabolism. They do, however, have a capacity for anaerobic metabolism, presumably for brief periods of greater effort.

SUMMARY

Histochemical profiles of individual muscle fibres from the diaphragm of the mouse, rat, rabbit, cat, dog, sheep, pig, ox and horse were classified according to their reaction to methods demonstrating myosin adenosine triphosphatase, succinate dehydrogenase and phosphorylase. Other evidence indicates that the myosin adenosine triphosphatase reaction differentiates between fast-twitch and slow-twitch muscle fibres and that the succinate dehydrogenase and phosphorylase reactions demonstrate the capacity for aerobic and anaerobic metabolism respectively. Fast-twitch fibres, which may use either an aerobic metabolism, an anaerobic metabolism or a com-

bined aerobic and anaerobic metabolism, and slow-twitch fibres, which may use either an aerobic metabolism or a combined aerobic and anaerobic metabolism, have been recognized in the diaphragm.

The diaphragm of smaller animals has a high proportion of fast-twitch fibres and a predominantly aerobic metabolism. The diaphragm of larger animals has a majority of slow-twitch fibres and a capacity for combined aerobic and anaerobic metabolism. Only the mouse and pig have mean fibre transverse-sectional areas significantly different from the mean of all the species studied.

We are indebted to Professor A. R. Muir for assistance in all stages of this study. One of us (A. S. D.) was supported by a grant from the Meat and Livestock Commission.

REFERENCES

ASHMORE, C. R. & DOERR, L. (1971). Comparative aspects of muscle fiber types in different species. *Experimental Neurology* **31**, 408–418.

BÁRÁNY, M. (1967). ATPase activity of myosin correlated with speed of muscle shortening. *Journal of General Physiology* **50**, 197–218.

BÁRÁNY, M. & CLOSE, R. (1971). The transformation of myosin in cross-innervated rat muscles. *Journal of Physiology, London* **213**, 455–474.

BARNARD, R. J., EDGERTON, V. R., FURUKAWA, T. & PETER, J. B. (1971). Histochemical, biochemical and contractile properties of red, white and intermediate fibers. *American Journal of Physiology* **220**, 410–414.

BARNARD, R. J., EDGERTON, V. R., PETER, J. B. (1970). Effect of exercise on skeletal muscle. I. Biochemical and histochemical properties. *Journal of applied Physiology* **28**, 762–766.

BERTALANFFY, L. VON & ESTWICK, R. R. (1953). Tissue respiration of musculature in relation to body size. *American Journal of Physiology* **173**, 58–60.

BLANCHAER, M. C. (1964). Respiration of mitochondria of red and white skeletal muscle. *American Journal of Physiology* **206**, 1015–1020.

BOCEK, R. M. & BEATTY, C. H. (1966). Glycogen synthetase and phosphorylase in red and white muscle of rat and rhesus monkey. *Journal of Histochemistry and Cytochemistry* **14**, 549–559.

BROOKE, M. H. & ENGEL, W. K. (1966). Nitro blue tetrazolium: selective binding within striated muscle fibers. *Neurology, Minneapolis* **16**, 799–806.

BUBENZER, H. J. (1966). Die dünnen und die dicken Muskelfasern des Zwerchfells der Ratte. *Zeitschrift für Zellforschung und mikroskopische Anatomie* **69**, 520–550.

BULLARD, H. H. (1919). Histological as related to physiological and chemical differences in certain muscles of the cat. *Johns Hopkins Hospital Reports* **18**, 323–328.

BULLER, A. J., ECCLES, J. C. & ECCLES, R. M. (1960). Differentiation of fast and slow mucles in the cat hind limb. *Journal of Physiology, London* **150**, 399–416.

BURKE, R. E. (1968). Firing patterns of gastrocnemius motor units in the decerebrate cat. *Journal of Physiology, London* **196**, 631–654.

BURKE, R. E., LEVINE, D. N., ZAJAC, F. E., TSAIRIS, P. & ENGEL, W. K. (1971). Histochemical profiles of three physiologically defined types of motor units in cat gastrocnemius muscle. *Science* **174**, 709–712.

CARDINET, G. H., TUNELL, G. L. & FEDDE, M. R. (1971). A comparative study of contractile and histochemical properties in normal and hypotrophic muscle in the dog. *Anatomical Record* **169**, 288–289.

CARDINET, G. H., WALLACE, L. J., FEDDE, M. R., GUFFY, M. M. & BARDENS, J. W. (1969). Developmental myopathy in the canine with Type II muscle fiber hypotrophy. *Archives of Neurology* **21**, 620–630.

CLOSE, R. (1964). Dynamic properties of fast and slow skeletal muscles of the rat during development. *Journal of Physiology, London* **173**, 74–95.

CROSFILL, M. L. & WIDDICOMBE, J. G. (1961). Physical characteristics of the chest and lungs and the work of breathing in different mammalian species. *Journal of Physiology, London* **158**, 1–14.

DAVIES, A. S. & GUNN, H. M. (1971). A comparative histochemical study of the mammalian diaphragm and m. semitendinosus. *Journal of Anatomy* **110**, 137–139.

DUBOWITZ, V. & PEARSE, A. G. E. (1960*a*). Reciprocal relationship of phosphorylase and oxidative enzymes in skeletal muscle. *Nature, London* **185**, 701–702.

DUBOWITZ, V. & PEARSE, A. G. E. (1960*b*). A comparative histochemical study of oxidative enzyme and phosphorylase activity in skeletal muscle. *Histochemie* **2**, 105–117.

Edgerton, V. R., Gerchman, L. & Carrow, R. (1969). Histochemical changes in rat skeletal muscle after exercise. *Experimental Neurology* **24**, 110–123.

Edgerton, V. R. & Simpson, D. R. (1969). The intermediate muscle fiber of rats and guinea pigs. *Journal of Histochemistry and Cytochemistry* **17**, 828–838.

Engel, W. K. (1962). The essentiality of histo- and cytochemical studies of skeletal muscle in the investigation of neuromuscular disease. *Neurology, Minneapolis* **12**, 778–794.

Engel, W. K. (1965). Diseases of the neuromuscular junction and muscle. In *Neurohistochemistry* (Ed. C. W. M. Adams). Amsterdam: Elsevier.

Engel, W. K. (1970). Selective and nonselective susceptibility of muscle fiber types: a new approach to human neuromuscular diseases. *Archives of Neurology* **22**, 97–117.

Gauthier, G. F. & Padykula, H. A. (1966). Cytochemical studies of fiber types in skeletal muscle. A comparative study of the mammalian diaphragm. *Journal of Cell Biology* **28**, 333–354.

George, J. C. & Naik, R. M. (1959). Studies on the structure and physiology of the flight muscles of birds. 6. Variation in the diameter of the fibres of the pectoralis major and its relation to the muscle size and mode of flight. *Journal of Animal Morphology and Physiology* **6**, 90–94.

George, J. C. & Susheela, A. K. (1961). A histophysiological study of the rat diaphragm. *Biological Bulletin* **121**, 471–480.

Gillespie, C. A., Simpson, D. R. & Edgerton, V. R. (1970). High glycogen content of red as opposed to white skeletal muscle fibers of guinea pigs. *Journal of Histochemistry and Cytochemistry* **18**, 552–558.

Gollnick, P. D. & King, D. W. (1969). Effect of exercise and training on mitochondria of rat skeletal muscle. *American Journal of Physiology* **216**, 1502–1509.

Günther, P. G. (1952). Die morphologischen Grundlagen der Bewegungs- und Haltleistung (Tetanus und Tonus) des Zwerchfells. *Acta anatomica* **14**, 54–64.

Günther, P. G. (1953). Das muskuläre Substrat der Bewegungs- und Haltleistung des menschlichen Zwerchfells. *Acta anatomica* **17**, 348–352.

Guth, L. & Samaha, F. J. (1969). Qualitative differences between actomyosin ATPase of slow and fast mammalian muscle. *Experimental Neurology* **25**, 138–152.

Hall-Craggs, E. C. B. (1968). The contraction times and enzyme activity of two rabbit laryngeal muscles. *Journal of Anatomy* **102**, 241–255.

Hill, A V. (1950). The dimensions of animals and their muscular dynamics. *Science Progress* **38**, 209–230.

Hill, A. V. (1956). The design of muscles. *British Medical Bulletin* **12**, 165–166.

Hitzeman, J. W. (1963). Observations on the subcellular localisation of oxidative enzymes with nitro blue tetrazolium. *Journal of Histochemistry and Cytochemistry* **11**, 62–70.

Holloszy, J. O. (1967). Biochemical adaptation in muscle. Effects of exercise on mitochondrial oxygen uptake and respiratory enzyme activity in skeletal muscle. *Journal of Biological Chemistry* **242**, 2278–2282.

Jasmin, G., Bokdawala, F. & Desrosiers, M. (1971). Identification de la fibre intermédiaire dans le muscle squelettique. *L'Union médicale du Canada* **100**, 706–708.

Jinnai, D. (1960). Functional differentiation of skeletal muscles. *Acta medicinae Okayama* **14**, 159–169.

Joubert, D. M. (1956). An analysis of factors influencing post-natal growth and development of the muscle fibre. *Journal of Agricultural Science* **47**, 59–102.

Julian, L. M. & Cardinet, G. H. (1961). Fiber sizes of the biceps brachii muscle of dogs which differ greatly in body size. *Anatomical Record* **139**, 243.

Karpati, G. & Engel, W. K. (1967). Neuronal trophic function: a new aspect demonstrated histochemically in developing soleus muscle. *Archives of Neurology* **17**, 542–545.

Karpati, G. & Engel, W. K. (1968). Correlative histochemical study of skeletal muscle after suprasegmental denervation, peripheral nerve section and skeletal fixation. *Neurology, Minneapolis* **18**, 681–692.

Kleiber, M. (1947). Body size and metabolic rate. *Physiological Reviews* **27**, 511–541.

Kraus, H., Kirsten, R. & Wolff, J. R. (1969). Die Wirkung von Schwimm- und Lauftrainung auf die celluläre Function und Struktur des Muskels. *Archiv für die gesamte Physiologie des Menschen und der Tiere* **308**, 57–79.

Krüger, P. (1952). *Tetanus und Tonus der quergestreiften Skelettmuskeln der Wirbeltiere und des Menschen.* Leipzig: Akademische Verlagsgesellschaft.

Kugelberg, E. & Edström, L. (1968). Differential histochemical effects of muscle contractions on phosphorylase and glycogen in various types of fibres; relation to fatigue. *Journal of Neurology, Neurosurgery and Psychiatry* **31**, 415–423.

Kunkel, H. O., Spalding, J. F., de Franciscis, G. & Futrell, M. F. (1956). Cytochrome oxidase activity and body weight in rats and three species of large animals. *American Journal of Physiology* **186**, 203–206.

Mommaerts, W. F. H. M. (1970). The role of the innervation of the functional differentiation of muscle. In *The Physiology and Biochemistry of Muscle as a Food* (Ed. E. J. Briskey, R. G. Cassens & B. B. Marsh) **2**, 53–66. Madison: University of Wisconsin Press.

Moody, W. G. & Cassens, R. G. (1968). Histochemical differentiation of red and white muscle fibers. *Journal of Animal Science* **27**, 961–968.

Nachlas, M. M., Tsou, K., de Souza, E., Cheng, C. & Seligman, A. M. (1957). Cytochemical demonstration of succinic dehydrogenase by the use of new p-nitrophenyl substituted ditetrazole. *Journal of Histochemistry and Cytochemistry* **5**, 420–436.

Nail, B. S., Sterling, G. M. & Widdicombe, J. G. (1969). Some properties of single phrenic motoneurones. *Journal of Physiology, London* **200**, 137 *P*–138 *P*.

Nishiyama, A. (1966). Histochemical studies on the red, white and intermediate muscle fibers of some skeletal muscles. III. Histochemical demonstration of oxidative enzymes, phosphorylase and glycogen in respiratory muscle fibers. *Acta medicinae Okayama* **20**, 137–146.

Novikoff, A. B., Shin, W. Y. & Drucker, J. (1961). Mitochondrial localisation of oxidative enzymes. Staining results with two tetrazolium salts. *Journal of Biophysical and Biochemical Cytology* **9**, 47–56.

Ogata, T. (1958). A histochemical study of the red and white muscle fibers. Part I. Activity of the succinoxidase system in muscle fibers. *Acta medicinae Okayama* **12**, 216–227.

Ogata, T. (1964). An electron microscopic study on the red, white and intermediate muscle fibers of the mouse. *Acta medicinae Okayama* **18**, 271–280.

Padykula, H. A. (1952). The localization of succinic dehydrogenase in tissue sections of the rat. *American Journal of Anatomy* **91**, 107–146.

Padykula, H. A. & Gauthier, G. F. (1963). Cytochemical studies of adenosine triphosphatases in skeletal muscle fibers. *Journal of Cell Biology* **18**, 87–107.

Padykula, H. A. & Gauthier, G. F. (1970). The ultrastructure of the neuromuscular junctions of mammalian red, white and intermediate skeletal muscle fibers. *Journal of Cell Biology* **46**, 27–41.

Padykula, H. A. & Herman, E. (1955). The specificity of the histochemical method for adenosine triphosphatase. *Journal of Histochemistry and Cytochemistry* **3**, 170–195.

Paul, M. H. & Sperling, E. (1952). Cyclophorase system. XXIII. Correlation of cyclophorase activity and mitochondrial density in striated muscle. *Proceedings of the Society for Experimental Biology and Medicine* **79**, 352–354.

Pieper, K.-S., Feustel, G. & Hübner, H.-J. (1969). Zur Localisation der Succinodehydrogenase in 'roten' (dünnen) Skelettmuskelfasern der weissen Ratte. *Acta histochemica* **33**, 171–178.

Prewitt, M. A. & Salafsky, B. (1970). Enzymic and histochemical changes in fast and slow muscles after cross-innervation. *American Journal of Physiology* **218**, 69–74.

Ranvier, L. (1873). Propriétés et structures différentes des muscles rouges et des muscles blancs chez les lapins et chez les raies. *Compte rendu de l'Académie des Sciences, Paris* **77**, 1030–1034.

Romanul, F. C. A. (1964). Enzymes in muscle: I. Histochemical studies of enzymes in individual muscle fibers. *Archives of Neurology* **11**, 355–368.

Roodyn, D. B. (1967). The mitochondrion. In *Enzyme Cytology* (Ed. D. B. Roodyn), pp. 103–180. London: Academic Press.

Rutenberg, A. M., Wohman, M. & Seligman, A. M. (1953). Comparative distribution of succinic dehydrogenase in six mammals and modification in the histochemical technic. *Journal of Histochemistry and Cytochemistry* **1**, 66–81.

Samaha, F. J., Guth, L. & Albers, R. W. (1970). Differences between slow and fast muscle myosin. Adenosine triphosphatase activity and release of associated proteins by p-chloromercuriphenylsulfonate. *Journal of Biological Chemistry* **245**, 219–224.

Sant'Ambrogio, G., Decandia, M. & Gantchev, N. G. (1969). The composite structure of the diaphragm of the rabbit. *Archivio di Fisiologia* **67**, 27–39.

Sant'Ambrogio, G. & Saibene, F. (1970). Contractile properties of the diaphragm in some mammals. *Respiration Physiology* **10**, 349–357.

Scarpelli, D. G. & Pearse, A. G. E. (1958). Cytochemical localisation of succinic dehydrogenase in mitochondria. *Anatomical Record* **132**, 133–152.

Seligman, A. M., Ueno, H., Morizono, Y., Wasserkrug, H., Katzoff, L. & Hanker, J. (1967). Electron microscopic demonstration of dehydrogenase activity with a new osmiophilic ditetrazolium salt (TC-NBT). *Journal of Histochemistry and Cytochemistry* **15**, 1–13.

Stein, J. M. & Padykula, H. A. (1962). Histochemical classification of individual skeletal muscle fibers of the rat. *American Journal of Anatomy* **110**, 103–124.

Suchenwirth, R. & Bundschu, H. D. (1970). Enzymhistologische Befunde an der Skeletmuskulatur des Menschen. 1. Methoden und Ergebnisse bei Normalpersonen. *Klinische Wochenschrift* **48**, 1096–1101.

Susheela, A. K. & George, J. C. (1963). Respiratory quotient of rat diaphragm. *Canadian Journal of Biochemistry and Physiology* **41**, 2221–2223.

SUSHEELA, A. K. & GEORGE, J. C. (1964). Fatty acid oxidation by rat diaphragm. *Journal of Animal Morphology and Physiology* **11**, 180–185.

SWANSON, M. A. (1948). Studies on the structure of polysaccharides. IV. Relation of the iodine color to the structure. *Journal of Biological Chemistry* **172**, 825–837.

TAKEUCHI, T. (1956). Histochemical demonstration of phosphorylase. *Journal of Histochemistry and Cytochemistry* **4**, 84.

TAKEUCHI, T. & KURIAKI, H. (1955). Histochemical detection of phosphorylase in animal tissues. *Journal of Histochemistry and Cytochemistry* **3**, 153–160.

TAKEUCHI, T. & SASAKI, M. (1968). Histochemical and electron microscopic differences between native glycogen and polyglucose synthesized by phosphorylase in tissue cells. *Acta histochemica et cytochemica* **1**, 63–78.

WACHSTEIN, M. & MEISEL, E. (1955). The distribution of histochemically demonstrable succinic dehydrogenase and of mitochondria in tongue and skeletal muscles. *Journal of Biophysical and Biochemical Cytology* **1**, 483–488.

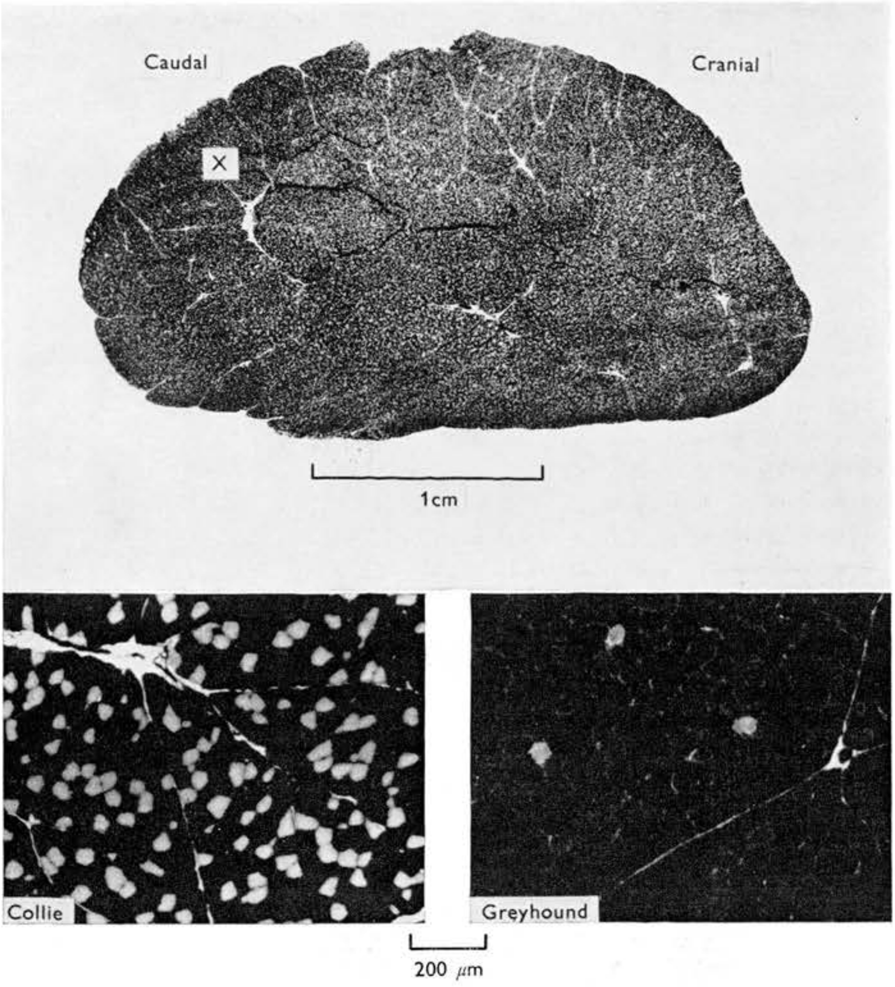


Fig. 4

23. Histochemical differences in the skeletal muscles of different breeds of horses and dogs. By H. M. Gunn (introduced by A. R. Muir). *Department of Veterinary Anatomy, University of Edinburgh* (Fig. 4).

The proportion of slow-twitch skeletal muscle fibres in the diaphragm and M. semitendinosus, as demonstrated by the histochemical reaction for myosin adenosine triphosphatase (myosin ATPase), decreases with increasing body size (Davies & Gunn, *J. Anat.* **112**, 1972). This finding corresponds to a decreasing speed of movement of the diaphragm and limbs with increasing body size.

A study of M. semitendinosus in 10 thoroughbreds and 9 other horses, 33 greyhounds and 9 other dogs, has been made. All the animals used were adults. The thoroughbreds and greyhounds had an unexpectedly low proportion of myosin ATPase low reacting (slow-twitch) fibres in relation to their body size.

The fresh frozen complete transverse section of M. semitendinosus of a collie, shown in Fig. 4, has been stained for myosin ATPase. A magnified area from this section, at ×, is shown together with an area from the same region of a greyhound semitendinosus. The deep cranial region of the M. semitendinosus of the dog and horse contains the highest proportion of slow-twitch fibres, occurring as groups of pale staining slow-twitch fibres. This proportion decreases progressively towards the superficial caudal region, where the slow-twitch fibres occur singly.

Complete cross-sections of M. semitendinosus of greyhounds and other large dogs have been compared. The greyhound semitendinosus has more fibres, and a smaller area of its cross-section occupied by slow-twitch fibres, as well as a smaller total number of slow-twitch fibres. The difference between thoroughbreds and other horses parallels this observation.

The significance of these findings will be discussed in relation to the athletic ability of these animals.

24. The effect of denervation on genotypic and compensatory growth of the immature avian salt gland.

By J. B. PITTARD and A. D. HALLY. *Department of Anatomy, University of Newcastle upon Tyne.*

Compensatory growth in the paired duck salt gland only follows unilateral ablation of one gland if there is a functional demand on the remaining gland (Jephcott & Hally, *J. Anat.* **106**, 1970). Compensatory growth is therefore an example of functional growth.

What is the role of the secretory nerve in this response? We denervated one gland in 3 day old ducklings, leaving the contralateral gland as control, and used unoperated ducklings as additional controls. We rested the operated birds for 1 day and then divided them into an unstimulated group with water *ad lib.* and a stimulated group which were injected daily with 10 % intravenous saline (20·5 m-equiv. NaCl/kg body weight). We killed the birds at 10 days post hatch and weighed the salt glands.

The mean Salt Gland Index (S.G.I.) (weight of two salt glands (mg)/kg body weight) of unoperated control glands: 291 ± S.E. 7, equalled that of the stimulated denervated glands: 297 ± S.E. 13. By contrast the S.G.I. of stimulated innervated glands rose 80 % to 537 ± S.E. 20.

We concluded that compensatory growth is wholly *dependent* on an intact nerve supply.

In the absence of functional demand unstimulated ducklings doubled their *absolute* body and salt gland weights during the experimental period by 'genotypic' growth.

The unstimulated denervated glands also grew at almost the same rate to reach an S.G.I. of 268 ± S.E. 9, so genotypic growth is largely *independent* of nerve supply.

25. Changes in rat dentine following systemic administration of adrenal glucocorticoid hormone.

By P. C. BALL (introduced by C. L. B. LAVELLE). *Department of Conservative Dentistry, University of Birmingham* (Fig. 5).

An investigation into the role played by the adrenal glucocorticoid hormones in the development of the dental tissues is being carried out. One aspect of this investigation involved a study of the mandibular incisors of 50 mature rats which were maintained in a hyperglucocorticoid state by the weekly injection of 0·1 ml Depo-Medrone (methylprednisolone acetate 40 mg/ml).

The systemic administration of high levels of glucocorticoids to rodents is known to result in an increased rate of eruption of the mandibular incisors. This increased eruption rate has been shown in this investigation to be associated with a marked thinning of the dentine walls of the tooth. The quantity of hormone used in this study has also been found to cause vascular changes in the incisor.

In the normal rodent all dentine is avascular. A histological examination of the rat incisors obtained in this investigation demonstrated vascular channels in the dentine of every hormone-treated animal. These blood vessels were situated mainly in the inner layer of newly deposited dentine but some could be traced passing from the pulp deep into the mature dentine. This vascularity of the dentine was found to occur within the first 7 days of administration of the hormone and to persist throughout the length of the experimental period. The photographs (Fig. 5) show two areas of transversely cut pulp and dentine from incisors of rats maintained for

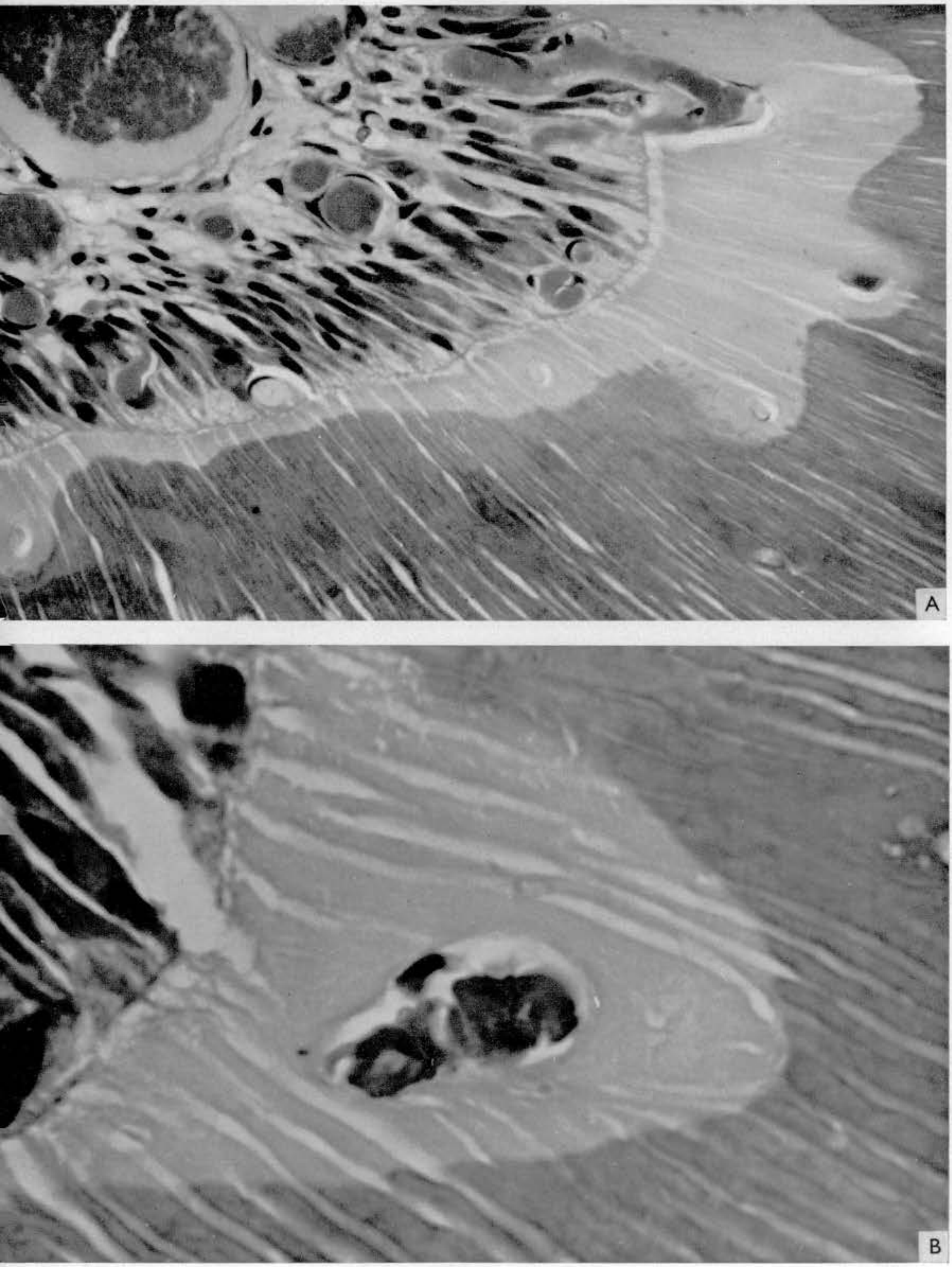


Fig. 5

a 5-week period in the hyperglucocorticoid state. Field A shows one blood vessel looping into the predentine and several other vessels transversely cut (× 100). Photograph B is of a single blood vessel at a magnification of 400 times.

An increase in the vascularity of the peripheral layer of the dental pulp was also noted in these hormone-treated animals.

DEMONSTRATIONS

D 1. The action of metabolic inhibitors on the sexual differentiation of the hypothalamus induced by neonatal androgen.

By D. F. SALAMAN (introduced by B. A. CROSS). *Department of Anatomy, University of Bristol.*

Testosterone propionate (TP) given to female rats within the first 10 days of life causes an acyclic pattern of gonadotrophin secretion to develop after puberty with failure of ovulation and permanent sterility. This demonstration illustrates the effects of the selective inhibitors of synthesis, hydroxyurea (DNA), actinomycin D and α-amanitin (RNA) and puromycin (protein) when administered simultaneously with TP to 4 day old female rats. Vaginal smears are taken from puberty and ovarian weight and the presence or absence of corpora lutea, ruptured follicles and eggs in the oviduct at death (90 days) are recorded.

The most effective inhibitor tested was α-amanitin which afforded almost complete protection against a low or moderate dose of TP (30 and 80 μg per rat). Hydroxyurea was partially effective against both doses, puromycin was only marginally effective against the lower dose of TP, while actinomycin D was without effect at either dose.

α-Amanitin is a selective inhibitor of non-ribosomal or informational RNA synthesis while actinomycin D at low doses inhibits ribosomal RNA synthesis preferentially. These results are consistent with an action of TP on hypothalamic messenger RNA rather than ribosomal RNA synthesis.

D 2. Intra-axonal transport of neurohypophysial hormones and related proteins in the rat.

By C. W. JONES, G. D. BURFORD and B. T. PICKERING (introduced by B. A. CROSS). *Department of Anatomy, University of Bristol.*

Small-scale chromatographic techniques have been developed for the isolation of isotopically pure oxytocin and vasopressin from the pooled neurohypophysis of four rats. By injecting radioactive amino acid into the CSF through the cisterna magna and killing the animals at various intervals after the injection, the time-course for the appearance of radioactive hormone into the gland and its disappearance from the gland has been determined. From these results we have been able to show that the intra-axonal transport of the hormones has a velocity of at least 1–2 mm/h, and have estimated the daily release rate from the gland to be about 19 mu. oxytocin and 29 mu. vasopressin. Calculations from these estimates allowed us to suggest that the steady-state plasma concentration for each hormone is about 3 μu./ml.

Besides the hormones, the neurohypophysis contains a family of cysteine-rich proteins – the neurophysins – which have long been considered as carrier proteins. We have developed a method, using polyacrylamide-gel electrophoresis, to study the neurophysins in individual rat glands. We have shown that the rat, in common with cattle and pigs, has two major and one minor neurophysin. All of these proteins become labelled after an intracisternal injection of [^{35}S]-cysteine and the time-course for the appearance of radioactivity in the two major neurophysins parallels that for the hormones. The minor neurophysin component appears to be a metabolic product of one of the major ones. One of the major components is absent from the glands of rats with hereditary hypothalamic diabetes insipidus (Brattleboro strain) and this finding, together with comparisons of relative amounts of the two proteins, enabled us to suggest that one major neurophysin is biosynthetically associated with vasopressin and the other with oxytocin.

A2. THE STRESS SYNDROME AND MEAT QUALITY

THE EFFECT OF BODY SIZE AND SELECTION ON SKELETAL MUSCLE FIBRE TYPES IN MAMMALS

H. M. GUNN and A. S. DAVIES

Department of Anatomy, Royal (Dick) School of
Veterinary Studies, Edinburgh

This study attempts to define and resolve some of the histochemical variations in the muscle fibres of mammals, and to demonstrate how the histochemical properties of muscle fibres may be influenced by selection and growth.

Fibre type profiles have been established in the diaphragm and M. semitendinosus of mammals of different body size, using succinate dehydrogenase as an indicator of aerobic capacity, phosphorylase as an indicator of anaerobic capacity and myosin adenosine triphosphatase as an indicator of intrinsic speed of contraction of individual fibres - fibres having a high activity of this enzyme being fast-twitch and those having a low activity being slow-twitch.

By using transverse frozen serial sections and back projection, histochemical profiles of about 400 individual muscle fibres were made on each sample taken from the diaphragms of adult shrews, mice, rats, rabbits, cats, dogs, sheep, pigs, oxen and horses; and from the semitendinosus muscle of adult mice, rats, rabbits, cats, dogs and horses. From these profiles the following types of muscle fibres were found: fast-contracting, aerobic; fast-contracting, with both aerobic and anaerobic capacity; fast-contracting, anaerobic: slow-contracting, aerobic; and slow-contracting, with both aerobic and anaerobic capacity. The proportion of slow-twitch fibres in the diaphragm and M. semitendinosus increases with increasing body size. This finding corresponds to a decreasing speed of movement of the diaphragm and limbs with increasing body size.

An increase in the proportion of fibres that are low in myosin adenosine triphosphatase activity, was seen in the longissimus muscles from 34 Large White pigs ranging from 1·3 to 93 kg live weight. This finding indicates a modification in the properties of some muscle fibres during growth to enable the animal to support itself.

A study of M. semitendinosus and M. anterior pectoral in 10 Thoroughbreds and 9 other horses, 33 Greyhounds and 9 other dogs, all the animals used being adults, showed that the Thoroughbreds and Greyhounds - breeds which have been selected to run quickly, had a lower proportion of slow-twitch fibres, in relation to their body size, than animals from other breeds.

L'EFFET DE LA TAILLE DU CORPS ET DE LA SELECTION SUR LE MUSCLE SQUELETTIQE TYPES DE FIBRES CHEZ LES MAMMIFERES

H.M. GUNN et A.S. DAVIES

Department of Anatomy, Royal (Dick) School of
Veterinary Studies, Edinburgh

Cette étude tente de définir et de résoudre certaines variations histochimiques dans les fibres musculaires des mammifères et de demonstrer comment les propriétés histo-chimiques des fibres musculaires peuvent etre influencées par la sélection et la croissance.

Des profils de type fibreux ont été établis dans le diaphragne et les muscles semi-tendineux de mammifères de taille différente, en utilisant la succinate deshydrase comme indicateur de la capacité aérobie, la phosphorylase comme indicateur de la capacité anaérobie et l'adénosine triphosphatase de myosine comme indicateur de vitesse de contraction intrinséque des fibres individuelles - les fibres réagissant beaucoup à cette enzymetétant à contraction rapide et celles réagissant moins étant à contraction lente.

En utilisant des sections transversales gelées et la "Back Projection", des profils histo-chimiques d'environ 400 fibres de muscle individuelles furent faits de chaque échantillon pris sur les diaphragmes de musaraignes adultes, souris, rats, lapins, chats, chiens, porcs, moutons, boeufs et chevaux: et du muscle semi-tendineux de souris, rats, lapins, chats, chiens et chevaux adultes. A partir de ces profils, on a découvert les différents types de fibres musculaires suivants: contraction rapide, aérobie; contraction rapide avec a la fois une capacité aérobie et anaerobie; contraction rapide anaérobie; contraction lente, aérobie; et contraction lente avec à la fois avec une capacité aérobie et capacité anaérobie. La proportion des fibres a contraction lente dans le diaphragme et les muscles semi-tendineux augmente avec l'accroissement de la taille. Cette découverte correspond à un ralentissement de la vitesse du movement due diaphragme et des membres avec l'accroissement de la taille du corps.

On a observé chez 34 porcs de type White Large (Blanc gros) dont le poids (vivant) varie de 1·3 kg. a 93 kg., un accroissement dans la proportion des fibres des muscles les plus longs qui ont une activité basse en triphosphatase adénosine de myosine. Cette découverte indique une modification des propriétés de certaines fibres musculaires pendant la croissance, en vue de permettre à l'animal de supporter son propre poids.

Une étude des muscles semi-tendineux et des muscles pectoraux antérieurs de 10 chevaux de race pure et de 9 autres chevaux, de 33 lévriers et de 9 autres chiens (tous ces animaux étant adultes) a montré que les chevaux de race pure et les lévriers - races qui ont été sélectionnées pour courir vite - ont une proportion de fibres musculaires à contraction lente plus basse par rapport à la taille de leur corps, que les animaux d'autres races.

AUSWIRKUNG VON KÖRPERGRÖSSE UND ZUCHTWAHL AUF SKELETTMUSKELFASERTYPEN BEI SÄUGETIEREN

H.M. GUNN und A.S. DAVIES

Department of Anatomy, Royal (Dick) School of
Veterinary Studies, Edinburgh

Zweck dieser Studie sind Definition und Analyse einiger histochemischer Variationen in Muskelfasern von Säugetieren. Es soll gezeigt werden, wie die histochemischen Eigenschaften von Muskelfasern durch Zuchtwahl und Wachstum beeinflußt werden können.

Im Diaphragma und M. semitendinosus von Säugetieren verschiedener Körpergröße wurden Fasertypprofile erstellt, unter Verwendung von Succinatdehydrogenase als Indikator aerober Kapazität, Phosphorylase als Indikator anaerober Kapazität und Myosin-Adenosin-Triphosphatase als Indikator der inhärenten Kontraktionsgeschwindigheiten einzelner Fasern. (Fasern mit hoher Aktivität dieses Enzyms haben hohe. Fasern mit geringer Aktivität geringe Kontraktionsgeschwindigkeit.)

Unter Verwendung tiefgekühlter transversaler Serienschnitte und Durchprojektion wurden histochemische Profile von ungefähr 400 einzelnen Muskelfasern aus jeder Probe erstellt, die dem Diaphragma ausgesachsener Spitzmäuse, Mäuse, Ratten, Kaninchen, Katzen, Hunden, Schafen, Schweinen, Ochsen und Pferden sowie dem M. semitendinosus ausgewachsener Mäuse, Ratten, Kaninchen, Katzen, Hunden und Pferden entnommen waren. Aus diesen Profilen ließen sich folgende Typen von Muskelfasern bestimmen: schnell kontrahierend, aerob; schnell kontrahierend, aerob und anaerob; schnell kontrahierend, anaerob; langsam kontrahierend, aerob; langsam kontrahierend, aerob und anaeob. Der Anteil von Fasern mit langsamer Kontraktion im Diaphragma und M. semitendinosus nimmt mit zunehmender Körpergröße zu. Dieser Befund entspricht der verringerten Geschwindigkeit der Bewegung in Diaphragma und Gliedern bei zunehmender Körpergröße.

Ein zunehmender Anteil von Fasern mit geringer Myosin-Adenosin-Triphosphatase-Aktivität wurde im M. longissimus von 34 Großen Weißen Schweinen mit einem Lebendgewicht von 1·3 kg - 93 kg gefunden. Dieser Befund weist auf eine Veränderung der Eigenschaften einiger Muskelfasern während des Wachstums zur Gewährleistung der Standfestigkeit des Tiers hin.

Eine Studie des M. semitendinosus und M. anterior pectoral bei 10 Vollblut- und 9 anderen Pferden, 33 Windhunden und 9 anderen Hunden (durchwegs ausgewachsene Tiere) zeigte, daß die Vollblutpferde und die Windhunde, die für schnelles Laufen gezüchtet werden, einen geringeren Anteil von Fasern mit langsamer Kontraktion bezogen auf die Korpergroße aufwiesen als Tiere anderer Züchtungen.

ВЛИЯНИЕ РАЗМЕРА ТЕЛА И СЕЛЕКЦИИ НА ТИПЫ СКЕЛЕТНЫХ МЫШЕЧНЫХ ТКАНЕЙ МЛЕКОПИТАЮЩИХ.

М. Ганн и А.С. Дейвис
Анатомического отделения Королевского института ветерних
наук (имени В.Дика), Эдинбург.

Это исследование пытается определить некоторые гистохимические отклонения в мышечных тканей млекопитающих, и показать, как могут влиять на гистохимию мышечных тканей процессы селекции и роста.

Установили профиля типов тканей в диафрагме и в полусухожильной мышце млекопитающих разных размеров, используя сукцино-дегидразу как указатель аэробной способности, фосфорилазу как указатель анаэробной способности и миозинаденозинтрифосфатазу как указатель присущей сократительной скорости отдельных тканей; причем, ткани, отличающиеся высокой активностью этого энзима - быстро-сокращающиеся, а ткани, имеющие низкую активность этого энзима - медленно-сокращающиеся.

Методом проекции поперечных замороженных серийных разрезов установили профиля примерно 400 отдельных мышечных тканей на каждой пробе, полученной из диафрагм взрослых землероек, мышей, крыс, кроликов, кошек, собак, овец, свиней, волов и лошадей; и из полусухожильных мышец взрослых мышей, крыс, кроликов, кошек, собак и лошадей. Изучая эти профиля, нашли следующие типы мышечных тканей: быстро-сокращающиеся, аэробные ткани, быстро-сокращающиеся с аэробной и анаэробной способностью, быстро-сокращающиеся, анаэробные; медленно-сокращающиеся, аэробные, и медленно-сокращающиеся, как и с аэробной, так и с анаэробной способностью. Число тканей в диафрагме и в полусухожильной мышце, сокращающиеся медленно, увеличивается соразмерно размеру тела; этот вывод соответствует уменьшению скорости движения диафрагмы и членов по мере увеличения размера тела.

В длинных мышцах от 34 больших белых свиней, в пределах от 1,3 до 93 кг живого веса, обнаружили увеличение количества тканей, в которых миозинаденозинтри[illegible]. Это указывает на то, что в процессе роста, вещества некоторых мышечных тканей изменяются, чтобы животное могло стоять.

Изучение полусухожильной мышцы и передней грудной мышцы на 10 чистокровных и на 9 других лошадях, на 33 борзых и на 9 других собаках (причем все изучаемые животные были взрослые) показало, что в чистокровных и борзых - породах, выбранных для быстрого бега - количество медленно-сокращающимся тканей по сравнению с размером тела меньше, чем у животных других пород.

THE EFFECT OF BODY SIZE AND SELECTION ON SKELETAL MUSCLE FIBRE TYPES IN MAMMALS

H. M. GUNN and A. S. DAVIES*

Department of Anatomy, Royal (Dick) School of
Veterinary Studies, Edinburgh

INTRODUCTION

Systems of classification of muscle fibres based on histochemical reactions have largely ignored the functional significance of the methods used. Nomenclature of fibres has been in terms of colour descriptions (Ogata, 1958), numerals (Dubowitz & Pearse, 1960; Engel, 1962) and alphabetical symbols (Stein & Padykula, 1962; Guth, Samaha & Albers, 1970; Brooke & Kaiser, 1970; Ashmore & Doerr, 1971), based on observations of histochemical reactions in muscle fibres of numerous muscles in a variety of mammals. These systems of classification may be superseded if fibres can be characterised by their mechanical and metabolic properties.

In this study the use of selected histochemical reactions and profile construction has enabled classification of individual fibres to be made according to their intrinsic speed of contraction and their capacity for aerobic and anaerobic metabolism. The myosin adenosine triphosphatase (myosin ATPase) reaction is used to indicate the intrinsic speed of contraction of a fibre - fibres having a high activity of this enzyme being fast-twitch those having a low activity being slow-twitch (Burke, Levine, Tsairis & Zajac, 1973). Succinate dehydrogenase activity is used as an indicator of aerobic metabolism and glycogen phosphorylase as an indicator of anaerobic metabolism. The diaphragm was used to establish histochemical profiles in a variety of mammals because it has a similar function in all the animals studied.

An increase in the proportion of fibres that are low in myosin ATPase activity during postnatal growth has been reported in the pectineus muscle of the dog by Cardinet, Wallace, Fedde, Guffy & Bardens (1969). A similar observation has been made by Karpati & Engel (1967) on the soleus of the rat, guinea-pig and cat. To investigate this phenomenon it was decided to study the effect of increasing body weight on the histochemical characteristics of muscle fibres in the domestic pig, both because the extent of postnatal growth of the pig exceeds that of most other domestic animals, and the skeletal muscle of the pig appears to be unique in its organisation of histochemical fibre types in that one or more bundles of fibres characterised by low activity of myosin ATPase are located within perimysium enclosed fasciculi.

The members of the Thoroughbred breed of horse and Greyhound breed of dog are notably quicker runners than their fellow specific members. These breeds have been selected to run quickly for approximately 300 years in the case of the Thoroughbred and 3,000 years in the case of the Greyhound. The possibility that a selection procedure (the criterion of selection being speed of running) may influence the proportions of different types of fibres in the muscles of these breeds is investigated. The results have been reported previously by Davies & Gunn, 1971; Gunn & Davies, 1971; Davies & Gunn, 1972; Davies, 1972 and Gunn, 1973.

MATERIALS AND METHODS

Samples were taken from the costal diaphragm of adult shrews, mice, rats, rabbits, cats, dogs, pigs, sheep, cattle and horses; from the dorsomedial region of m. longissimus at the level of the thoraco-lumbar junction from Large White pigs of 1·3 to 93 kg. live weight; and from the left m. pectoralis transversus of horses at the manubrium sterni. The samples were removed from each animal within 45 minutes of death. Complete cross-sections of the middle third of m. semitendinosus from mice, rats, rabbits, cats, dogs and horses were also taken as soon as possible after death. The outline of the transverse sectional area (T.S.A.) of m. longissimus of pigs at the level of the thoraco-lumbar junction, adjacent to the sampling site, was drawn on paper and the T.S.A. measured by the paper weighing method.

After rapid freezing of a block of fresh muscle, about ten adjacent serial sections, 10 μm thick, were cut transversely to the direction of the muscle fibres. The histochemical methods used are described by Davies & Gunn (1972); they are modifications of the methods used by Nachlas, Tsou, de Souza, Cheng & Seligman (1957) to demonstrate succinate dehydrogenase activity; Takeuchi & Kuriaki (1955) to demonstrate glycogen phosphorylase activity; and Padykula & Herman (1955) to demonstrate myosin ATPase activity. The serial sections were back projected on to tracing paper so that individual fibres could be outlined and their metabolic profiles constructed. To estimate the level of activity of enzymes that showed a continuous spectrum of activity between fibres, a simple division into high and low was made for each fibre relative to the overall level of activity of fibres in each section. Mean fibre T.S.A. were estimated by counting the number of fibres projected within an area of known magnification and where applicable the mean T.S.A. of each fibre type was determined by cutting out and weighing the tracing paper on which the profiles were constructed.

Low power projection of sections stained for myosin ATPase activity enabled an assessment to be made of the number of myosin ATPase low reacting bundles of fibres in samples from m. longissimus of pigs. Using the measurement of the T.S.A. of the whole muscle, an estimate of the total numbers of bundles in the T.S.A. was made. At the same time, the number of myosin ATPase low fibres in each bundle was recorded and the mean number calculated. Similarly, the total number of myosin ATPase low reacting fibres was assessed in the m. semitendinosus of dogs by sampling the muscle at 2 mm. intervals across its entire transverse section. The total area of myosin ATPase low reacting fibres was calculated from this figure, and the mean area of myosin ATPase low reacting fibres in the section.

RESULTS

The following types of fibres exist in significant though differing proportions, in the diaphragms of the ten species examined: fast-twitch, aerobic; fast-twitch, with both aerobic and anaerobic capacity; fast-twitch anaerobic; slow-twitch aerobic; and slow-twitch with both aerobic and anaerobic capacity. The proportions of each of these fibre types in the diaphragms of the ten species examined is given in Table 1.

Table 1 Percentages of histochemical fibre types in the diaphragm of ten mammalian species.

Species	No. of animals studied	No. of fibres counted	Percentage of fibre types*										
			Ah				Al				Ah	Sh	Ph
			Sh		Sl		Sh		Sl				
			Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl			
Shrew	2	1120	-	100	-	-	-	-	-	-	100	100	-
Mouse	4	1436	-	93	-	-	-	7	-	-	93	100	-
Rat	3	1337	7	25	27	2	5	38	-	-	61	75	35
Rabbit	3	1605	21	-	36	-	-	43	-	-	57	64	57
Cat	2	1612	16	-	45	-	-	39	-	-	61	55	61
Dog	4	3573	64	-	-	-	-	36	-	-	64	100	64
Sheep	3	2938	45	-	-	-	41	14	-	-	45	100	86
Pig	6	2148	37	3	12	3	4	41	-	-	55	45	53
Ox	3	1879	26	-	-	-	56	18	-	-	26	100	82
Horse	2	2559	21	-	-	-	77	2	-	-	21	100	98

*Key: Ah, Sh, Ph: high activity of myosin ATPase, SDHase or phosphorylase respectively.
Al, Sl, Pl: low enzyme activity.

Table 1 demonstrates that the proportion of myosin ATPase high reacting (fast-contracting) fibres increased with decreasing body size. Differences in succinate dehydrogenase activity between fibres were not as conspicuous as the difference in myosin ATPase activity, and the porportion of fibres having a high or low succinate dehydrogenase activity did not show a body size correlation. Phosphorylase activity tended to show an opposite trend to that of myosin ATPase activity. The horse had nearly 100% of its fibres high in phosphorylase activity, but in the shrew diaphragm no fibres with high phosphorylase activity were seen.

In the larger species, fast contracting fibres were high in phosphorylase activity, showing that fast-contracting fibres in these species use mainly an anaerobic metabolism. In smaller animals, however, the proportion of fibres with high myosin ATPase activity exceeded that of fibres with high phosphorylase activity, demonstrating that fast-contracting fibres may also use aerobic metabolism.

Observations on the complete cross sections of m. semitendinosus of mice, rats, rabbits, cats, dogs and horses of mixed breeds, showed that the caudal superficial region of the muscle of smaller animals contained only myosin ATPase high reacting fibres. With increasing body size, the deep region of mixed fibre population occupied a larger proportion of the muscle and the proportion of its fibres low in myosin ATPase activity increased.

---

*Present address: Department of Physiology and Anatomy, Massey University, Palmerston North, New Zealand.

The transverse sectional area of m. longissimus of the pigs studied, reased with increasing body weight in a relationship to the $^2/3$ power of body weight. The increase in mean fibre transverse sectional area is ectly proportional to the transverse sectional area of the whole muscle in s of live weight from 3·7 to 98 kg. The histological appearance of the lomysium and perimysium did not suggest a disproportionate development of sues other than muscle fibres. After ten days of age (3·7 kg live weight this study), growth in T.S.A. of m. longissimus of the pig is therefore ounted for by growth of a constant population of muscle fibres.

The number of myosin ATPase low reacting bundles of fibres remained stant throughout growth. However, the mean number of fibres per bundle reased from 1·0 in early postnatal life to 3·2 at 98 kg. live weight (Fig. 1).

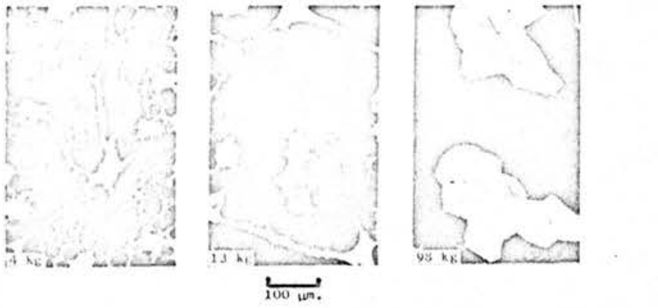


Fig. 1. Fibre types differentiated by the myosin ATPase reaction in m. longissimus at three stages of growth.

res with intermediate reaction for myosin ATPase were seen adjacent to the osin ATPase low bundles". This observation was made frequently in pigs ween birth and 15 kg. live weight.

Comparison of the T.S.A. of the muscle occupied by myosin ATPase low cting fibres with total body weight by means of double logarithmic ressions showed that the area of the muscle occupied by myosin ATPase low cting fibres bears a linear relationship to body weight (log Y = 0·99 x X).

The results obtained by assessing the total area of m. semitendinosus upied by slow-twitch fibres in 12 Greyhounds and eight other dogs are given Table 11. The area occupied by slow twitch fibres in the Greyhound is significantly less than the other dogs at the ·1% level. In samples from similar areas of m. pectorales transversus of five Thoroughbreds and six other horses, the area of slow-twitch fibres was significantly less at the ·5% level in Thoroughbreds than in other horses.

Table 11

QUANTITATIVE HISTOCHEMISTRY OF THE CANINE SEMITENDINOSUS MUSCLE

Proportion of the transverse sectional area occupied by myosin

ATPase low reacting (slow-twitch) fibres

GREYHOUNDS

Dog No.	Sex	Body Weight (kg)	%
1	F	37	3·3
2	F	26	1·6
3	F	29	0·8
4	F	27	3·2
5	F	31	2·8
6	F	34	3·3
7	F	25	3·3
8	F	31	5·1
9	F	30	0·3
10	F	34	2·8
11	M	34	1·6
12	M	22	0·9
		MEAN	2·4
		S.D.	1·4

OTHER DOGS

Dog No.	Breed	Sex	Body Weight (kg)	%
1	Great Dane	F	47	5·4
2	Collie	F	14	12·8
3	Collie	M	12	26·6
4	Collie	F	22	10·2
5	Labrador	M	33	24·9
6	Terrier X	M	10	14·2
7	Afghan	F	25	11·0
8	Afghan	F	32	7·0
			MEAN	17·4
			S.D.	6·5

DIFFERENCE BETWEEN MEANS IS SIGNIFICANT AT THE 0·1% LEVEL

DISCUSSION

The effect of body size on fibre types in adult animals

The biochemical studies of Bertalauffy & Estwick (1953), on a series of mice and rats, show that the capacity of the diaphragm for aerobic metabolism decreases with increasing body size. On that basis it may be expected that the capacity for oxidative metabolism may be less in the diaphragm of the larger animals in our series, in fact they have a high capacity for aerobic metabolism as shown histochemically, and also a capacity for anaerobic metabolism, presumably for brief periods of high respiratory rate.

The increasing proportion of fast-twitch fibres with decreasing body size may be related to the faster speed of contraction of the diaphragm in smaller mals. The proportion of fast-twitch fibres in m. semitendinosus also ears to be inversely proportional to body size, although the effect is not marked as in the diaphragm. This property of m. semitendinosus is to be ected from dimensional theory (Hill, 1950), according to which the limb cles of larger animals should have a lower intrinsic speed of contraction.

The unequal distribution of slow-twitch fibres across the transverse tion of m. semitendinosus results in a higher incidence of slow-twitch res in the deep, medial region than the superficial lateral region of the cle. This allows the deep region to be more suited for a postural ction, and the superficial region having a greater mechanical advantage be more suited for a predominantly propulsive function.

effect of changing body size during growth on m. longissimus of pigs

If an animal maintains roughly the same shape as it grows, the cross-tional area of any muscle will increase only by a factor of the 2/3 power the weight. This was confirmed by the comparison, using double logarithmic ressions, of T.S.A. of m. longissimus with total body weight. Although the cle should become proportionally weaker by this growth, the T.S.A. of the cle occupied by slow-twitch fibres in fact increases in direct proportion to weight. Awan & Goldspink (1972) have shown that slow-contracting fibres develop and maintain more tension per µmole of creatine phosphate used and therefore ergonomically more efficient for postural activity than fast-racting fibres. Thus, the contractile apparatus of m. longissimus adapts he changing demands placed on it during growth by the relative increase in economical fibres. Histochemical evidence has been obtained which shows this adaptation may cause a transformation of the physiological properties ertain fibres.

effect of selection for speed of running on fibre types

On a body size basis it might be expected that large horses and dogs should a greater area of their skeletal muscle occupied by slow-contracting es than smaller members of their species. However, as Thoroughbreds and hounds have a lower proportion of slow-contracting fibres in their limb les than smaller members of their species, a procedure of selection for d movement may override the effect of body size. So selection for speed produced, over a large number of generations, animals with subtle erences in their musculature. These differences appear to be neuro-cally determined since the myosin ATPase activity of a fibre is influenced ts type of innervation. Therefore, the differences seen in the ortion of different types of fibres in the muscles of these animals may llied to differences in their nervous system.

General Discussion

The ratio of slow-contracting to fast-contracting fibres, as determined ochemically, can be related functionally to ontogenetic and phylogenetic ease in size, to selection for rapid limb movement and to the functional nds made on different parts of the same muscle.

Changes in the characteristics of muscle fibres as basic as the ATPase activity of its myosin and its intrinsic speed of contraction imply considerable adjustment of the motor unit. During normal growth this change may involve either the conversion of a motor neurone, or a localized denervation of a muscle fibre associated with a colonizing re-innervation from a neighbouring motor unit of a different type. These possibilities merit further investigation.

REFERENCES

ASHMORE, C.R. & DOERR, L. (1971). Experimental Neurology 31, 408-418.

AWAN, M.Z. & GOLDSPINK, G. (1972). Journal of Mechanochemistry and Cell Motility 1, 97-108.

BERTALANFFY, L. VON & ESTWICK, R.R. (1953). American Journal of Physiology 173, 58-60.

BROOKE, M.H. & KAISER, K.K. (1970). Archives of Neurology 23, 369-379.

BURKE, R.E., LEVINE, D.N., TSAIRIS, P. & ZAJAC, F.E. (1973). Journal of Physiology 234, 723-748.

CARDINET, G.H., WALLACE, L.J., FEDDE, M.R., GUFFY, M.M. & BARDENS, J.W. (1969). Archives of Neurology 21, 620-630.

DAVIES, A.S. (1972). Journal of Anatomy 113, 213-240.

DAVIES, A.S. & GUNN, H.M. (1971). Journal of Anatomy 110, 137-139.

DAVIES, A.S. & GUNN, H.M. (1972). Journal of Anatomy 112, 41-60.

DUBOWITZ, V. & PEARSE, A.G.E. (1960). Histochemie 2, 105-117.

ENGEL, W.K. (1962). Neurology, Minneapolis 12, 778-794.

GUNN, H.M. (1973). Journal of Anatomy 114, 303.

GUNN, H.M. & DAVIES, A.S. (1971). Biochemical Journal 125, 108-109.

GUTH, L., SAMAHA, F.J. & ALBERS, R.W. (1970). Experimental Neurology 26, 126-135.

HILL, A.V. (1950). Science Progress 38, 209-230.

KARPATI, G. & ENGEL, W.K. (1967). Archives of Neurology 17, 542-545.

NACHLAS, M.M., TSOU, K., DE SOUZA, E., CHENG, C. & SELIGMAN, A.M. (1957). Journal of Histochemistry and Cytochemistry 5, 420-436.

OGATA, T. (1958). Acta medicinae Okayama 12, 216-227.

PADYKULA, H.A. & HERMAN, E. (1955). Journal of Histochemistry and Cytochemistry 3, 170-195.

STEIN, J.M. & PADYKULA, H.A. (1962). American Journal of Anatomy 110, 103-124.

TAKEUCHI, T. & KURIAKI, H. (1955). Journal of Histochemistry and Cytochemistry 3, 153-160.

[*From the Proceedings of the Physiological Society*, 13–14 *September* 1974
Journal of Physiology, **244**, 49–50*P*]

The identification of factors favouring athletic ability in dogs

BY H. M. GUNN and the late A. R. MUIR. *Department of Anatomy, Royal (Dick) School of Veterinary Studies, Edinburgh EH9 1QH*

This study compares the skeletal muscle of greyhounds, a breed selected for high-speed running, with other breeds by gross dissection, histometric and histochemical methods to identify any adaptations of their skeletal muscle which would favour their superior athletic capabilities.

Total carcass dissection was carried out on seven adult greyhounds and five other adult dogs. Muscles were grouped into functional units, weighed and the data analysed by analysis of covariance at the 5% level of significance. Total hind-limb muscle and m. longissimus weight occupied a greater proportion of total body weight than in the other breeds. This specialization would lead to greater propulsion by the spinal column and hind limb in the greyhound. A greater proportional mass of the hind limb was found above the stifle in the adult greyhound, and this would allow the hind limb to have a higher natural frequency of oscillation than the hind limb of other dogs (Tricker & Tricker, 1967), thus favouring a faster speed of non-forced limb movement. These differences were not found in eleven greyhound and four other pups, and the adult differences can be attributed to a greater growth rate of the functional units in the greyhound.

Another feature of the greyhound is its greater acceleration capability. At similar body masses the transverse sectional area of a muscle may be related to its acceleration capacity. The transverse sectional area of m. semitendinosus – a propulsive muscle of the hind limb – was compared in thirty-three greyhounds and twenty-six other dogs (adults and pups) and was found to be significantly greater in the greyhound, due to a greater number of fibres in the muscle.

Adult greyhounds have a higher proportion of myosin adenosine triphosphatase high-reacting (fast-twitch) fibres in their semitendinosus muscle than other dogs (Gunn, 1973). A histochemical investigation on m. semitendinosus of greyhound and other pups established that the difference in the proportions of myosin adenosine triphosphatase high-reacting (fast-twitch) and low-reacting (slow-twitch) fibres present in the respective adults was not as marked in the pups, either between the two types of dog or across the transverse section of the muscle.

It appears that greyhounds have gross morphological as well as subtle differences in their musculature which favour their greater speed of running. The gross differences develop as a result of the natural growth of

[P.T.O.

these animals, and the differences in the proportion of slow and fast-twitch fibres seen in the adults, which is neurogenically controlled, are not present at birth.

REFERENCES

GUNN, H. M. (1973). *J. Anat.* **114**, 303.

TRICKER, R. A. R. & TRICKER, B. J. K. (1967). *The Science of Movement.* London: Mills and Boon.

Reprinted from "Equine Veterinary Journal", Vol. 4, No. 3.

Histochemical Observations on Laryngeal Skeletal Muscle Fibres in 'Normal' Horses

H. M. GUNN M.V.B., M.R.C.V.S.

Department of Anatomy, Royal (Dick) School of Veterinary Studies, Edinburgh

ATROPHY of the left dorsal crico-arytenoid muscle of the horse is associated with laryngeal paralysis (Cole, 1946), and the consequent inability to dilate the rima glottidis sufficiently during exercise may produce a "roaring" sound on inspiration (Cook, 1965).

Cole (1946) provided the following evidence that atrophy of the left dorsal crico-arytenoid is of neurogenic origin. The muscles supplied by the left recurrent laryngeal nerves were atrophic, and in three cases atrophy occurred in the contralateral muscles. Histologically, atrophied muscles showed groups of small diameter fibres. Many horses with atrophy of left laryngeal muscles had smaller diameter recurrent laryngeal nerves on the left side. These nerves showed disintegration of axons and disappearance of myelin sheaths, particularly in small finely myelinated fibres at the periphery.

The present paper attempts to determine whether any neurogenic alterations can be shown in the laryngeal muscles of apparently normal horses. This approach is possible because of the ability to demonstrate various histochemical fibre types in muscle, and because of the experimental evidence that these fibre types are affected by their innervation pattern. This is shown by the effects on muscles of changing their nerve supply, thus causing the nerve to one histochemical type of muscle to innervate a muscle of a different histochemical type (Dubowitz, 1967; Guth, Samaha and Albers, 1970), and by the reinnervation studies of Karpati and Engel (1968a).

MATERIALS AND METHODS

The larynges from 12 randomly selected horses, six adult cattle, and three greyhounds were obtained from the abattoir and post-mortem room. These animals had no clinical features of laryngeal paralysis, as described by Cook (1965) but only one (No. 10) was examined with an endoscope and it was normal. Both dorsal crico-arytenoid muscles were removed rapidly by severing their origins and insertions, and immediately weighed. The tendinous portion of these muscles and samples of the diaphragm, semitendinosus, anterior superficial pectoral and psoas muscles, were then frozen rapidly in Arcton 12 (I.C.I.) cooled to its melting point of —158°C with liquid nitrogen. Fresh frozen serial sections were cut 10 µm thick on a cryostat.

The methods used are described by Davies and Gunn (1972): they are modifications of the methods used by Nachlas, Tsou, de Souza, Cheng and Seligman (1957) to demonstrate succinate dehydrogenase (SDHase)

TABLE I

POSSIBLE HISTOCHEMICAL FIBRE TYPE PROFILES USING THE ENZYMES MYOSIN ADENOSINE TRIPHOSPHATASE (myosin ATPase), SUCCINATE DEHYDROGENASE (SDHase), AND GLYCOGEN PHOSPHORYLASE (GPase)

Myosin ATPase	SDHase	GPase	Speed of Contraction	Metabolism	% Fibre Types in an Area of Left Dorsal Crico-arytenoid of Horse No. 11
Ah	Sh	Ph	Fast	Combined aerobic and anaerobic	72%
Ah	Sh	Pl	Fast	Aerobic	—
Ah	Sl	Ph	Fast	Anaerobic	—
Ah	Sl	Pl	Fast	—	—
Al	Sh	Ph	Slow	Combined aerobic and anaerobic	27%
Al	Sh	Pl	Slow	Aerobic	1%
Al	Sl	Ph	Slow	Anaerobic	—
Al	Sl	Pl	Slow	—	—

Key: Ah, Sh, Ph: high activity of myosin ATPase, SDHase or phosphorylase respectively.
Al, Sl, Pl: low enzyme activity.

TABLE II

Type of Horse	Number	Age (years)	Sex	Weights of Muscles (g) Left	Weights of Muscles (g) Right	Mean Group Size* Left	Mean Group Size* Right
Pony	1	6	Gelding	4.9	4.8	3.8	—
Pony	2	Aged	Female	7.2	7.3	3.6	3.7
Pony	3	Aged	Gelding	6.3	6.4	3.6	4.1
Pony	4	3	Gelding	6.9	7.1	2.0	3.6
Shetland Pony	5	4	Gelding	2.5	2.6	2.2	1.8
Pony	6	One-half	Male	4.3	4.5	2.1	2.6
Arab x Thoroughbred	7	One-third	Male	5.0	5.1	2.4	1.9
Thoroughbred	8	6	Gelding	4.5	5.1	3.4	2.5
Hunter	9	Aged	Gelding	9.3	8.6	13.9	3.9
Thoroughbred	10	8	Gelding	12.4	10.7	4.7	2.9
Thoroughbred	11	2	Female	6.5	6.7	2.1	1.7
Carthorse	12	Aged	Male	11.3	13.0	9.8	3.5

* Number of ATPase low fibres per group.

activity; Takeuchi and Kuriaki (1955) to demonstrate glycogen phosphorylase (GPase) activity; and Padykula and Herman (1955) to demonstrate myosin adenosine triphosphatase (ATPase) activity. These serial sections were back projected on to tracing paper so that individual fibres could be outlined and their metabolic profiles constructed. The mean transverse sectional areas of each fibre type was determined by cutting out and weighing the tracing paper.

Grouping of fibre types was assessed by counting the fibres with a low activity for myosin ATPase. The counts were made on transverse bands taken across the mid-portion of the dorsal crico-arytenoid muscles from the medial to their lateral borders. The numbers of myosin ATPase low fibres and the number of fibres forming contiguous groups were counted. A group was defined as a number of fibres in the same fasciculus, that were low in myosin ATPase, and whose sides (rather than angles) were in contact. The mean number of fibres per group and the range of size of groups expressed as a percentage of the total number of ATPase low reacting fibres sampled was used to compare animals.

RESULTS

(a) *Normal fibre types in horse muscles*

The evidence that succinate dehydrogenase activity indicates aerobic activity; glycogen phosphorylase activity indicates anaerobic activity; and myosin ATPase activity is related to the intrinsic speed of contraction is presented by Davies and Gunn (1972).

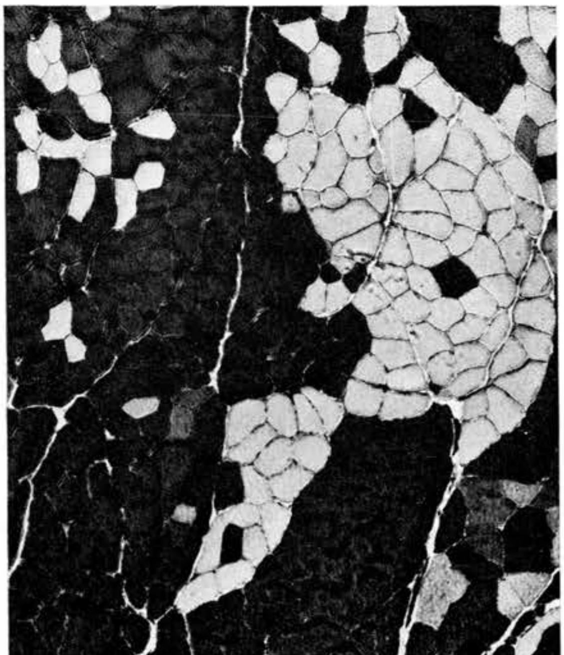


Fig. 1. Transverse section of left dorsal crico-arytenoid of a Hunter (horse No. 9), stained for myosin ATPase, showing "type grouping". X 60.

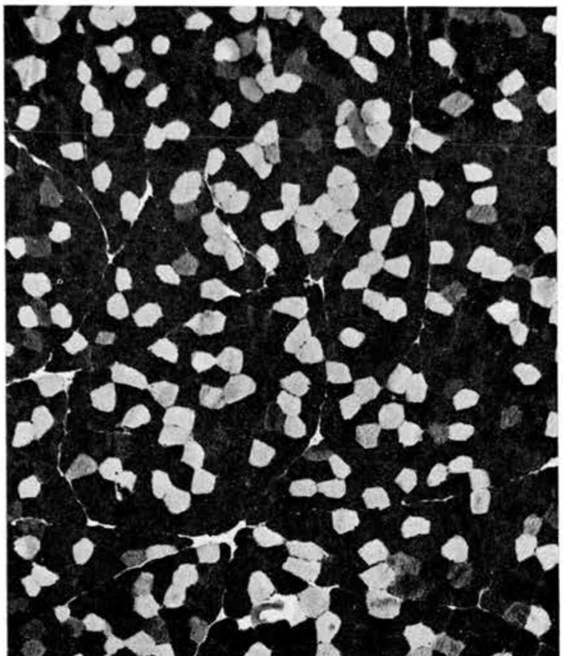


Fig. 2. Transverse section of right dorsal crico-arytenoid of a Thoroughbred gelding (horse No. 8), stained for myosin ATPase, showing a normal mosaic pattern. X 60.

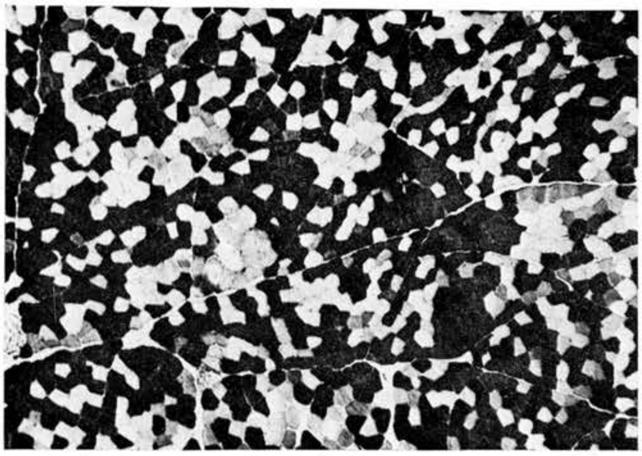


Fig. 3. Transverse section of left dorsal crico-arytenoid of a foal (horse No. 7), stained for myosin ATPase, showing "type grouping". X 60.

Using these reactions, the possible histochemical fibre types are shown in Table I.

Of these, only four types are found in normal equine muscle. They are: Ah, Sl, Ph; Ah, Sh, Ph; Al, Sh, Pl; and Al, Sh, Ph. Myosin ATPase low fibres are frequently characterized by a succinate dehydrogenase reaction in which diformazan deposits occur as intense blue punctate dots, randomly distributed throughout the fibres. In myosin ATPase high fibres, the diformazan deposits are not as clearly defined and tend to be concentrated under the sarcolemma. The proportion of these types of fibres varies between muscles and between regions of certain muscles.

Differences in proportion also occur between breeds and at different ages in the same breed (Gunn, 1972). These differences were not considered to affect the results of the present study because contralateral pairs of muscles were always compared.

(b) *Normal fibre types in the dorsal crico-arytenoid muscle*

All fibres in the normal dorsal crico-arytenoid muscle, e.g. No. 11, see Table II, have a high activity of succinate dehydrogenase, and therefore only Ah, Sh, Ph; Al, Sh, Ph and Al, Sh, Pl fibres are present. Slow twitch aerobic (Al, Sh, Pl) fibres, comprise less than 7 per cent of the total fibres.

These three fibre types are normally distributed in the mosaic pattern shown in figs. 2 and 4. However, some dorsal crico-arytenoid muscles show replacement of the normal mosaic pattern by groups of myosin ATPase low and high fibres, figs. 1 and 3. It was shown that over 85 per cent of 2,512 myosin ATPase low fibres counted in normal left dorsal crico-arytenoid muscles occurred in groups of less than 10 fibres.

"Normal" muscles in this context were taken as those which showed little differences between the left and right muscles, either in fibre type or in distribution of these fibres. The left dorsal crico-arytenoid of horses, Nos. 5, 6 and 11 (Table II), were "normal" with these criteria.

(c) *Abnormalities in the grouping of fibre types in the dorsal crico-arytenoid muscles*

Some dorsal crico-arytenoid muscles, e.g. the left from horses Nos. 9 and 7, figs. 1 and 3 respectively, show that the normal mosaic pattern of figs. 2 and 4 has been replaced by groups of fibres with low myosin ATPase activity. Fig. 5 compares the grouping patterns between a normal and an abnormal distribution by showing the sizes of the groups of contiguous fibres expressed as a percentage of the total number of ATPase low fibres counted.

It can be seen in this histogram, and in other severely affected specimens, that when there is extensive grouping in the left muscle, there is an increase in size of group in the right muscle. Type grouping occurred in a foal, No. 7, in the left dorsal crico-arytenoid, figs. 3, 4 and 6. The dorsal crico-arytenoid muscle has a similar origin and insertion, and should have a similar function in the horse, ox and dog. Abnormal grouping was not seen in the left dorsal crico-arytenoid of six adult cattle and three greyhounds.

Horse No. 9 had the abnormal fibre types: Ah, Sh, Pl; Al, Sl, Ph; and Al, Sl, Pl. As the myosin ATPase low fibres could have either a high or low activity for glycogen phosphorylase, the latter enzyme does not reveal the grouping as clearly as myosin ATPase.

(d) *Atrophy*

Fresh muscle weights shown in Table II do not indicate any unilateral muscular atrophy. The differences of the weights of the muscles on either side is not significant using Student's 't' test. Indeed, the markedly affected left muscle of horse No. 9 is actually heavier than its partner. So the changes in fibre types and their groupings are expressions of changes in functional properties of the fibres, and there is unlikely to be any marked change in the total number of fibres present.

The main difference in area noted was that the ATPase low fibres in the large groups of horse No. 9 had a mean area of 7,000 μm² which is greater than the mean area of 4,500 μm² for ATPase low fibres in smaller groups of the same animal.

DISCUSSION

The muscle fibre types found in the arytenoid muscles are similar to those fibre types reported in the diaphragm of the horse (Davies and Gunn, 1972). This may be related to the fact that both move rhythmically during breathing (Negus, 1949), and are therefore continually acting muscles.

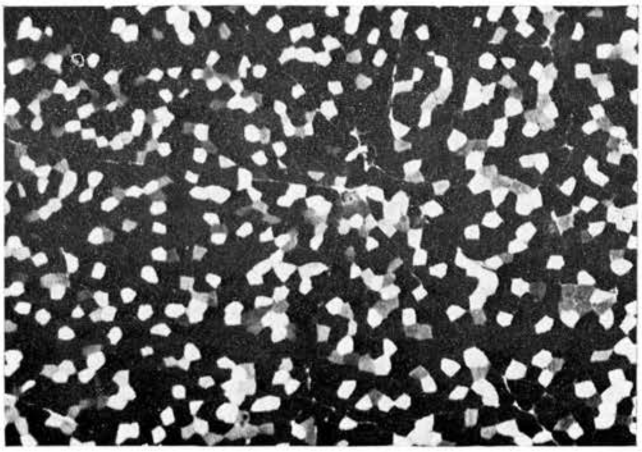


Fig. 4. Transverse section of right dorsal crico-arytenoid of a foal (horse No. 7), stained for myosin ATPase, showing a normal mosaic pattern. X 60.

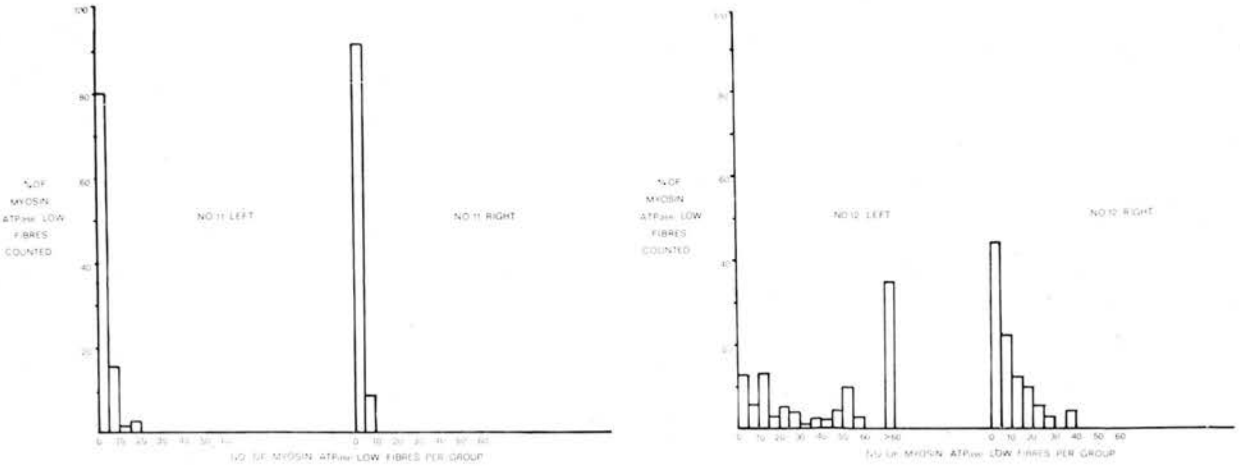


Fig. 5. Frequency distribution of the number of myosin ATPase low fibres per group (frequency interval of 5 fibres), expressed as a percentage of the total myosin ATPase low fibres counted, in the left and right dorsal crico-arytenoid of a normal horse (*No.* 11), *and one showing grouping* (*No.* 12).

Karpati and Engel (1968a) have shown that by crushing a nerve on three separate occasions and by sectioning a nerve and re-suturing it, type grouping of muscle fibres was demonstrated in the limb muscles of the guinea-pig by the myosin ATPase reaction when the muscles were examined 4-6 months after the operative procedures. They showed that the mechanism of completing the re-innervation of these muscles was by collateral branching of successful regenerating nerve fibres.

Type grouping was also shown to occur 2-4 months after experimental sectioning and re-suturing of the nerve supplying the tibialis anterior muscle of the white rat by Edström and Kugelberg (1969). They showed grouping both by the succinate dehydrogenase reaction and by PAS negativity in individual motor units after stimulating single motor units to deplete their glycogen content. However, when the sciatic nerve was sectioned and regeneration not allowed to occur by removing part of the nerve, type grouping did not occur in the soleus and gastrocnemius of the guinea-pig (Karpati and Engel, 1968b).

The enzyme NADH diaphorase can show the dependence of a fibre on oxidative metabolism. Karpati and Engel (1968b) have shown that three weeks after section of the nerve to the soleus and gastrocnemius in guinea-pigs, this enzyme does not differentiate fibre types because of a decline in its activity. One horse, No. 9, had a noticeable fall in activity of the aerobic enzyme used in this study, SDHase, in some of its fibres. Grouping of phosphorylase low fibres did not occur to the same extent as grouping of ATPase low fibres. Studies relating to muscular pathology in the horse should therefore incorporate enzymes of aerobic and anaerobic metabolism as well as myosin ATPase.

Some of the suggested aetiological factors concerned in laryngeal paralyses in the equine are listed by Johnson (1970). Quinlan and Morton (1957) were unable to finish their experiments, but suggest a hereditary predisposition to laryngeal paralysis. Cook (1966) shows that a mycotic infection in the guttural pouch may be associated with laryngeal paralysis. Horse No. 10 had such an infection on the left side which had regressed before death.

This study shows that neurogenic changes occur in the dorsal crico-arytenoid muscles of randomly selected horses which did not have laryngeal paralysis. Edström and Kugelberg (1969) suggest that as a disease progresses the newly formed groups in "type grouping" become denervated, and so these groups atrophy. This sequence is seen in amyotrophic lateral sclerosis in man.

Group atrophy is seen in the haematoxylin and eosin stained photomicrographs of Cole (1946). The groups seen in the horses studied may have progressed to a stage when they would have atrophied if the animals had been allowed to live longer, and so some of the animals used may eventually have become clinical "roarers".

The work of increasing the respiratory exchange in a large animal is greater than that for a small animal (Crossfill and Widdicombe, 1961). It is possible, therefore, that a slight interference to normal breathing in a large animal, such as the horse, which would not be detected clinically but which increases its work of breathing, may decrease its athletic ability.

Further studies, to find out if these neurogenic changes observed are due to an intermittent disruption in nerve supply or a developmental defect, are required. Observations on the branchial efferent nucleus of the

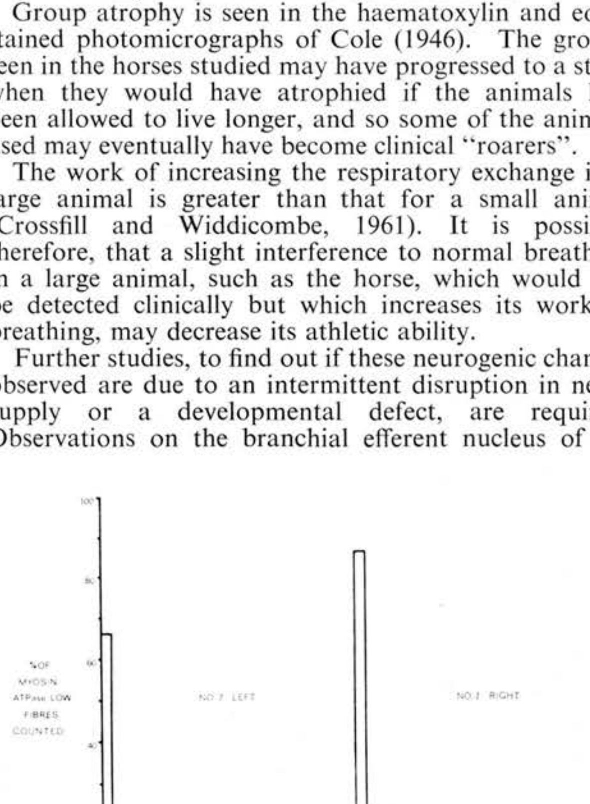


Fig. 6. Frequency distribution of the number of myosin ATPase low fibres per group (frequency interval of 5 fibres), expressed as a percentage of the total myosin ATPase low fibres sampled, in the left and right dorsal crico-arytenoid of a foal (*No.* 7).

vagus and accessory nerves in the medulla oblongata as well as quantitative estimations of the number of axons in both recurrent laryngeal nerves may show whether the origin of these neurogenic disturbances in the laryngeal muscles are central or peripheral. This may show why the clinical condition of laryngeal paralysis apparently has various aetiologies.

SUMMARY

Histo-chemical fibre types in normal skeletal muscle of the horse are described. Extensive grouping of fibre types and the occurrence of abnormal fibre types have been recognised in the left dorsal crico-arytenoid muscles of randomly selected horses which were not suspected of having abnormal larynges.

Type grouping was observed in the right muscles of those horses that had severely disrupted fibre type patterns in their left dorsal crico-arytenoids and also in the left dorsal crico-arytenoid of a foal. Type grouping was demonstrable in the absence of any assymmetry, either in the weights of the muscles or in the diameters of their fibres.

RÉSUMÉ

Les types histo-chimiques de fibres musculaires striées du Cheval sont décrits.

L'existence de fibres anormales et de groupements anormaux au niveau des muscles crico arytènoidiens dorsaux gauches, prélevés sur des chevaux choisis au hasard, a été constatée, bien que ces chevaux n'aient point été suspectés d'avoir un larynx anormal.

Le groupement par type fut observé dans les muscles du coté droit des chevaux présentant des anomalies des fibres des muscles crico arytènoidiens dorsaux gauches et aussi dans le muscle correspondant d'un foal. Ceci en l'absence d'assymètrie, soit dans le poids des muscles soit dans le diamètre de leurs fibres.

ZUSAMMENFASSUNG

Histochemisch definierte Fasertypen des normalen Skelettmuskels beim Pferd werden beschrieben. Eine übermässige Gruppierung gewisser Fasertypen und das Auftreten abnormer Typen wurde im linken, dorsalen m. crico-arythaenoideus bei zufällig untersuchten Pferden gefunden, bei denen kein Verdacht auf Abnormitäten am Larynx bestand.

Eine Typ-Gruppierung wurde in den rechten Muskeln von Pferden beobachtet, die in ihren linken crico-arythaenoid-Muskeln schwer gestörte Fasertyp-Muster zeigten und auch im linken, dorsalen m. crico-arythaenoideus eines Fohlens. Die Typ-Gruppierung war nachzuweisen ohne dass eine Asymmetrie bestand (Muskelgewicht und Faserdurchmesser).

REFERENCES

Cole, C. R. (1946). Changes in the equine larynx associated with laryngeal hemiplegia. *Am. J. vet. Res.* **7,** 69.

Cook, W. R. (1965). The diagnosis of respiratory unsoundness in the horse. *Vet. Rec.* **77,** 516.

Cook, W. R. (1966). Observations on the aetiology of epistaxis and cranial nerve paralysis in the horse. *Vet. Rec.* **78,** 396.

Crosfill, M. L. and Widdicombe, I. G. (1961). Physical characteristics of the chest and lungs and the work of breathing in different mammalian species. *J. Physiol,* Lond. **158,** 1.

Davies, A. S. and Gunn, H. M. (1972). Histochemical fibre types in the mammalian diaphragm. *J. Anat.*, in press.

Dubowitz, V. (1967). Cross-innervated mammalian skeletal muscle; histochemical, physiological and biochemical observations. *J. Physiol.*, Lond. **193,** 481.

Edström, L. and Kugelberg, E. (1969). Histochemical mapping of motor units in experimentally re-innervated skeletal muscle. *Experientia* **25,** 1044.

Gunn, H. M. (1972). Unpublished observations.

Guth, L. Samaha, F. J. and Albers, R. W. (1970). The neural regulation of some phenotypic differences between the fibre types of mammalian skeletal muscle. *Expl. Neurol.* **26,** 126.

Johnson, J. H. (1970). Laryngoplasty for advanced laryngeal hemiplegia. *Vet. Med.* **65,** 347.

Karpati, G. and Engel, W. K. (1968a). "Type grouping" in skeletal muscles after experimental re-innervation. *Neurology* (Minneap.) **18,** 447.

Karpati, G. and Engel, W. K. (1968b). Histochemical investigation of fibre type ratios with the myofibrillar ATPase reaction in normal and denervated skeletal muscles of guinea-pig. *Amer. J. Anat.* **122,** 145.

Nachlas, M. M. Tsou, K. de Souza, E., Cheng, C. and Seligman, A. M. (1957). Cytochemical demonstration of succinate dehydrogenase by the use of new p-nitrophenyl substituted ditetrazol. *J. Histochem. Cytochem.* **5,** 420.

Negus, V. E. (1949). Comparative anatomy and physiology of the larynx. P. 72, London, William Heinemann, Medical Books Ltd.

Padykula, H. A. and Herman, E. (1955). The specificity of the histochemical method for adenosine triphosphatase. *J. Histochem. cytochem.* **3,** 170.

Quinlan, J. and Morton, D. D. (1957). Paralysis of the branches of the nervus vagus—N. recurreus, N. pharyngeus and N. laryngeus cranialis—as an aetiological factor in "whistling" and "roaring" in horses; with some remarks on its heredity and surgical procedures in its treatment. *Jl. S. Afr. vet. med. Ass.* **28,** 63.

Takeuchi, J. and Kuriaki, H. (1955). Histochemical detection of phosphorylase in animal tissues. *J. Histochem. Cytochem.* **3,** 153.

Reprinted from "Equine Veterinary Journal", Vol. 5. No. 2.

Further Observations on Laryngeal Skeletal Muscle in the Horse

H. M. GUNN

Department of Anatomy, Royal (Dick) School of Veterinary Studies, University of Edinburgh

EVIDENCE for a progressive neurogenic atrophy in the dorsal cricoarytenoid muscle of several horses with no clinical symptoms of laryngeal paralysis was reported in a previous communication (Gunn, 1972). Because the premonitory signs of a neurogenic atrophy were shown to occur in a four-month-old foal, it was considered unlikely that postnatal environmental factors are important in the aetiology of equine laryngeal paralysis.

The opportunity has since arisen to study the larynges of foetal horses and one horse in which the clinical symptoms of laryngeal paralysis had occurred. It has therefore been possible to determine whether a neurogenic disturbance is present prenatally, and if the change in the pattern of innervation occurs without a significant loss in the numbers of fibres in an obviously atrophic laryngeal muscle.

MATERIALS AND METHODS

The larynges from three randomly selected foetuses, and one horse which had been ventriculectomised eight years previously to alleviate the clinical symptoms of laryngeal paralysis, were obtained from the post-mortem room (Tables I and II).

The methods used were similar to those described previously by Gunn (1972). The right and left dorsal cricoarytenoid muscles of each of the four animals used were removed and weighed. Both halves of the transverse arytenoid and both cricothyroid muscles of the adult horse were also removed and weighed. Complete transverse sections of the mid-bellies of the muscles were prepared for histological examination.

The histochemical methods used for myosin adenosine triphosphatase (myosin ATPase), succinate dehydrogenase (SDHase), and glycogen phosphorylase (GPase)

TABLE I
CHARACTERISTICS OF THE DORSAL CRICOARYTENOID OF FOETAL HORSES

Type of horse	Number	Age (days in utero)	Sex	Weight of muscles (g)		Mean group size*		Percentage of Myosin ATPase low reacting fibres contained in groups greater than 5	
				Left	Right	Left	Right	Left	Right
Thoroughbred	13	330	Male	.8	.8	1.2	1.1	2	0
Thoroughbred	14	338	Female	1.5	1.4	1.4	1.1	9	3
Thoroughbred	15	338	Male	1.2	1.4	1.1	1.1	1	0

* Number of Myosin ATPase low fibres per group.

TABLE II
HORSE NUMBER 16, A 14-YEAR-OLD THOROUGHBRED MARE

	M. Dorsal Cricoarytenoid		M. Transverse Arytenoid		M. Cricothyroid	
	Left	Right	Left	Right	Left	Right
Muscle weight (g)	4.0	11.0	1.7	3.0	6.7	7.9
Mean size of myosin ATPase low groups	3.6	1.7	*	2.8	1.3	1.3
Total fibre number	35500	38600				
Total number of myosin ATPase low fibres	3200	3200				
TSA of muscle occupied by muscle fibres (μm^2)	26×10^6	187×10^6				

* No myosin ATPase low reacting fibres present in this muscle.

were similar to those already described (Gunn, 1972). A high molecular weight dextran was added to the phosphorylase incubation medium after the method of Meijer (1968).

A fibre having a high activity of the enzyme myosin ATPase (Ah) is designated as fast-twitch, and a fibre with a low activity (Al) as slow-twitch. The SDHase and GPase reactions indicate the capacity of a fibre for aerobic and anaerobic metabolism respectively. The symbols Sh and Sl indicate a high or low SDHase enzymic activity, and the symbols Ph and Pl refer to the GPase activity.

Metabolic profiles of individual fibres were constructed and an assessment of grouping of fibre types was carried out. In the adult horse the total number of each type of fibre was measured by counting each fibre in the left dorsal cricoarytenoid, and the total number of fibres in the right muscle was estimated by sampling the entire transverse section at 2 mm intervals.

RESULTS

Fibre types

Late foetal laryngeal muscle contains the same fibre types as those found in normal adult laryngeal muscles, which are: fast-twitch combined aerobic and anaerobic (Ah, Sh, Ph) fibres, slow-twitch combined aerobic and anaerobic (Al, Sh, Ph) fibres, and a few slow-twitch predominantly aerobic (Al, Sh, Pl) fibres (Gunn, 1972). The overall density of reaction products due to the succinate dehydrogenase and glycogen phosphorylase reaction was less in foetal than in adult laryngeal muscle.

While it is recognised that the histochemical methods used do not quantitatively indicate the overall enzyme activity, foetal laryngeal muscle always gave weaker reactions for both these enzymes.

Areas of reduced fibre size were observed in the laryngeal muscles of the adult horse with laryngeal paralysis. In the left dorsal cricoarytenoid and in the two halves of the transverse arytenoid some areas had fibres with reduced activities of succinate dehydrogenase and glycogen phosphorylase.

In a sample of such an area from the left dorsal cricoarytenoid, 13 per cent of the fast-twitch fibres were Sl in contrast to the normal, which contains no such fibres. Slow-twitch fibres which were Sl (7 per cent) and Pl (29 per cent) are also absent from control specimens.

A significant number of Sl or Pl fibres is abnormal in any region of adult horse laryngeal muscle, as normally all the fibres are aerobic and only 1 per cent do not have anaerobic capacity. This suggests that in regions of severe fibre atrophy, fast-twitch fibres had a reduced capacity for aerobic metabolism, and slow-twitch fibres had a reduced capacity for anaerobic metabolism.

Central nuclei were apparent in some fibres, and fibres having a higher SDHase activity centrally than peripherally were also present. In areas of severe hypotrophy, fibres were surrounded by connective tissue which sometimes contained fat cells.

An interesting observation is that the left half of the transverse arytenoid muscle consists entirely of fast-twitch fibres, while the right half, which is separated from the left by a fibrous raphe, contains some slow-twitch fibres. Further, in the left half 6 per cent of the fast-twitch fibres are Pl, while in the right half 8 per cent of these fibres are Sl, and some fast-twitch fibres do not react for either of the metabolic enzymes. The slow-twitch fibres in the right half include 13 per cent which were Sl, and 44 per cent which were Pl.

The significance of these observations is obscure, but it may be related to the interaction between fibres which insert onto a common raphe.

Abnormalities in the grouping of fibre types

The right dorsal cricoarytenoid muscle of one of the foetuses, horse No. 14 (fig. 1), shows the normal regular pattern of fibre types. However, the contralateral muscle (fig. 2) has groups of fibres with low myosin ATPase activity. Nine per cent of the myosin ATPase low reacting fibres occurred in groups of over five (Table I). The percentage of myosin ATPase low reacting fibres in groups greater than five was much lower in this muscle in the other two foetuses.

Groups of myosin ATPase low reacting fibres were seen in the left dorsal cricoarytenoid (figs. 3 and 4), and in the right half of the transverse arytenoid of the adult horse. These muscles did not have groups of myosin ATPase low reacting fibres as large as those

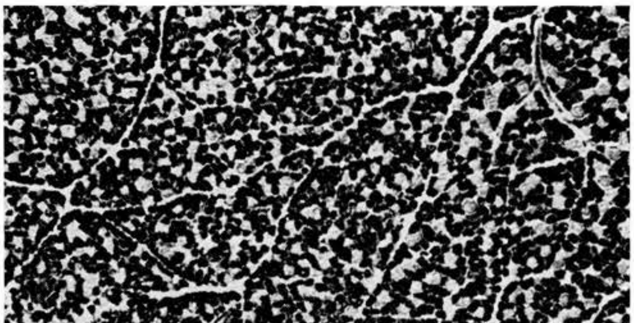


Fig. 1. Transverse section of right dorsal cricoarytenoid of a Thoroughbred foetus (horse No. 14), stained for myosin ATPase. Low reacting fibres occur in a regular pattern. X 60.

Fig. 2. Transverse section of left dorsal cricoarytenoid of a Thoroughbred foetus (horse No. 14), stained for myosin ATPase. Low reacting fibres are arranged irregularly in groups. X 60.

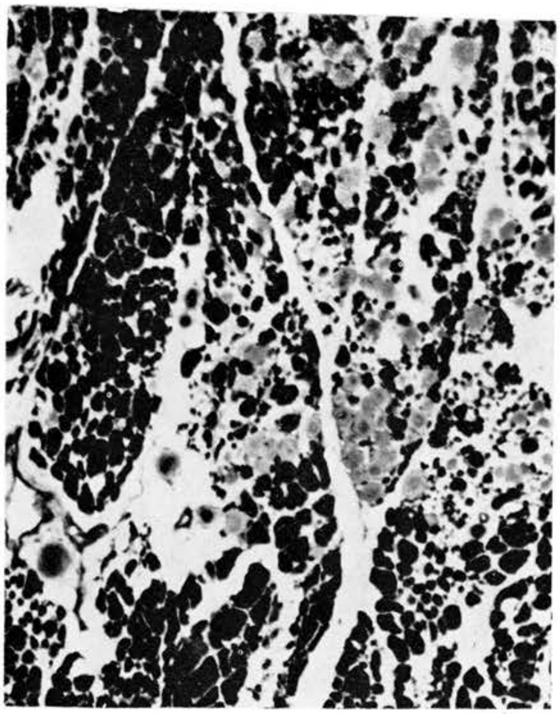


Fig. 3. Transverse section of left dorsal cricoarytenoid of a Thoroughbred mare (horse No. 16), stained for myosin ATPase. Both types of fibres occur in groups. The reduction in mean transverse sectional area of the myosin ATPase high reacting fibres suggests a preferential atrophy of this type of fibre. X 60.

seen in some of the muscles of apparently normal horses (Gunn, 1972).

Groups of myosin ATPase low reacting fibres were not seen in either of the cricothyroid muscles. The entire transverse section of the left transverse arytenoid consisted of bundles of hypotrophic fast-twitch fibres enclosed in thickened fibrous tissue septae.

Atrophy

Atrophy, as shown by the low weights relative to those of the contralateral muscles, was observed in the left dorsal cricoarytenoid and left half of the transverse arytenoid muscles of the adult horse (Table II). Fresh muscle weights of the other pair of muscles and of the dorsal cricoarytenoid muscles of the foetuses shown in Tables I and II do not indicate unilateral muscular atrophy.

Marked reduction of mean fibre transverse sectional area (T.S.A.) was apparent in the complete transverse section of the left dorsal cricoarytenoid, and in the left half of the transverse arytenoid, and in areas of the right half of the transverse arytenoid of the adult horse (figs. 3 and 4). The total number of fibres in both cricoarytenoid muscles was approximately the same (Table II).

Atrophy of the muscle on the left side was due to a decrease in mean T.S.A. of both types of fibre. However, the mean T.S.A. of the myosin ATPase high reacting fibres was 738 μm^2 on the left side and 5,735 μm^2 on the right side. The mean T.S.A. of the myosin ATPase low reacting fibres was 990 μm^2 on the left side and 5330 μm^2 on the right side.

DISCUSSION

The occurrence of an abnormal pattern of fibre type distribution in the left dorsal cricoarytenoid of a foetal horse suggests a neurogenic disturbance occurring in this muscle before birth. A reduction in the transverse sectional area of the left dorsal cricoarytenoid muscle due to a decrease in size of the individual fibres combined with, in some regions, a decrease in their metabolic capacity, would render the muscle inadequate to cope with a period of high functional demand.

The preferential atrophy of myosin ATPase high reacting fibres seen in this study is similar to that seen by Engel, Brooke and Nelson (1966) in the cat gastrocnemius muscle following experimental denervation.

The occurrence of atrophy in the right half of the transverse arytenoid is similar to the observations by Cole (1946). He shows that the three larynges with the greatest atrophy in the left dorsal cricoarytenoid muscle also had atrophy of their right transverse arytenoid muscles. This may indicate involvement of the right caudal (recurrent) laryngeal nerve as well as the contralateral nerve. Signs of a neurogenic disturbance are not present in the cricothyroid muscles, which are innervated by the cranial laryngeal nerve.

It appears from these studies that the condition of laryngeal paralysis in the horse is congenital in character and progressive in nature. It is a neurogenic disease involving the left caudal laryngeal nerve and possibly the right nerve to a lesser extent.

SUMMARY

An abnormal pattern of fibre type distribution has been observed in the left dorsal cricoarytenoid of a foetal horse. The gross atrophy of the left dorsal cricoarytenoid of a case of equine laryngeal paralysis occurred due to a decrease in mean transverse sectional area of its fibres, in particular a hypotrophy of the

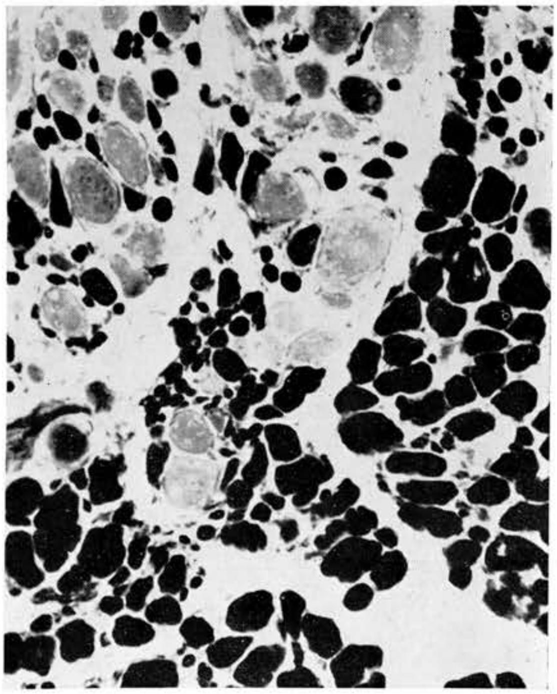


Fig. 4. Same section as Fig. 3. X 150.

myosin ATPase high reacting fibres, rather than a decrease in fibre number.

RÉSUMÉ

Une disposition anormale dans la distribution des fibres a été observée dans le muscle crico arytenoide dorsal gauche d'un foetus equin.

Dans un cas de paralysie laryngée du cheval l'altération la plus importante constatée au niveau du muscle crico arytenoide dorsal gauche fut la réduction de la surface moyenne de section des fibres et en particulier une hypotrophy des fibres à myosine ATPase "high activity", beaucoup plus qu'une réduction dans le nombre des fibres.

ZUSAMMENFASSUNG

Ein abnormer Aufbau der Faserverteilung konnte im linken, dorsalen Cricoarythaenoid eines Pferdefoeten beobachtet werden. Die Atrophie des linken, dorsalen Cricoarythaenoids bei einem Fall von Larynxparalyse trat eher wegen einer Abnahme in der Ausdehnung der Faserfläche auf, insbesondere bestand eine Hypotrophy der Myosin-ATPase reichen Fasern, als wegen einer Abnahme der Faseranzahl.

ACKNOWLEDGEMENTS

I am indebted to Professor A. R. Muir for assistance in all stages of this study, and to all the people concerned in supplying the material used.

REFERENCES

Cole, C. R. (1946). Changes in the equine larynx associated with laryngeal hemiplegia. *Am. J. vet. Res.* **7**, 69.

Engel, W. K., Brooke, M. H. and Nelson, P. G. (1966). Histochemical studies of denervated or tenotomised cat muscle: illustrating difficulties in relating experimental animal conditions to human neuromuscular diseases. *Ann. N.Y. Acad. Sci.* **138**, 160.

Gunn, H. M. (1972). Histochemical observations on laryngeal skeletal muscle fibres in "normal" horses. *Equine vet. J.* **4**, 144.

Meijer, A. E. F. H. (1968). Improved histochemical method for the demonstration of the activity of α-glucan phosphorylase. II. Relation of molecular weight of glucosyl acceptor dextran to activation of phosphorylase. *Histochemie* **16**, 134.

W. JEFFERSON & SON LTD., ELY. 11347