GROSS MORPHOLOGY AND GENERAL ANATOMY OF PROVENTRICULUS, VENTRICULUS AND INTESTINE OF DEVELOPING FOWL AND QUAIL AND CERTAIN ADULT BIRDS.

CHAPTER II

GROSS MORPHOLOGY AND GENERAL ANATOMY OF PROVENTRICULUS, VENTRICULUS AND INTESTINE OF DEVELOPING FOWL AND QUAIL AND CERTAIN ADULT BIRDS.

Growth and development of birds have recently engendered considerable interest. Rate of increase in body weight is known for many species (Ricklefs, 1968a, 1972) but relative growth of organs and changes in body composition are poorly known (Myrcha and Pinowski, 1969; Diehl *et al.*, 1972). Relative growth of each body component has its own distinctive growth pattern and involves changes not only in gross weight but also in the relative sizes of the component parts (Brody, 1945; Impekoven, 1962 and Laird, 1965) and in general the components involved in locomotor and insulative functions grew relatively more rapidly than components involved in food processing (Austin and Ricklefs, 1977).

It has long been recognized that birds vary considerably in their posthatching growth rates (Kramer, 1953; Portman, 1955; Ricklefs, 1983). Much of this variations can be correlated to differences in body mass and some of the developmental modes. The wide spectrum of avian hatchlings ranging from precocial to altricial makes them a useful general model to study. A comparison of posthatching growth rate (which is defined as the rate of acquisition of mature function) showed that precocial chicks attain adult size more slowly, on average, than altricial chicks. (Ricklefs, 1967; 1968 and Starck, 1994). Although there has been only very few broad comparative studies on growth in birds, several generalizations about the course of weight increase has been apparent for a long time (Shah and Panicker, 1974; O' Connor, 1975, 1976; King and Hubbard, 1981; Lilja, 1983; Lightbody and Ankney, 1984; Laskey and Edens, 1985; Mitchell and Smith, 1991; Pawiina *et al.*, 1993; Panicker and Acharya, 1994). It is also increasingly realized that the young of large species usually require more time to attain adult size than those of small species and young which are fed by their parents grow more rapidly than those which feed themselves.

The increase in weight of an organism is the sum of many simultaneous processes. The proportion of the basic body constituents change markedly during the course of growth as do the relative size of the body organs (Brody, 1945; Bailey *et al.*, 1960 and Ricklefs, 1967b). If changes in body size are necessarily accompanied by anatomical and physiological adjustments, growth process may similarly be affected (Ricklefs, 1968). Most growth studies are confined to

measurements of weight gain and external measurements, but the growth process involves a great many internal changes as well. Growth process vary among species of the same developmental mode and detailed studies should be of value in analyzing differences in ecological adaptations (Dunn, 1973; 1975b). Brody (1945) showed that most organisms undergo changes of form due to differential growth rates of different organs and tissues. These changes are reflected in the anatomy and physiology of the animal. Since growth is essentially a quantitative phenomenon, one of its most important properties is its rate which is found to vary considerably between species. Ricklefs (1968) and Bjornhag (1979) demonstrated that growth rate and size were specifically correlated in birds. The different species of birds - young and adult - under investigation have different growth strategies and thus permit comparison of the extent to which differential growth of the body components and structures constitute a general feature of the pattern of development and the extent to which it reflects specific adaptations.

MATERIALS AND METHODS

Newly hatched chicks of fowl (of Rhode Island Red variety) and newly hatched chicks of Japanese quail were purchased from Government Hatchery, Baroda and Mualia Farm, Dahod, Gujarat respectively and were kept in a well maintained aviary of the department. The chicks were fed on a commercial starter and grower diets throughout the experimental periods. Water was given *ad libitum* to both the species.

Six birds from each species were selected at random on 0, 5, 10, 20 and 30 days of age. They were weighed and killed by decapitation. The intestine, proventriculus and ventriculus were quickly excised, emptied and weighed. Six adult birds (22 weeks of age for fowl and 7 weeks for quail) were also sacrificed to obtain the final dimensions. Allometric growth was calculated according to the equation (On/Oh) / (BWn/BWh) where O is the organ weight, n is the day of experiment, h is the initial weight, Bw is the body weight (Fisher, 1984).

The external dimensions (length, breadth and thickness) were measured using vernier calliper. The same procedure was followed even for the adult birds of swift, sparrow and pigeon.

RESULTS

Gross Morphology

Body and organ weights of developing and adult fowl and quail
(Tables 1, 2, 3a, b; Figures 1a, b; 2a, b, c).

The body weight of fowl and quail increased from 30 and 4.35 gm on day of hatching to about 1850 and 99.16 gm in adult (an average increase of about 20% and 42% by day 5; 33% and 168% by day 10; 131% and 596% by day 20; 377% and 1279% by day 30). However, on attainment of adulthood in fowl (22 weeks) and quail (7 weeks) the average increase was about 6000% and 2200% respectively. With respect to the stomach complex of these two developing birds, the proventricular and ventricular weight in fowl increased during the growth period from an average of 0.25 and 2.31 gm on the day of hatching to 4.67 and 33.72 gm in adult, an average increase of about 1700% and 1360% respectively; whereas in quail from an initial weight of 0.073 and 0.370 gm to 0.48 and 2.54 gm in adult, an increase of about 560 and 590% respectively. As far as growth of intestine of fowl and quail are concerned the initial weight of 1.08 and 0.65 gm rose to 7.95 and 6.35 gm respectively in adult, an average increase of 636% and 264%. Intestine length in these developing birds increased from an initial 36.50 and 18.37 cm to 122.08 and 48.30 cm in adult, an average increase of about 234% and 162%. Irrespective of the striking differences noted in the morphometric characteristics of these birds, the value of allometric growth (table 3b) was greater than 1 and less than 1 in case of fowl and quail respectively. The value of the same was more than 1 during the first half of ventricular development in fowl and less than 1 during the remaining periods of development and in adult. In quail the value was always less than 1. The value of allometric growth of intestine (weight and length) was also less than 1, except in case of fowl where it exceeded 1 on day 10 and 20 and in case of quail on day 5 of development.

Adult birds (Table 4)

All other adult birds presently under observation are altricial and their basic growth data, therefore, showed phenomenal differences. The maximum body weight was of pigeon (257 gm)

followed by sparrow (22 gm) and swift (20 gm) in that order. Whereas the relative weight of proventriculus and ventriculus was maximum in sparrow (0.44 and 2.92) followed by swift (0.42 and 2.65) and pigeon (0.24 and 1.85) respectively. The intestine weight and length did not differ much in case of swift (0.61 and 10.16) and sparrow (0.64 and 15.50) while the pigeon (7.65 and 61.00) registered the maximum values.

General Anatomy - Proventriculus (Table 5 and Figure 3a).

Developing and adult fowl

The small and large multiple glands showed an increase throughout the developmental stages i.e. from 383 μ and 1890 μ on day of hatching to 1204 μ and 3428 μ on attainment of adulthood, whereas similar pattern was also observed for the diameter of proventriculus and thickness of outer layer. The value noted on the day of hatching was 4814 μ for the size of proventriculus and for the thickness of outer layer 121 μ which increased to 14733 μ and 435 μ respectively.

Developing and adult quail

The readings noted on the day of hatching for the small and large multiple glands were 299 μ and 484 μ which increased to 535 μ and 2224 μ respectively. The diameter of proventriculus increased from 2166 μ on the day of hatching to 7015 μ on attainment of adulthood and increase was also noted for the thickness of outer layer from 66 μ to 221 μ when reached to adulthood.

General anatomy - Ventriculus (Table 6; Figure 3b).

Developing and adult fowl and quail

All the four structural components of ventriculus of fowl and quail depicted an increase from the day of hatching to adulthood.

Plate Ia,b.

Domestic Fowl (0 day old)

Organ	: Proventriculus	Organ:	: Ventriculus
Thickness	: 0.2 cm	Thickness	: 0.6 cm
Length	: 1.0 cm	Length + Breadth	: 1.3 + 1.1 cm
Weight	: 0.25 gm	Weight	: 0.657 gm

1a

1b

Plate IIa,b.

Domestic Fowl (Adult)

Organ	: Proventriculus	Organ	: Ventriculus
Thickness	: 2.0 cm	Thickness	: 2.5 cm
Length	: 4.5 cm	Length + Breadth	: 5.0 + 5.2 cm
Weight	: 4.6 gm	Weight	: 32.0 gm

2a

2b

Plate IIIa,b.

Japanese Quail (0 day old)

Organ	: Proventriculus	Organ:	: Ventriculus
Thickness	: 0.3 cm	Thickness	: 0.5 cm
Length	: 0.8 cm	Length + Breadth	: 0.8 + 1.0 cm
Weight	: 0.073 gm	Weight	: 0.370 gm

3a

3b

Plate IVa,b.

Japanese Quail (Adult)

Organ	: Proventriculus	Organ:	: Ventriculus
Thickness	: 1.6 cm	Thickness	: 1.2 cm
Length	: 2.5 cm	Length + Breadth	: 2.0 + 1.7 cm
Weight	: 0.48 gm	Weight	: 2.540 gm

4a

4b

Plate Va,b.

House Swift (Adult)

Organ	: Proventriculus	Organ:	: Ventriculus
Thickness	: 0.2 cm	Thickness	: 0.8 cm
Length	: 1.6 cm	Length + Breadth	: 1.6 + 1.8 cm
Weight	: 0.082 gm	Weight	: 0.530 gm

5a

5b

Plate VIa,b.

House Sparrow (Adult)

Organ	: Proventriculus	Organ:	: Ventriculus
Thickness	: 0.25 cm	Thickness	: 0.85 cm
Length	: 1.7 cm	Length + Breadth	: 1.8 + 1.6 cm
Weight	: 0.10 gm	Weight	: 0.642 gm

6a

6b

Plate VIIa,b.

Blue Rock Pigeon (Adult)

Organ	: Proventriculus	Organ:	: Ventriculus
Thickness	: 1.6 cm	Thickness	: 1.2 cm
Length	: 3.0 cm	Length + Breadth	: 3.0 + 2.8 cm
Weight	: 0.618 gm	Weight	: 4.761 gm

7a

7 b

Table 1. Morphological characteristics of proventriculus, ventriculus and intestine of developing and adult fowl in relation to body weight.

AGE (DAYS)	BODY WEIGHT (gm)	PROVENTRICULUS		VENTRICULUS		INTESTINE	
		ABSOLUTE WEIGHT (gm)	RELATIVE WEIGHT (%)	ABSOLUTE WEIGHT (gm)	RELATIVE WEIGHT (%)	EMPTY WEIGHT (gm)	LENGTH (cm)
0	30.00 ± 2.02@	0.25 ± 0.01	0.83 ± 0 07	2.31 ± 0.34	7.70 ± 0.44	1.08 ± 0 13	36 50 ± 2.58
5	36 16 ± 2.20	0.41 ± 0.02	1.13 ± 0.14	3.15 ± 0.41	8 71 ± 0.64	1.25 ± 0 17	39.00 ± 1.85
10	40.00 ± 2.42	0.59 ± 0.03	1.48 ± 0.13	5.14 ± 0.62	12.85 ± 1.19	2 08 ± 0 25	47.66 ± 1.20
20	69.50 ± 3.85	0.81 ± 0.04	1 17 ± 0.16	6.04 ± 0.74	8.69 ± 0.57	2.89 ± 0.13	58.66 ± 2.74
30	143.33 ± 7.11	1.47 ± 0.13	1.03 ± 0.11	8.64 ± 0.92	6 03 ± 0.57	3 80 ± 0.26	70.33 ± 3 02
ADULT	1850.00 ± 48.99	4.67 ± 0.39	0 25 ± 0.05	33.72 ± 2.11	1 82 ± 0.19	7 95 ± 0 87	122.08 ± 6 20

@ Values expressed as mean ± SEM of six animals.

Table 2. Basic growth data for proventriculus, ventriculus and intestine of developing and adult quail in relation to body weight.

AGE (DAYS)	BODY WEIGHT (gm)	PROVENTRICULUS		VENTRICULUS		INTESTINE	
		ABSOLUTE WEIGHT (gm)	RELATIVE WEIGHT (%)	ABSOLUTE WEIGHT (gm)	RELATIVE WEIGHT (%)	EMPTY WEIGHT (gm)	LENGTH (cm)
0	4.35 ± 0.17@	0.073 ± 0.01	1.68 ± 0.14	0.37 ± 0.02	8.55 ± 0.61	0.65 ± 0.27	18.37 ± 1.61
5	6.19 ± 0.40	0.09 ± 0.02	1.50 ± 0.13	0.46 ± 0.02	7.40 ± 0.54	1.40 ± 0.18	26.30 ± 2.43
10	11.66 ± 1.02	0.13 ± 0.01	1.12 ± 0.10	0.62 ± 0.02	5.34 ± 0.44	1.73 ± 0.13	30.60 ± 2.67
20	30.30 ± 1.61	0.25 ± 0.02	0.81 ± 0.09	0.87 ± 0.04	2.85 ± 0.36	3.19 ± 0.32	37.00 ± 2.45
30	60.00 ± 3.69	0.44 ± 0.03	0.74 ± 0.12	1.81 ± 0.12	3.02 ± 0.33	4.58 ± 0.34	42.00 ± 3.57
ADULT	99.16 ± 4.83	0.48 ± 0.03	0.49 ± 0.08	2.54 ± 0.37	2.56 ± 0.48	6.35 ± 0.52	48.30 ± 3.33

@ Values expressed as mean ± SEM of six animals.

Table 3a. Rate of body growth and increase in dimensions of different components of digestive system during postnatal development in fowl and quail.

AGE	PERCENTAGE (%) INCREASE COMPARED TO THE 0 DAY VALUE									
	BODY WEIGHT		PROVENTRICULUS (WEIGHT)		VENTRICULUS (WEIGHT)		INTESTINE (WEIGHT)		INTESTINE (LENGTH)	
	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL
5	21@	42	64	23	52	24	16	22	7	43
10	33	168	136	78	123	68	93	49	31	67
20	132	597	224	242	161	135	168	83	61	101
30	378	1279	488	503	274	389	252	166	93	129
ADULT	6067	2180	1768	558	1360	568	636	265	234	163

@ % is corrected to the nearest whole number. n = 6.

Table 3b. Allometric growth of different components of digestive system of developing fowl and quail.

AGE	ALLOMETRIC GROWTH COMPARED TO 0 DAY VALUE							
	PROVENTRICULUS (WEIGHT)		VENTRICULUS (WEIGHT)		INTESTINE (WEIGHT)		INTESTINE (LENGTH)	
	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL
5	1.36@	0.86	1.13	0.87	0.96	1.51	0.88	1.00
10	1.77	0.66	1.66	0.62	1.44	0.36	0.97	0.62
20	1.39	0.49	1.12	0.33	1.15	0.70	0.69	0.28
30	1.23	0.44	0.78	0.35	0.73	0.51	0.40	0.16
ADULT	0.30	0.28	0.23	0.30	0.12	0.42	0.05	0.11

@ n = 6.

Table 4. Morphological characteristics of proventriculus, ventriculus and intestine of adult birds in relation to body weight.

ANIMAL MODEL	BODY WEIGHT (gm)	PROVENTRICULUS		VENTRICULUS		INTESTINE	
		ABSOLUTE WEIGHT (gm)	RELATIVE WEIGHT (%)	ABSOLUTE WEIGHT (gm)	RELATIVE WEIGHT (%)	WEIGHT (gm)	LENGTH (cm)
SWIFT	20.00 ± 1.02@	0.08 ± 0 02	0 42 ± 0.14	0.53 ± 0.05	2 65 ± 0 12	0 61 ± 0.02	10.16± 0 95
SPARROW	22.50 ± 1.21	0.10 ± 0.004	0.44 ± 0 028	0.66 ± 0.03	2.92 ± 0.19	0.64 ± 0.03	15.50 ± 1.63
QUAIL	99.16 ± 4.83	0.48 ± 0 03	0.49 ± 0.08	2.54 ± 0.37	2.56 ± 0.48	6.35± 0.52	48.30 ± 3.33
PIGEON	257.70 ± 8.73	0.62 ± 0.01	0.24 ± 0 008	4 76 ± 0 51	1.85 ± 0.03	7.65 ± 0.97	61 00 ± 3.54
FOWL	1850.00 ± 48.99	4 67 ± 0 39	0 25 ± 0.05	33.72 ± 2.11	1.82 ± 0 19	7.95 ± 0.87	122.08 ± 6.20

@ Values expressed as mean ± SEM of six animals.

Table 5. Histomorphometry* of various components of proventriculus of developing and adult fowl and quail.

AGE (DAYS)	SMALL MULTIPLE GLAND		LARGE MULTIPLE GLAND		DIAMETER OF THE GLAND		OUTER LAYER	
	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL
0	383.32 ± 18.32@	299.70 ± 16.31	1890.00 ± 156	484.50 ± 12.49	4814 28 ± 188	2166.66 ± 208	121 42 ± 7.82	66.80 ± 4.36
5	474.05 ± 19.60	358.13 ± 19.42	2204.00 ± 193	816 83 ± 23.16	6452.38 ± 264	3433 33 ± 187	138 09 ± 9.75	85 71 ± 6 77
10	681.15 ± 32.35	407.05 ± 21.89	2498.50 ± 177	1073.10 ± 85.50	7476.16 ± 265	4505 00 ± 230	185.71 ± 12.77	109.52 ± 8 75
20	918.65 ± 45.60	455.51 ± 32.28	2869.00 ± 185	1377.50 ± 96.54	7857.14 ± 280	5350.10 ± 334	211.90 ± 16.70	142 85 ± 12.65
30	1152.35 ± 80.37	503.50 ± 34.31	3106.05 ± 201	1776.33 ± 96.99	10592.38 ± 457	6683.60 ± 352	254 76 ± 14 04	183.32 ± 14 72
ADULT	1204.83 ± 99.64	535.05 ± 45.15	3428.33 ± 311	2224.16 ± 125.11	14733.33 ± 538	7015.33 ± 461	435.50 ± 21.30	221.00 ± 15.20

* Measured in microns.

@ Values expressed as mean ± SEM of six animals.

Table 6. Histomorphometry* of various layers of ventriculus of developing and adult fowl and quail.

AGE (DAYS)	KOILIN LAYER		MUCOSAL LAYER		SUBMUCOSAL LAYER		MUSCULAR LAYER	
	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL
0	178.60 ± 8.29@	79.30 ± 3.35	290.70 ± 8.72	101.65 ± 6.25	63.63 ± 3.88	49.31 ± 3.48	6938 80 ± 305	2303 00 ± 149
5	211.85 ± 8.65	98.80 ± 5.60	399.95 ± 10.22	128.72 ± 5.14	91.20 ± 3.12	63.65 ± 4.60	7220.00 ± 465	2935 50 ± 225
10	269.80 ± 8.29	122.53 ± 6.54	456.47 ± 15.14	157.22 ± 7.08	121.60 ± 6.32	71.25 ± 3.12	7471.66 ± 490	3277.50 ± 233
20	306.85 ± 9.84	138.75 ± 7.75	547.92 ± 12.56	212.80 ± 9.05	142.97 ± 5.22	76.95 ± 4.54	8863.16 ± 476	2852 25 ± 281
30	347.22 ± 9.19	172.90 ± 7.57	665.47 ± 14.39	237.02 ± 9 68	170.05 ± 6.41	83.60 ± 3.89	9313.08 ± 599	4085 00 ± 364
ADULT	430.66 ± 12.77	208.25 ± 14.65	751.45 ± 62.28	263.00 ± 11.12	215.33 ± 9.94	91 78 ± 6.54	10882.66 ± 612	4250 01 ± 352

* Measured in microns.
@ Values expressed as mean ± SEM of six animals.

Table 7. Histomorphometry* of various components of proventriculus of adult birds.

ANIMAL MODEL	SMALL MULTIPLE GLAND	LARGE MULTIPLE GLAND	DIAMETER OF THE GLAND	OUTER LAYER
SWIFT	235.16 ± 19.87@	538.33 ± 25.59	3117.01 ± 289	112.15 ± 10.59
SPARROW	334.33 ± 18.26	640.00 ± 25.59	3315.00 ± 279	127.50 ± 9.31
QUAIL	535.05 ± 45.15	2224.16 ± 125.11	7015.33 ± 461	221.00 ± 15.20
PIGEON	600.66 ± 21.17	2635.00 ± 193.01	7366.66 ± 475	252.16 ± 10.94
FOWL	1204.83 ± 99.64	3428.33 ± 311.92	14733.33 ± 538	435.50 ± 21.30

* Measured in microns.
@ Values expressed as mean ± SEM of six animals.

Table 8. Histomorphometry* of various layers of ventriculus of adult birds.

ANIMAL MODEL	KOILIN LAYER	MUCOSAL LAYER	SUBMUCOSAL LAYER	MUSCULAR LAYER
SWIFT	165.50 ± 8.92@	45.33 ± 3.38	22.10 ± 1.63	1473.33 ± 105
SPARROW	199.50 ± 9.72	80.50 ± 4.92	39.33 ± 2.13	1756.66 ± 187
QUAIL	208.25 ± 14.65	263.00 ± 11.12	91.78 ± 6.54	4250.01 ± 352
PIGEON	538.33 ± 18.38	631.83 ± 25.82	396.66 ± 18.42	9010.01 ± 356
FOWL	430.66 ± 12.77	751.45 ± 62.28	215.33 ± 9.94	10882.66 ± 612

* Measured in microns.
@ Values expressed as mean ± SEM of six animals.

Fig 1a. Body weight (in gm) of growing birds.

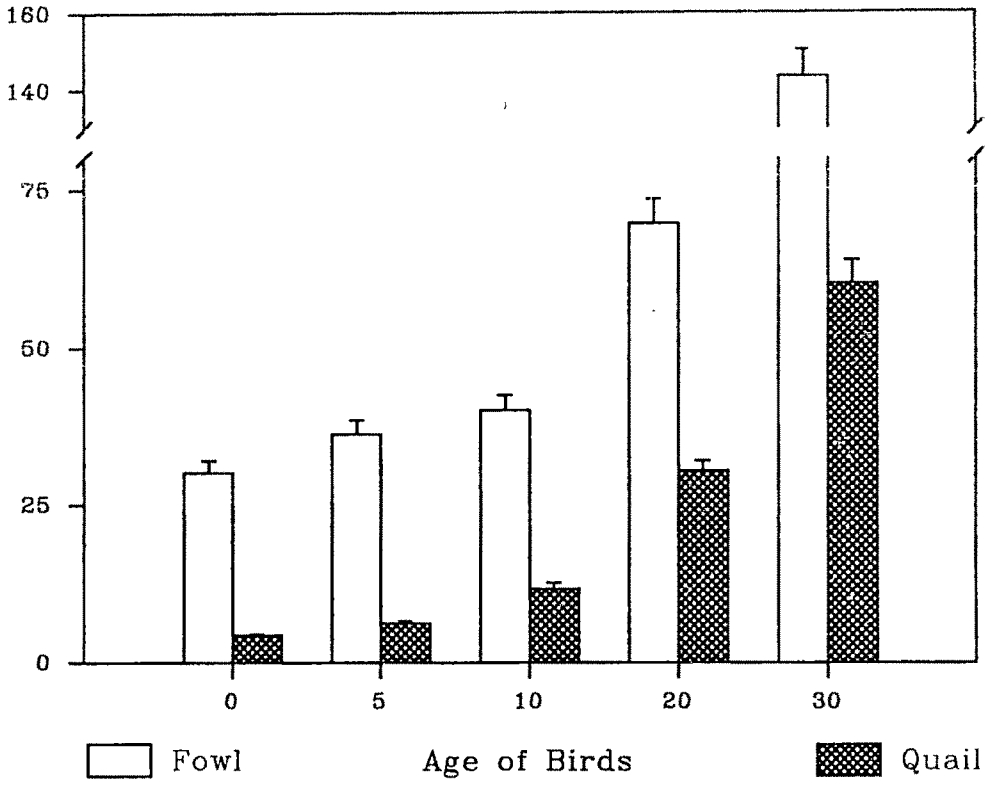


Fig 1b. Body weight (in gm) of adult birds.

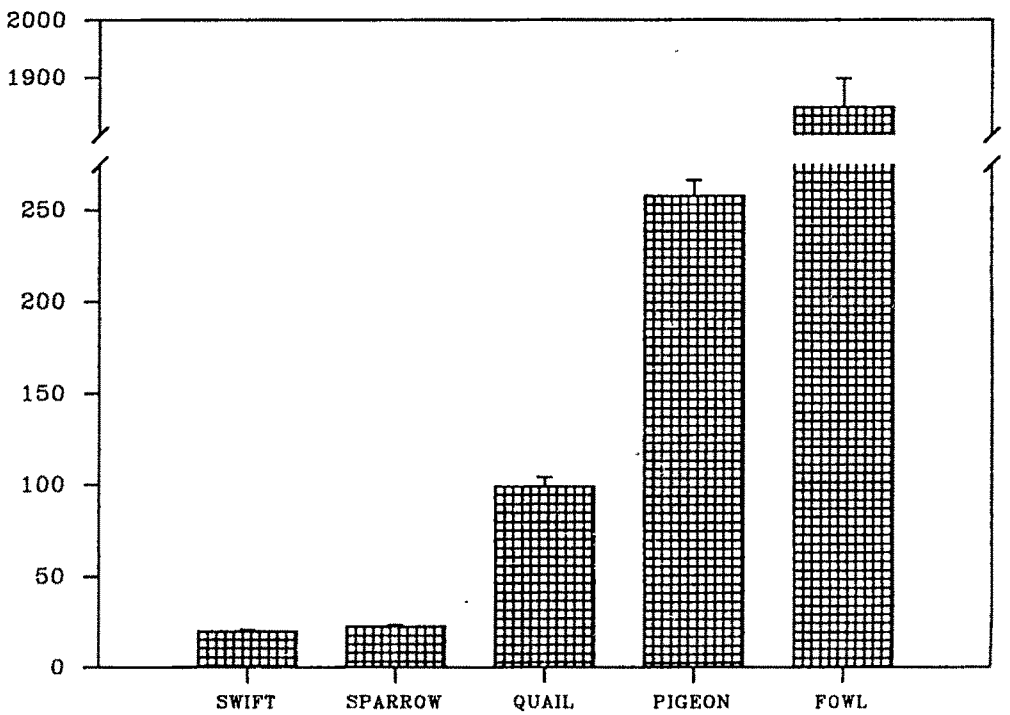


Fig 2a.Morphological data of proventriculus

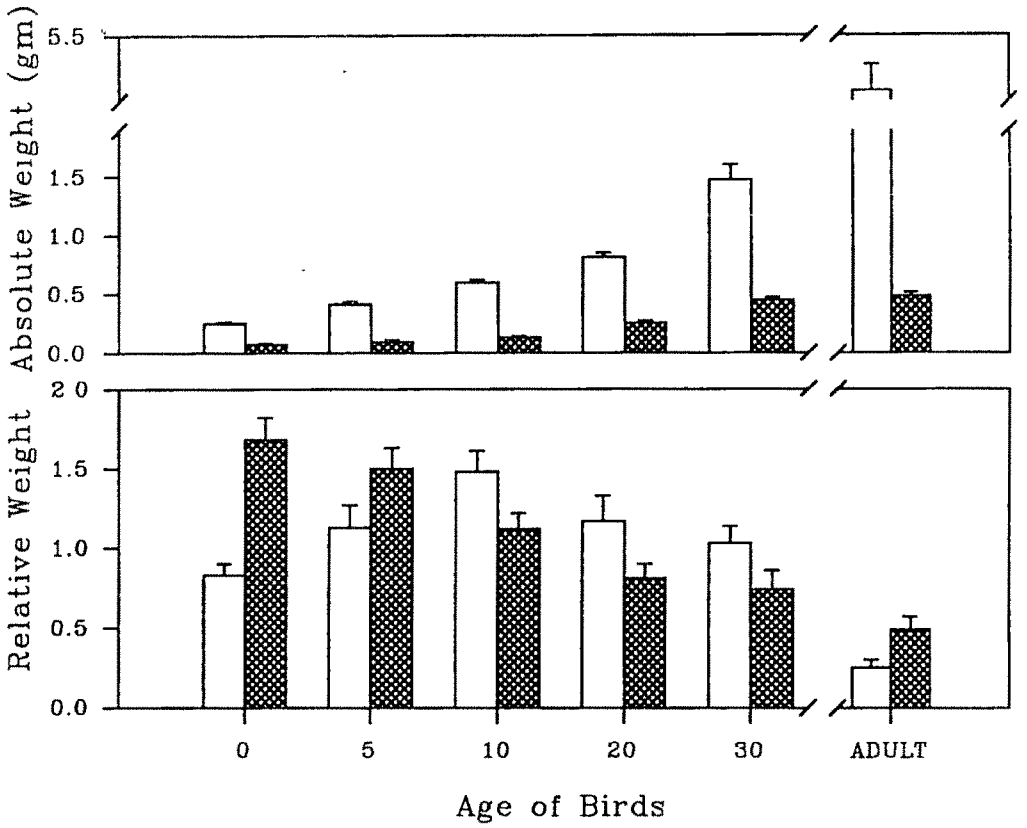


Fig 2b. Morphological data of ventriculus

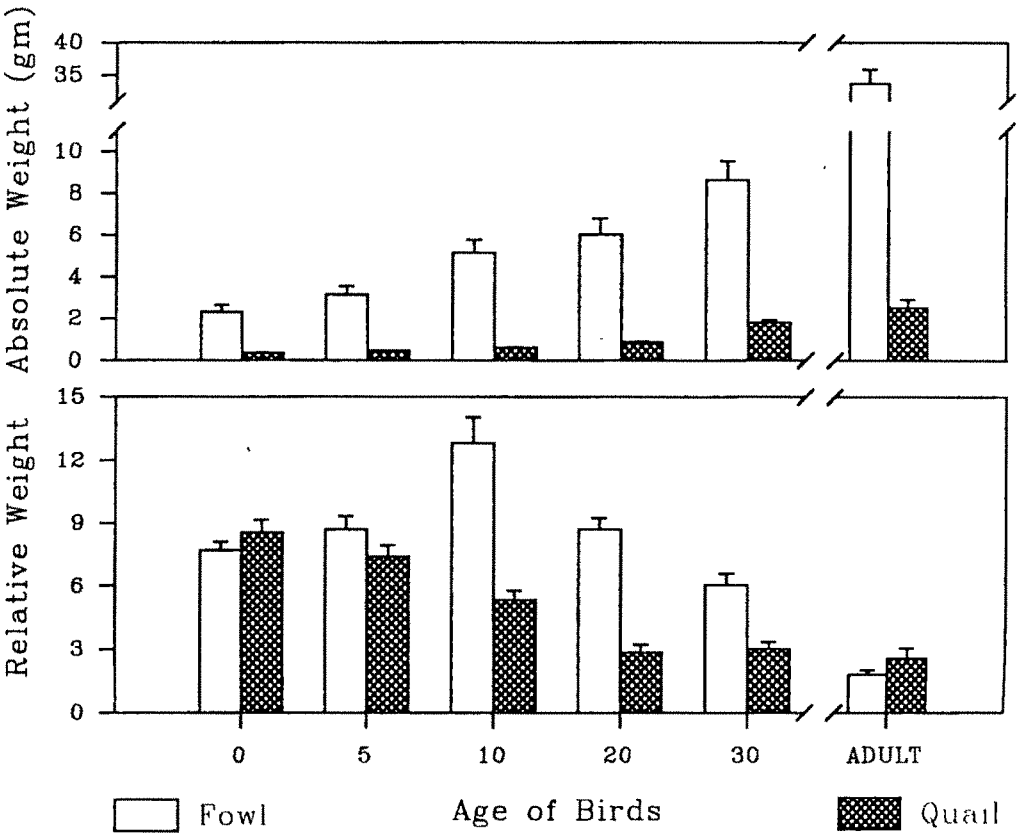


Fig 2c. Intestinal morphometry of growing birds.

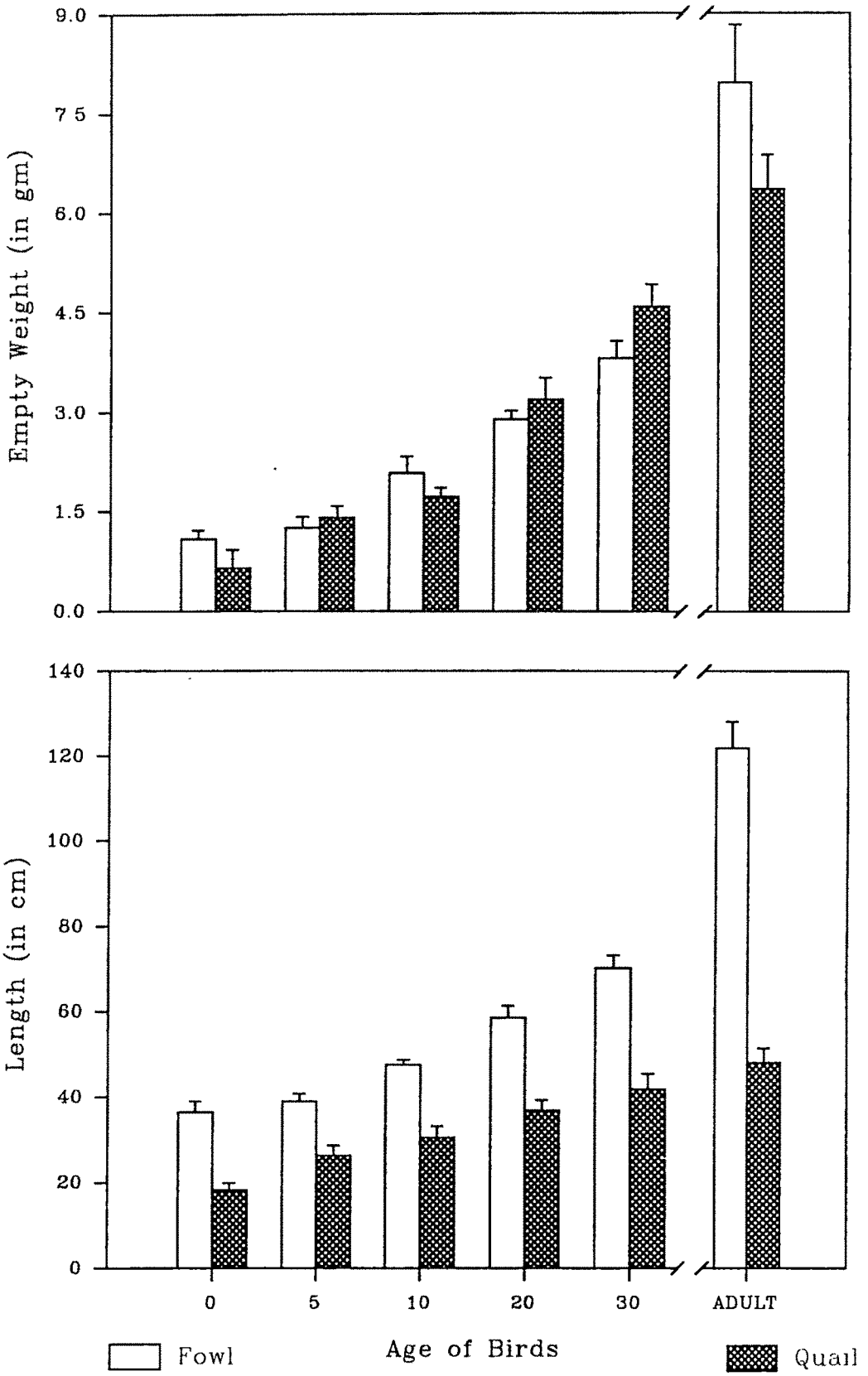


Fig 3a. Histomorphometry of proventriculus: Growing birds

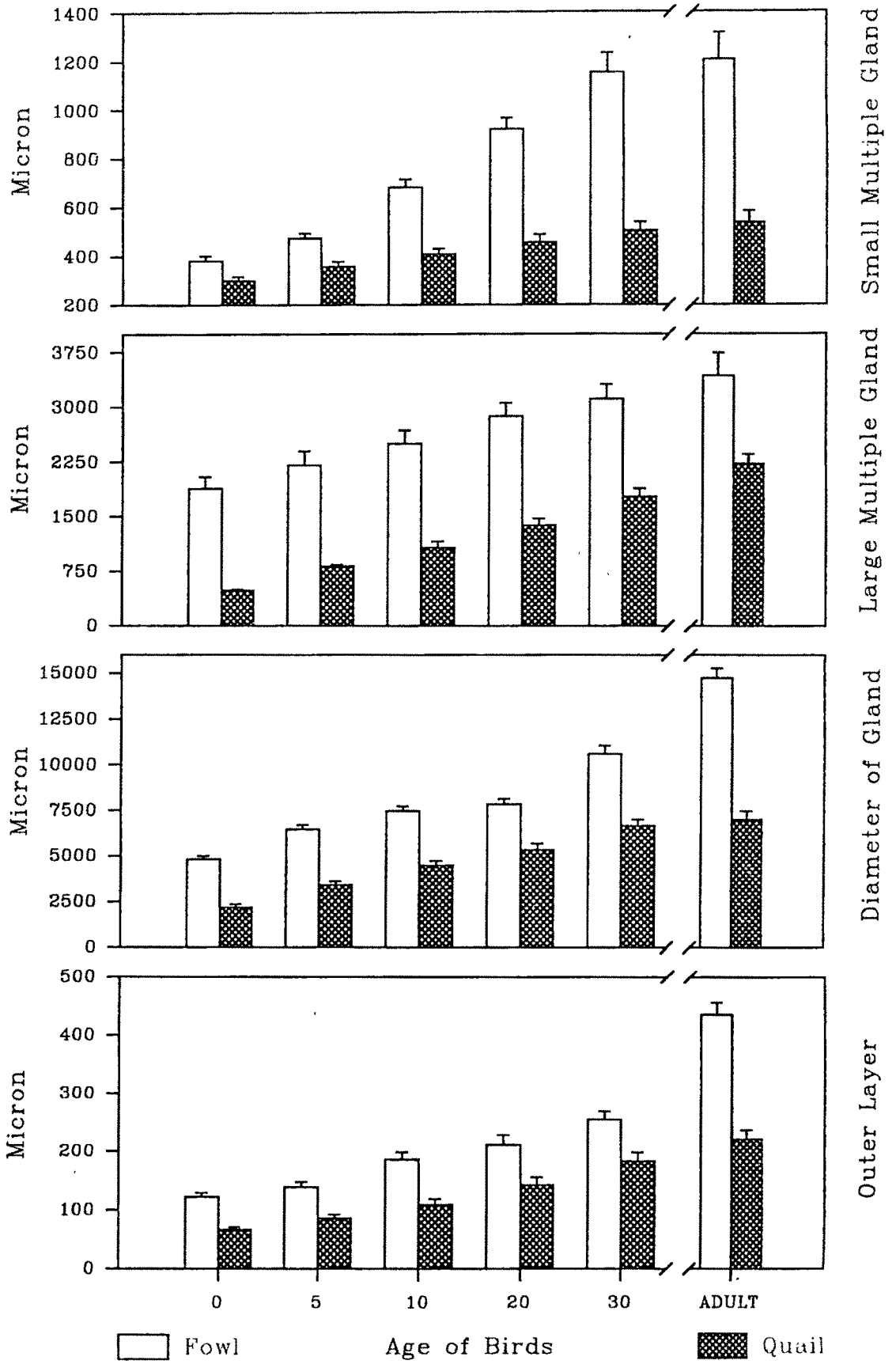


Fig 3b. Histomorphometry of ventriculus: Growing birds.

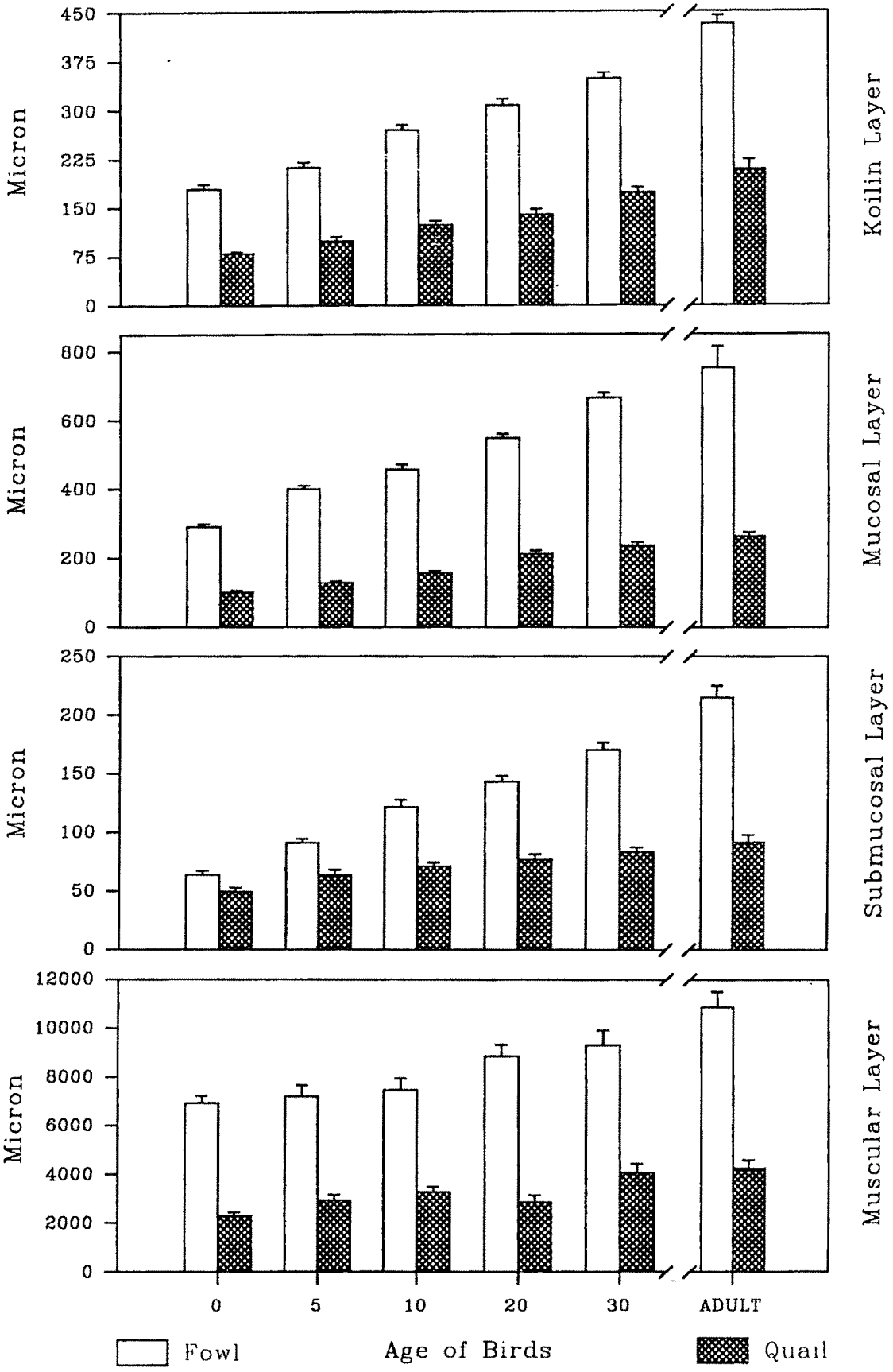


Fig 4a. Histomorphometry of proventriculus: Adult birds.

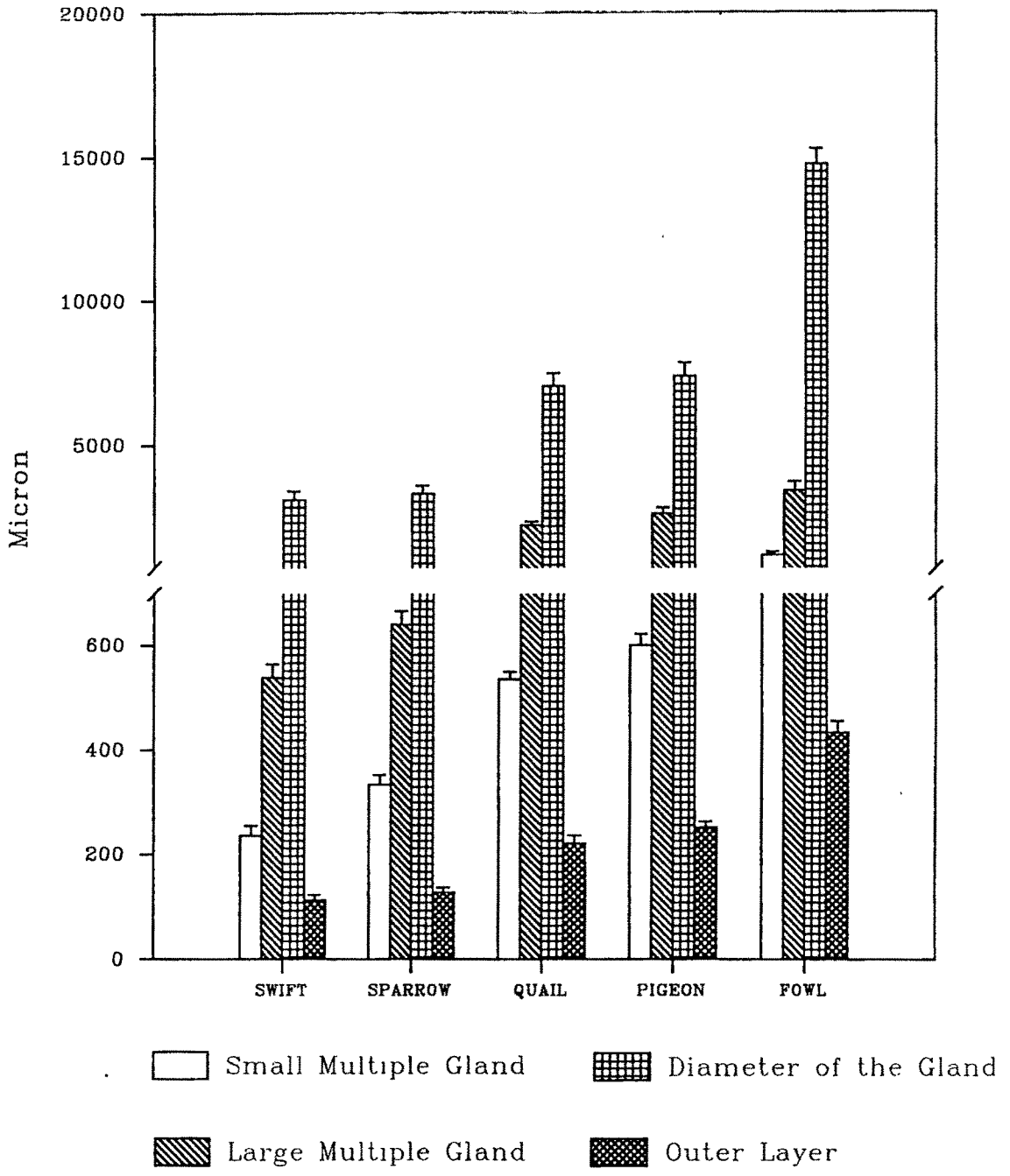
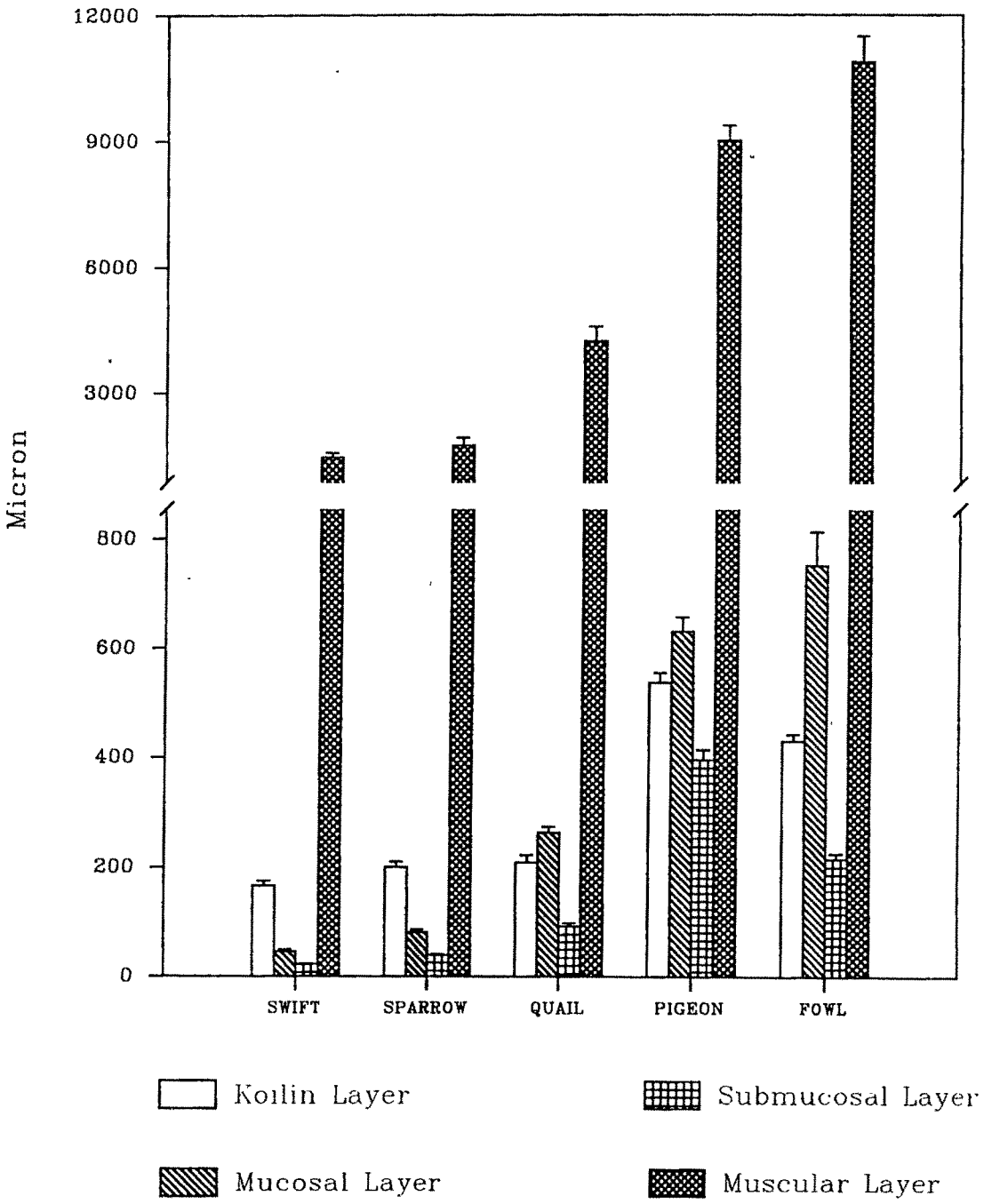


Fig 4b. Histomorphometry of ventriculus: Adult birds.



Adult birds - Proventriculus and ventriculus (Tables 7, 8; Figures 4a, b).

As far as the proventriculus of adult birds was concerned all the structural elements showed maximum growth in pigeon followed by sparrow and swift. In the ventriculus the four structural components followed the same pattern as observed in case of proventriculus with pigeon depicting the maximum value followed by sparrow and swift.

DISCUSSION

A wealth of information is available on avian development regarding the rate of growth (weight gain), increase in external dimensions and attainment of thermoregulation (Ricklefs, 1968; 1973 and Dunn, 1973; 1975b). In addition Ricklefs (1967b) and Panicker and Acharya (1994) presented some data comparing the growth of internal organs in altricial and precocial birds and observed that growth of the digestive system was initially rapid in the altricial and semi-precocial birds and slow in later stages. But the digestive system of precocial domestic chicks grows more slowly after hatching than in altricial species. The digestive organs examined herein developed linearly in both fowl and quail in an order broadly in accord with that expected in the light of their function. The proventriculus and ventriculus were relatively large during the initial days of growth as evidenced by the increase in relative weight at this time. This period of development coincided with a time of rapid overall growth (table 1, 2 and 3a, b) and must surely facilitate the intake and conversions of food for this purpose. Such hypothesis has previously been advanced by Ricklefs (1967) to explain the selective growth of the digestive organs in young red-winged blackbird nestlings and in the liver and ventriculus in *Gallus domesticus* chick (Romanoff, 1960). An increase in the weight and length of intestine was also noted in the present study and this fluctuated increase was in agreement with the observation of Dunn (1975a) on the digestive system and intestinal length in cormorants. Thus, if a comparison is made on the percentage of body growth, organ growth and allometric growth (table 3b), in these two avian species during development, it is observed that the quail grows rapidly than the fowl till day 30. The intestine weight and length also showed an increase almost identical with that of the proventricular and ventricular growth. This observation on the allometric growth was in conformity with the one made by Lilja (1983) on the digestive tube of developing goose, quail and turkey. Intestinal length is known to be related to body size and to diet. An increase of

1.59% in intestine length for each one percent increase in the cube root of body weight has been reported by Herpol (1966). Presently observed increase in the percentage of body growth and a corresponding increase in the percentage of intestinal weight and length are in conformity with the observation of a greater intestine length in herbivores and seed eaters by Zisweiler and Farner (1972). Even in the adult birds presently under study, those which are granivores or predominantly granivores have higher intestinal length and weight while others consuming mixed food and insectivores, a reduced weight and length are noted. It is stated by Ankney and Scott (1988) that the intestine length and weight and gizzard weight are inversely related to diet quality and directly related to quantity of food eaten. However, an increased food consumption and/or nutrient demand can be more important than diet quality in affecting the size of digestive organs, particularly intestine length.

With regard to the observations made on the component part of the proventriculus and ventriculus of developing fowl and quail, it becomes evident that there is a linear increase in size of all the parts of stomach complex. An increase in the size of the proventriculus, its multiple glands and the thickness of the outer layer was the characteristic feature during the course of development of these two species of birds culminating in the highest values observed in the adult (Table 5; Figure 3a). A similar increase in the size of the ventriculus, its component parts *viz.*, the koilin, mucosal, submucosal and muscular layers was also noted (Table 6; Figure 3b). In this connection, the observation of Ricklefs (1969) that the relative sizes of body components during growth were apparently determined largely by the functional priority of each tissue is highly noteworthy. Further, this increase, when viewed with the functional aspects of the organs indicated the amount of sustained activity the organ had to perform during the different periods of early posthatching development. Far back in 1936, Kuo and Shen had conclusively proved that the peristaltic contraction of chicken gizzard started from the day 9 or 10 of incubation. Studies of Bennet and Cobb (1969), also on chicken, indicated that the morphological changes observed in the gizzard after hatching are associated with a tremendous increase in the muscular layer of that organ. Brody (1945), Impekoven (1962), Laird (1965) and Ricklefs (1967) have all indicated that the growth and development involved changes not only in the gross weight but also in the relative sizes of component parts. As the development progresses, gradual changes in the consistency of the food that is ingested by the young ones are seen. Changes in the size and thickness of the structural elements of proventriculus and ventriculus are correlated with the

changes in the quality and/or quantity of diet. There is considerable evidence that the size of digestive organs is strongly influenced by diet quality and/or quantity in ducks (Ankney, 1977; Paulus, 1982; Drobney, 1984; Kehoe and Ankney, 1985) and in domestic fowl (Moss, 1974; 1983; Savory and Gentle, 1976 and Thomas, 1984). Further, these increased structural changes in the component parts are for meeting the necessary functional (mechanical) requirements of the organs. Thus the allometric growth of these digestive organs during development, was in response to its functional adaptations at different periods. Therefore, the increase in the size of the proventricular multiple glands was correlated with an increased functional activity and/or adaptations of the organ during different stages of development.

The increase in the connective tissue and muscularity of ventriculus are correlated with the degree of mechanical action the organ has to put in; being of low, medium and high orders during the initial, middle and final periods of development and finally in adult. As the organ was increasing in size, there was a corresponding increase in the smooth muscle fibres. The increase in the connective tissue in the interfascicular region was to provide anchorage for increasing number of smooth muscle fibres. Changes in the thickness of the mucosal tubules for the differential treatment needed in the mechanical digestion of food. Incidently a more pronounced mucosal layer could be for active synthesis and secretion of koilin which is required for the mechanical breakdown of the grains.

From the data obtained from the three adult birds with altricial mode of development and varied feeding habits, it becomes apparent that they do not fall into any linearly accountable categories. Generally it is said that the size of a particular organ is due to the physiological demand imposed on it. However, there is another belief which contends that the growth and size of an organ are genetically predetermined. The influx of information on the problem of regulation of growth was echoed by Goss (1972). According to him " ---------- allometric growth of each organ is, of course, adapted to the needs of the organism. These genetic adaptations have been shaped by natural selection. Physiological adaptations on the other hand are responsible for the fluctuations in organ weights that reflect increases or decreases in functional demands. These two adaptations work together like the coarse and fine adjustments in focussing a microscope". It is quite certain that the work load of stomach varies according to the size and consistency of food. Irrespective of difference in the type and consistency of food in these different birds the relative weight of

proventriculus and ventriculus remained little affected (Table 4). Since the structural peculiarities of the stomach are under the influence of genes, the birds with inherent habits of preferring specific type of food cannot change their diet or feeding habits. However they differ each other in the size and thickness of their component parts (tables 7, 8; figures 4a, b) which are undoubtedly based on the type and consistency of food which perhaps, may reflect in the physiological and/or biochemical aspects of the organ. Such differences in activity calls for metabolic adaptations rather than structural ones.