METABOLIC PROFILES OF THE PROVENTRICULUS AND VENTRICULUS OF THE GROWING AND ADULT DOMESTIC FOWL AND JAPANESE QUAIL AND CERTAIN ADULT AVIAN SPECIES.

CHAPTER III

METABOLIC PROFILES OF THE PROVENTRICULUS AND VENTRICULUS OF THE GROWING AND ADULT DOMESTIC FOWL AND JAPANESE QUAIL AND CERTAIN ADULT AVIAN SPECIES.

Each organ is specialised in its function and it is expected that metabolic status of each will vary from the other in accordance with its function (Mohapatra *et al.*, 1993). During the development of an animal, the tissues and organs have to observe economy in utilizing available energy so as to maximise process of cell proliferation, growth, differentiation and functional maturity. These processes not only call for high energy requirements but also for specific metabolic activities. For a complete understanding of the metabolic machinery of any organ certain properties have to be understood, taking into account the need of the organ or organism as well as the availability and type of nutrients supplied to the embryo or the young ones. In birds, the embryo gets, within the egg, a limited but sufficient amount of nutrients which are rich in protein and fat. The metabolism of these nutrients provide sufficient energy for cell division, growth and differentiation which are major features during development.

Glycogen metabolism in the tissues of most animals is regulated by the balance between synthesis (Glycogen synthase, GS) and degradation (Glycogen phosphorylase). In turn, both the enzymes are regulated by phosphorylation and dephosphorylation reactions which are controlled by both hormonal and dietary factors (Rosebrough and Von Vleck, 1990). Studies on the significance of carbohydrate metabolism and the fluctuations in the amount of enzymes concerned with carbohydrate metabolism have been carried out in different tissues by a number of investigators (Panicker, 1974; Postle and Blovan, 1980; Radziuk, 1982; Riesenfeld *et al.*, 1982; Radziuk and Inculet, 1983; Pilkis, 1985; Garcia *et al.*, 1986 and Rosebrough and Von Vleck, 1990).

The role of fat as the major fuel reserve for energy during long and sustained activity has been well established (George and Berger, 1966). This metabolite, being of high caloric value, serves as an important source for various energy linked reactions in animal tissues. Energy storage is important for the support of various physiological, developmental and reproductive events taking place in the organisms. Large lipid reserves, however, are considered both advantageous and disadvantageous to the animals (Meir and Burns, 1976). Seasonal and developmental fluctuations in the amount of stored lipid are considered evolutionary peculiarities to make lipids available when they are adaptive.

Cholesterol is present in tissues and in plasma lipoproteins as free cholesterol or combined with long chain fatty acid as cholesterol esters. It is typically a product of animal metabolism and therefore occurs in foods of animal origin. Cholesterol is an amphipathic lipid and as such is an essential structural component of membranes and of the outer layer of plasma lipoproteins. Additionally, lipoproteins transport free cholesterol in the circulation, where it readily equilibrates with cholesterol in other lipoproteins and in membranes. Cholesterol ester is a storage form of cholesterol found in most tissues (Mayes, 1988).

There are evidences that during the period of hatching, the bird embryo (in precocious bird, like the domestic fowl) changes greatly from a mainly lipid based (yolk) energetic metabolism to a more carbohydrate and low quality protein based (chicken chow) energetic metabolism that characterizes free life (Garcia *et al.*, 1986). The dramatic changes in the concentration of metabolites and activities of enzymes involved in carbohydrate, lipid and amino acid metabolism taking place during the transitional period from foetal to neonatal stages in mammals and at about the time of hatching in the chick are established facts (Raheja *et al.*, 1971). Gluconeogenic enzymes increase in activity during the progressive development of a chick embryo and reach a maximum near the time of hatching (Okuno *et al.*, 1964; Felicioli *et al.*, 1967 and Sheid and Hirschberg, 1967). This is attributed to the fact that in the avian species, the embryo develops as an isolated system without a constant supply of glucose from the maternal source, thereby necessitating active gluconeogenesis during embryonic development. Raheja *et al.* (1971), based on their studies on the activities of enzymes involved in lipids and carbohydrate metabolism in the chick, concluded that gluconeogenesis is active in early life and again after maturity, whereas, lipogenesis is minimal at day one, increases rapidly during the first week and declines rapidly after three weeks. Apparently, the posthatched phases of avian species is marked by adaptive metabolic shifts preparatory to the establishment of adult pattern of metabolic homoeostasis.

The species specific variations taking place during development of birds are accountable to the duration of nestling and fledgling periods, active or inactive life they lead after hatching, the mode of feeding and the type of food they consume. These variations, especially in the types of food consumed, might also be reflected on the rate and time of attainment of functional status by the metabolic and enzymatic machineries of the digestive organs. Birds, are known to differ in their habits of selecting diets and these differences in diet should also reflect on the metabolic and enzymatic peculiarities. In order to corroborate this contention, a series of metabolic studies were carried out in the stomach complex of developing fowl and quail (precocial development) and also on the stomach complex of adult birds having different dietary preferences.

MATERIALS AND METHODS

Newly hatched chicks of domestic fowl and Japanese quail were purchased from Government Poultry Farm, Baroda and Mualia Farm, Dahod respectively and were housed in a well ventilated aviary of the departmental animal house. The young ones and adults were allowed free access to water and food *ad libitum*. Six birds were selected from each species (as outlined in chapter I) for the present study and were sacrificed by decapitation on day 0, 5, 10, 20 and 30. Six adult birds of sparrow, swift, Blue Rock pigeon, quail and fowl were also taken for the present study.

Pieces of proventriculus and ventriculus were quickly excised and used for the quantitative evaluation of the metabolites and phosphorylase assay.

Analytical Procedures

Glycogen: Known amount of proventriculus and ventriculus were used for the estimation of glycogen following the method of Seifter *et al.* (1950) using Anthrone reagent.

Phosphorylase (EC 2.4.1.1): Total phosphorylase activity in the proventriculus and ventriculus was assayed by the modified method of Cori *et al.* (1943) as adopted by Cahill *et al.* (1957). Inorganic phosphate liberated was estimated by the method of Fiske and SubbaRow (1925).

Protein: Quantitative analysis of total protein content in the proventriculus and ventriculus was carried out as per the method of Lowry *et al.* (1951).

Lipids: Total lipid was estimated by employing the gravimetric method of Folch *et al.* (1957).

Cholesterol: The quantitative estimation of cholesterol (total) was done following the method of Crawford (1958). Free cholesterol was determined by the same method after precipitation using digitonin. Readings were taken at 540 nm and the activity was expressed as mg/100 mg wet tissue.

RESULTS

Glycogen content in proventriculus of fowl and quail (Table 1; Figure 1a).

It is clear from the data that the glycogen content in the proventriculus of both the developing birds (fowl and quail) declined gradually till day 30 of development. However, an increase was observed in adult.

Glycogen content in ventriculus of fowl and quail (Table 1; Figure 1a).

Similar trend as observed in the proventriculus was noted in the glycogen content of the ventriculus of developing birds. However, the concentration of glycogen was marginally higher in the proventriculus than that of ventriculus.

Glycogen content in adult birds (Table 2; Figure 2b).

Both the proventriculus and ventriculus of adult birds showed identical patterns of concentration of glycogen with the sparrow having the maximum concentration followed by quail, pigeon, fowl and swift.

Phosphorylase activity in proventriculus of fowl and quail (Table 1; Figure 1b).

It is evident from the data that phosphorylase activity increased strikingly till day 5 in the proventriculus of both the developing birds followed by a sharp fall on day 10. Thereafter an increase was noted on days 20 and 30 to be followed by a reduction in adult.

Phosphorylase activity in ventriculus of fowl and quail (Tables 1; Figure 1b).

It is discernible from the data that there was an increase in total phosphorylase activity on day 5 in ventriculus of both the birds followed by a decrease on day 10, increase on day 20, a decrease on day 30 and finally an increase in adult.

Phosphorylase activity in adult birds (Table 2; Figures 2a, 2b).

Proventriculus: Phosphorylase activity was noted to be maximum in pigeon followed by swift, sparrow, quail and fowl.

Ventriculus: Ventriculus of pigeon depicted maximum activity of phosphorylase followed by quail, sparrow, fowl and swift in that order.

Lipid content in proventriculus of fowl and quail (Table 3; Figure 3a).

It is apparent from figure (3a) that fowl showed a reduction in the lipid content on day 5 with a negligible increase on day 10 followed by a decline in the lipid content on day 20 and 30 with a hike in adult. Whereas in case of quail there was an increase in the lipid content till day 10 followed by a sharp fall on day 20 which again showed increase on day 30 and also on attainment of adulthood.

Lipid content in ventriculus of fowl and quail (Table 3; Figure 3a).

Both the developing birds registered divergent pattern in the lipid content. Fowl registered a sharp fall on day 5 followed by an increase on day 10 reaching peak level on day 20 to be followed by a decline on day 30 and in adult. Whereas quail registered an increase in the total lipid content on day 5 followed by reduction on day 10 which increased on 20 day and again decreased on day 30 and adult.

Lipid content in adult birds (Table 4; Figure 3b).

Proventriculus showed maximum amount of total lipid in sparrow whereas swift depicted half the content of total lipid noted in sparrow, followed by fowl, quail and pigeon. However, in the ventriculus, the amount of lipid content was almost double in pigeon and fowl when compared to swift and sparrow. Whereas quail showed the lowest value for total lipid content.

Total cholesterol in proventriculus of fowl and quail (Table 5; Figure 4a).

In case of fowl a gradual decrease was the feature of total cholesterol content till day 20 followed by an increase on day 30 and a fall in the adult. Quail also registered a gradual decline till day 10 but showed an increase on day 20 followed by a sharp fall on day 30. Thereafter the level of total cholesterol registered an increase in the adult.

Free cholesterol in proventriculus of fowl and quail (Table 5; Figure 4a).

A sharp fall in the free cholesterol content was noted on day 5, followed by a rise on day 10 and a decline on day 20, followed by an increase which fell back on attainment of adulthood in case of fowl. Whereas quail showed an increase in the free cholesterol content on day 5 followed by a reduction on day 10. Thereafter an increase was the notable feature till adulthood.

Total cholesterol in ventriculus of fowl and quail (Table 5; Figure 4b).

During different developing stages, fowl depicted a decline in the total cholesterol content on days 5, 20 and adult and registered increase on days 10 and 30. Whereas in quail an increase on days 5, 20 and adult and a decline on days 10 and 30 were noted.

Free cholesterol in ventriculus of fowl and quail (Table 5; Figure 4b).

In fowl day 5 showed a decrease in the free cholesterol content which increased on day 10 to be followed by a gradual decline on days 20, 30 and in adult. Whereas in case of quail

Table 1. Levels of glycogen* and phosphorylase** in proventriculus and ventriculus of developing and adult fowl and quail.

AGE (DAYS)	PROVENTRICULUS				VENTRICULUS			
	GLYCOGEN		PHOSPHORYLASE		GLYCOGEN		PHOSPHORYLASE	
	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL
0	0.08 ± 0.002@	0.12 ± 0.003	86.21 ± 2.21	84.66 ± 3.80	0.07 ± 0.004	0.07 ± 0.001	78.51 ± 3.73	76.27 ± 3.27
5	0.06 ± 0.001	0.11 ± 0.001	95.95 ± 3.60	88.30 ± 3.51	0.05 ± 0.001	0.06 ± 0.003	94.74 ± 4.27	81.88 ± 3.96
10	0.06 ± 0.003	0.10 ± 0.002	42.90 ± 2.91	51.73 ± 4.72	0.04 ± 0.003	0.05 ± 0.001	59.91 ± 3.88	62.14 ± 3.80
20	0.05 ± 0.001	0.09 ± 0.002	57.23 ± 2.40	55.18 ± 3.80	0.03 ± 0.001	0.04 ± 0.001	65.61 ± 3.34	77.84 ± 3.77
30	0.04 ± 0.001	0.08 ± 0.002	59.05 ± 3.50	79.32 ± 4.62	0.03 ± 0.001	0.03 ± 0.001	47.67 ± 3.24	66.79 ± 2.62
ADULT	0.05 ± 0.002	0.10 ± 0.001	50.92 ± 4.54	63.50 ± 3.64	0.05 ± 0.002	0.06 ± 0.001	86.88 ± 3.85	106.55 ± 8.90

* mg/100 mg wet tissue.
** μg phosphorus released/mg protein/10 minutes.
@ Values expressed as mean ± SEM of six animals.

Table 2. Levels of glycogen* and phosphorylase** in proventriculus and ventriculus of adult birds.

ANIMAL MODEL	PROVENTRICULUS		VENTRICULUS	
	GLYCOGEN	PHOSPHORYLASE	GLYCOGEN	PHOSPHORYLASE
SWIFT	0.05 ± 0.002@	87.75 ± 3.83	0.05 ± 0.005	80.24 ± 2.50
SPARROW	0.26 ± 0.01	73.86 ± 2.14	0.11 ± 0.01	101.45 ± 6.80
QUAIL	0.10 ± 0.001	63.50 ± 3.64	0.06 ± 0.001	106.55 ± 8.90
PIGEON	0.07 ± 0.008	137.50 ± 6.14	0.06 ± 0.004	144.10 ± 5.00
FOWL	0.05 ± 0.002	50.92 ± 4.54	0.05 ± 0.002	86.88 ± 3.85

* mg/100 mg wet tissue.
** μg phosphorus released/mg protein/10 minutes.
@ Values expressed as mean ± SEM of six animals.

Table 3. Levels of lipid* content in proventriculus and ventriculus of developing and adult fowl and quail.

AGE (DAYS)	PROVENTRICULUS		VENTRICULUS	
	FOWL	QUAIL	FOWL	QUAIL
0	5.77 ± 0.76@	3.01 ± 0.20	6.73 ± 0.35	2.58 ± 0.16
5	3.04 ± 0.42	3.35 ± 0.42	2.51 ± 0.31	4.34 ± 0.28
10	3.28 ± 0.24	5.27 ± 0.20	3.72 ± 0.35	2.43 ± 0.23
20	2.05 ± 0.20	2.69 ± 0.31	9.97 ± 0.39	3.14 ± 0.27
30	2.00 ± 0.12	3.77 ± 0.10	7.43 ± 0.27	1.55 ± 0.12
ADULT	4.69 ± 0.17	4.66 ± 0.25	4.01 ± 0.19	1.29 ± 0.09

* mg/100 mg wet tissue.
@ Values expressed as mean ± SEM of six animals.

Table 4. Levels of lipid* content in proventriculus and ventriculus of adult birds.

ANIMAL MODEL	PROVENTRICULUS	VENTRICULUS
SWIFT	6.82 ± 0.99@	2.54 ± 0.23
SPARROW	8.19 ± 0.82	2.43 ± 0.11
QUAIL	4.66 ± 0.25	1.29 ± 0.09
PIGEON	3.15 ± 0.27	4.02 ± 0.38
FOWL	4.69 ± 0.17	4.01 ± 0.19

* mg/100 mg wet tissue.
@ Values expressed as mean ± SEM of six animals.

Table 5. Levels of cholesterol* (total and free) in proventriculus and ventriculus of developing and adult fowl and quail.

AGE (DAYS)	PROVENTRICULUS				VENTRICULUS			
	TOTAL		FREE		TOTAL		FREE	
	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL	FOWL	QUAIL
0	0.26 ± 0.02@	0.51 ± 0.03	0.24 ± 0.02	0.33 ± 0.02	0.24 ± 0.02	0.16 ± 0.008	0.13 ± 0.01	0.07 ± 0.008
5	0.22 ± 0.02	0.46 ± 0.02	0.06 ± 0.01	0.42 ± 0.03	0.13 ± 0.01	0.26 ± 0.01	0.10 ± 0.009	0.15 ± 0.01
10	0.19 ± 0.02	0.40 ± 0.02	0.11 ± 0.02	0.16 ± 0.008	0.25 ± 0.02	0.14 ± 0.01	0.18 ± 0.01	0.06 ± 0.01
20	0.14 ± 0.02	0.62 ± 0.04	0.07 ± 0.01	0.18 ± 0.01	0.90 ± 0.05	0.32 ± 0.01	0.06 ± 0.008	0.20 ± 0.02
30	0.21 ± 0.03	0.33 ± 0.01	0.11 ± 0.01	0.19 ± 0.02	0.11 ± 0.01	0.12 ± 0.008	0.05 ± 0.01	0.11 ± 0.01
ADULT	0.11 ± 0.01	0.60 ± 0.03	0.10 ± 0.01	0.42 ± 0.02	0.04 ± 0.002	0.28 ± 0.02	0.02 ± 0.001	0.23 ± 0.02

* mg/100 mg wet tissue.

@ Values expressed as mean ± SEM of six experiments.

Table 6. Levels of cholesterol* (total and free) in proventriculus and ventriculus of adult birds.

ANIMAL MODEL	PROVENTRICULUS		VENTRICULUS	
	TOTAL	FREE	TOTAL	FREE
SWIFT	0.53 ± 0.04@	0.10 ± 0.01	0.15 ± 0.01	0.05 ± 0.001
SPARROW	0.47 ± 0.06	0.16 ± 0.02	0.16 ± 0.01	0.07 ± 0.004
QUAIL	0.60 ± 0.03	0.42 ± 0.02	0.28 ± 0.02	0.23 ± 0.02
PIGEON	0.79 ± 0.08	0.50 ± 0.03	0.34 ± 0.02	0.27 ± 0.01
FOWL	0.11 ± 0.01	0.10 ± 0.01	0.04 ± 0.002	0.02 ± 0.001

* mg/100 mg wet tissue.
@ Values expressed as mean ± SEM of six animals.

Fig. 1a. Levels of glycogen in growing birds.

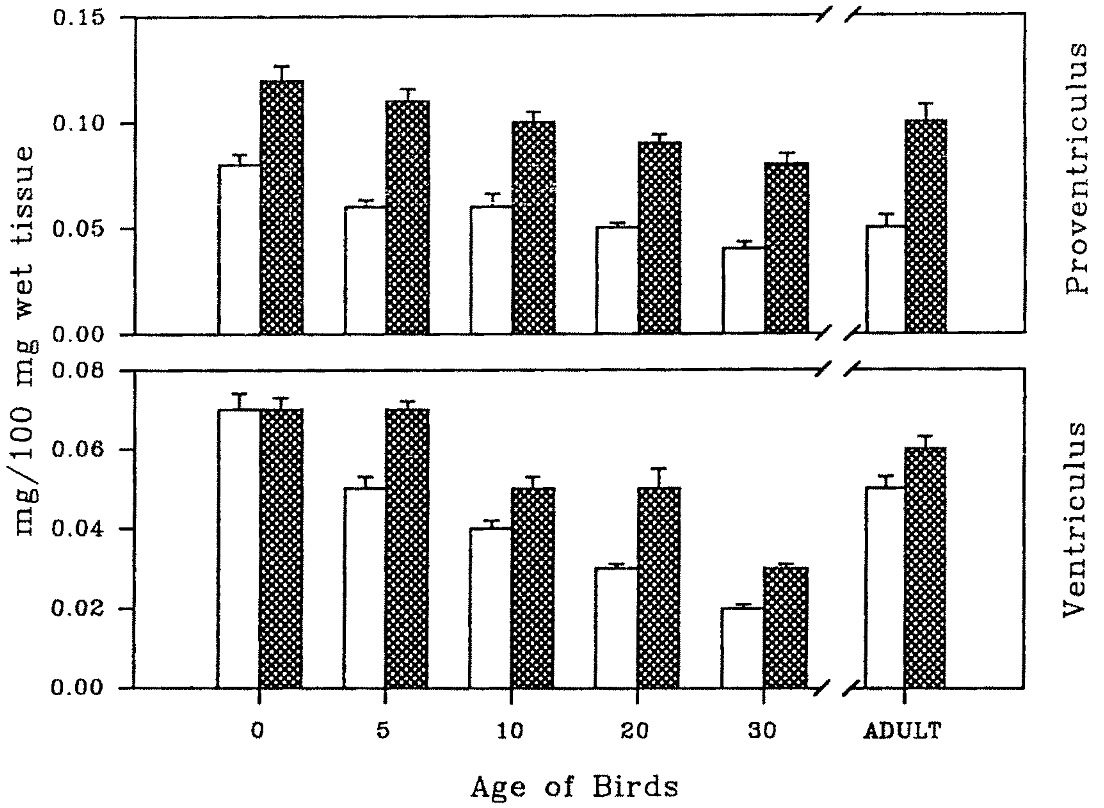


Fig. 1b. Levels of phosphorylase in growing birds.

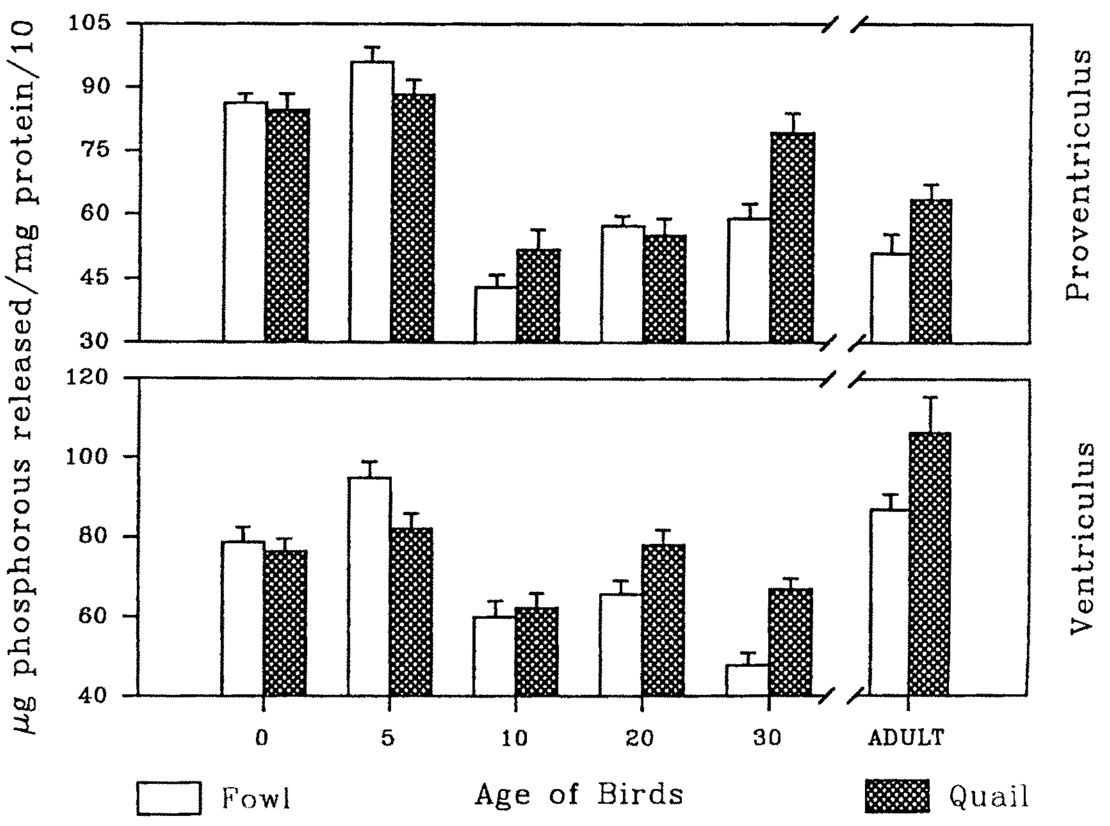


Fig. 2a. Levels of glycogen in adult birds.

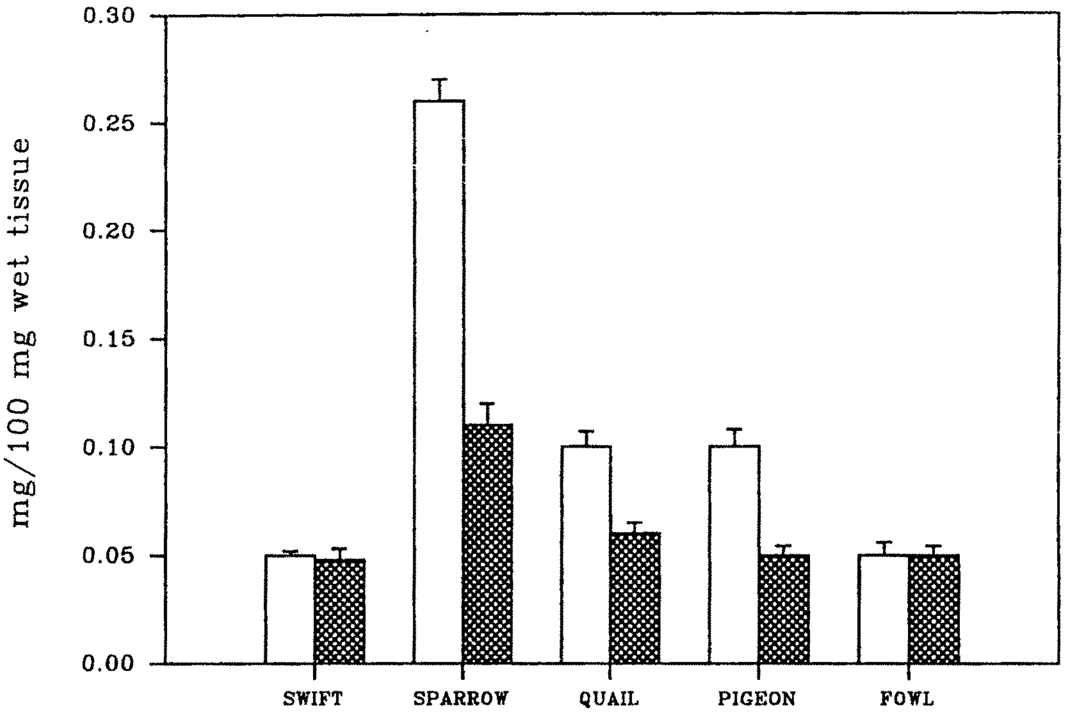


Fig. 2b. Levels of phosphorylase in adult birds.

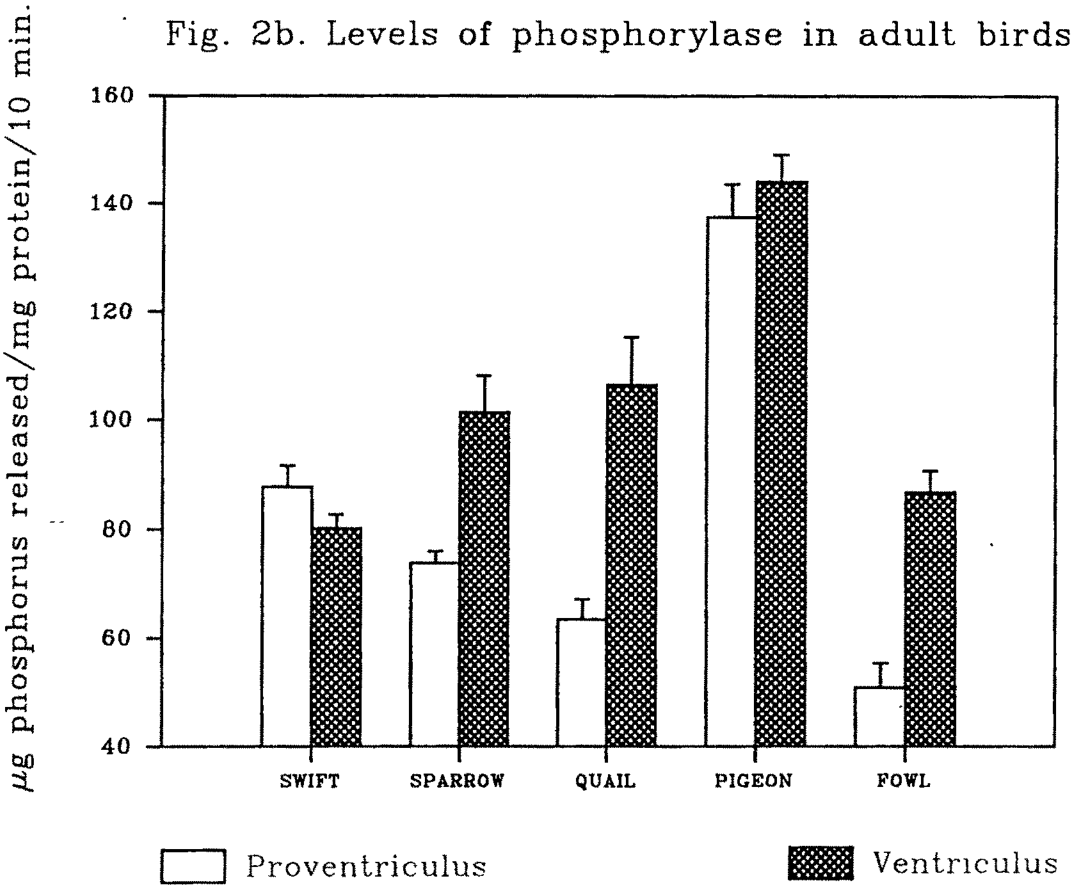


Fig 3a.Total lipid content in growing birds.

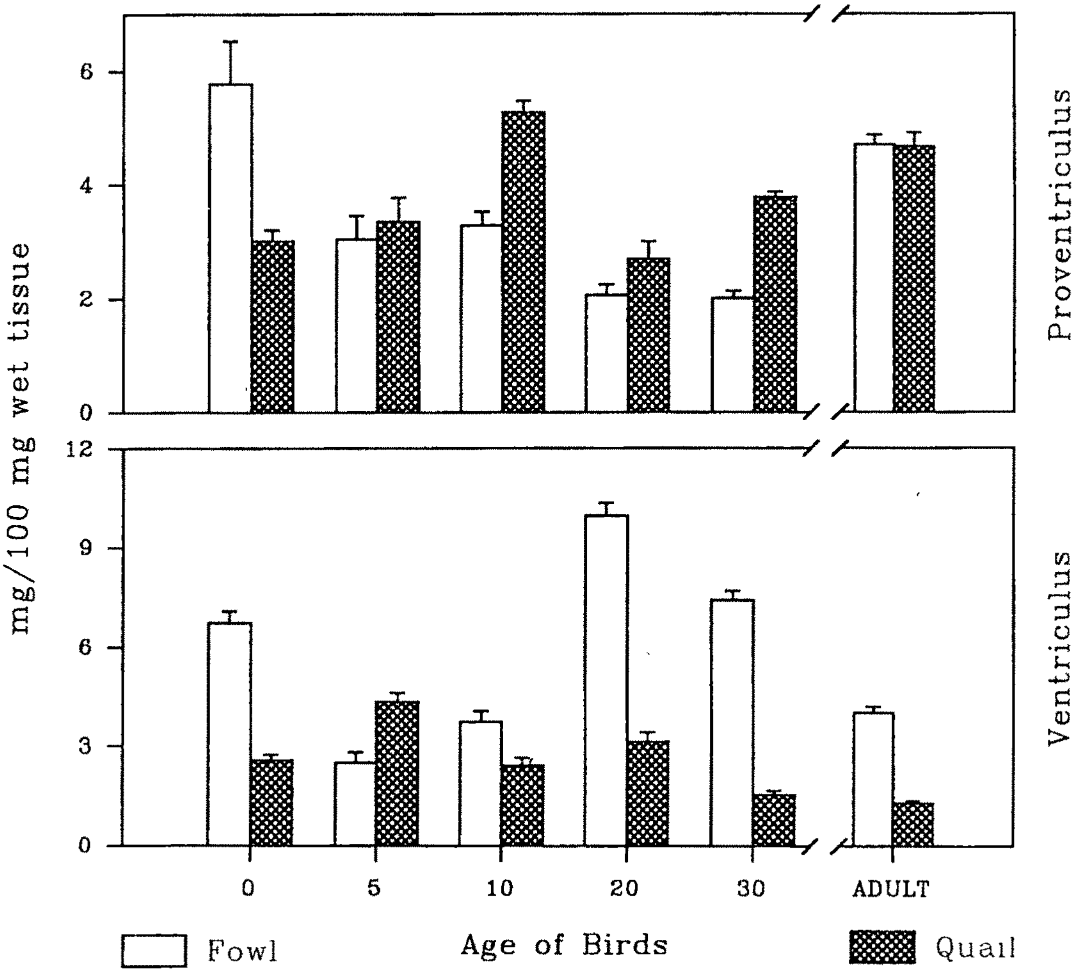


Fig 3b.Total lipid content in adult birds.

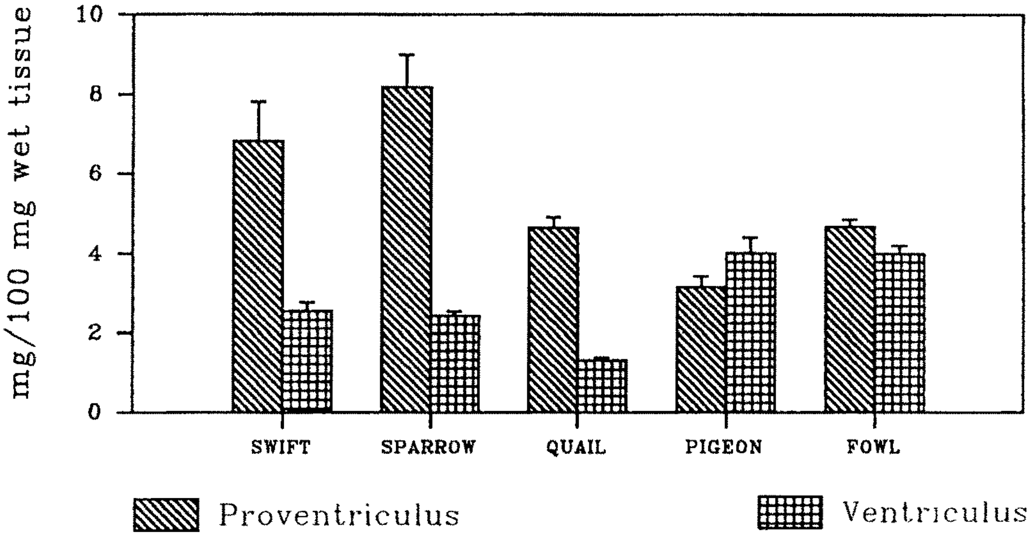


Fig 4a.Levels of cholesterol in proventriculus

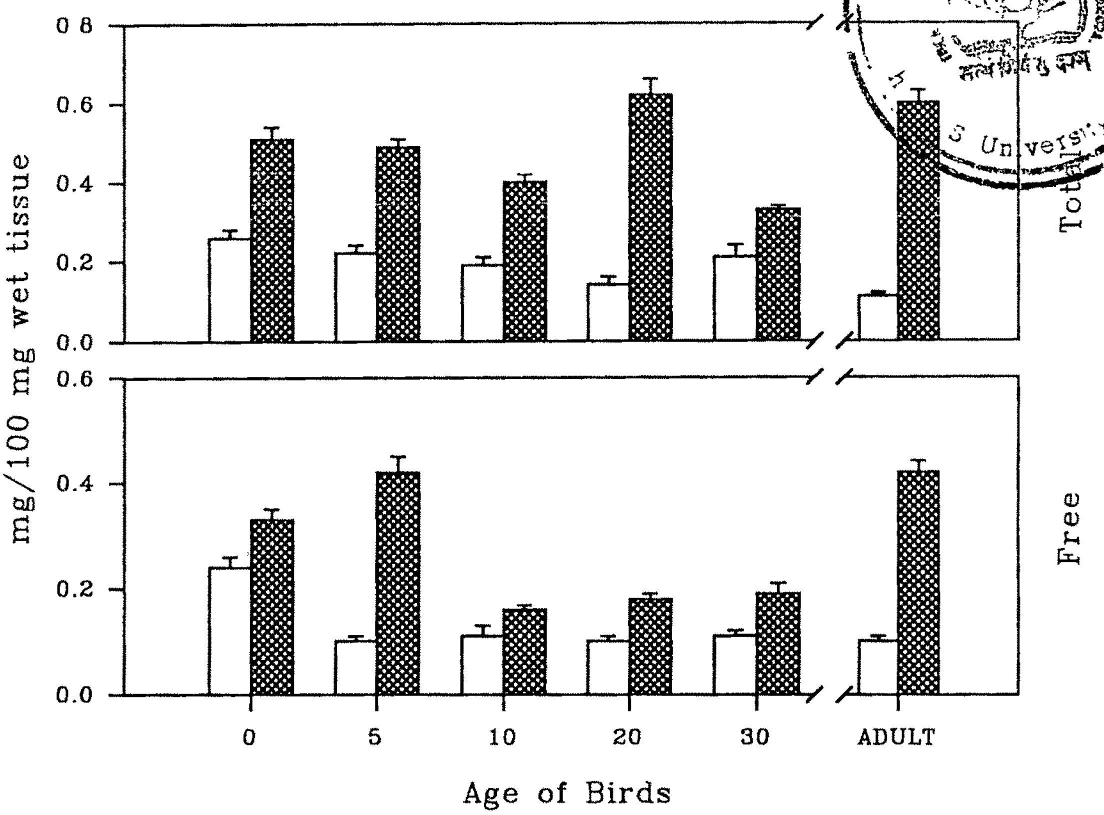


Fig 4b.Levels of cholesterol in ventriculus

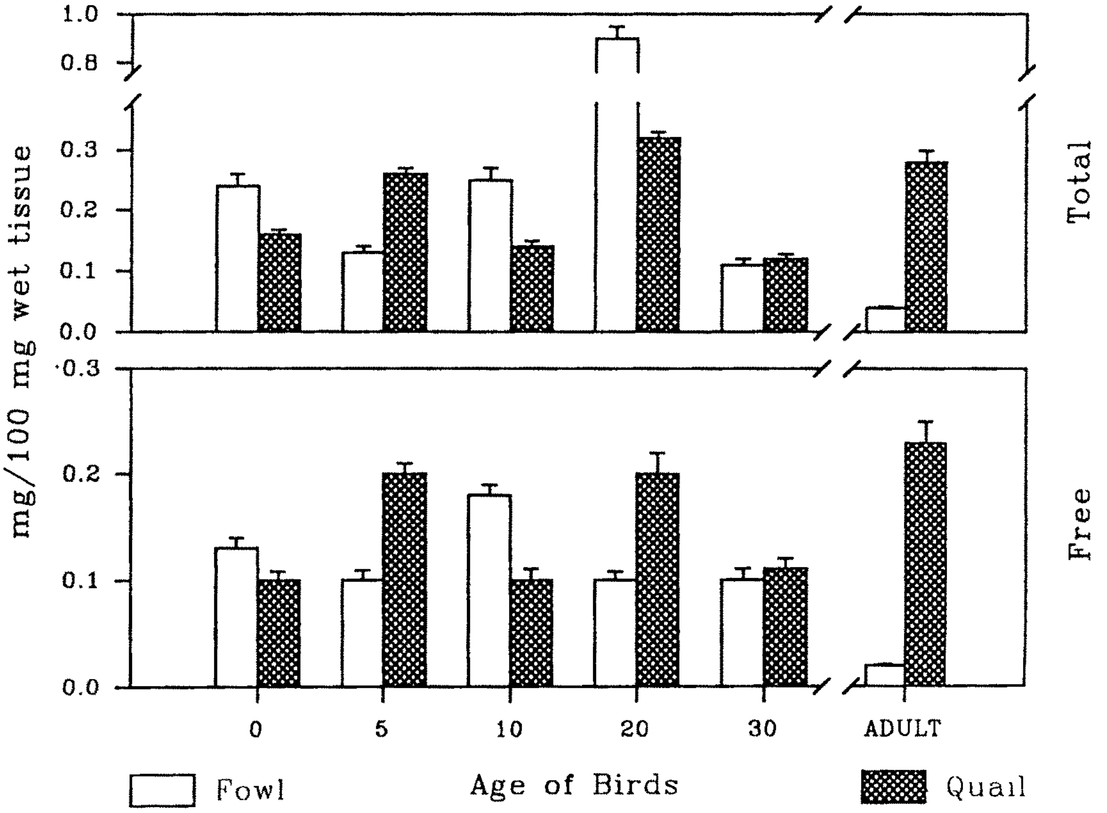
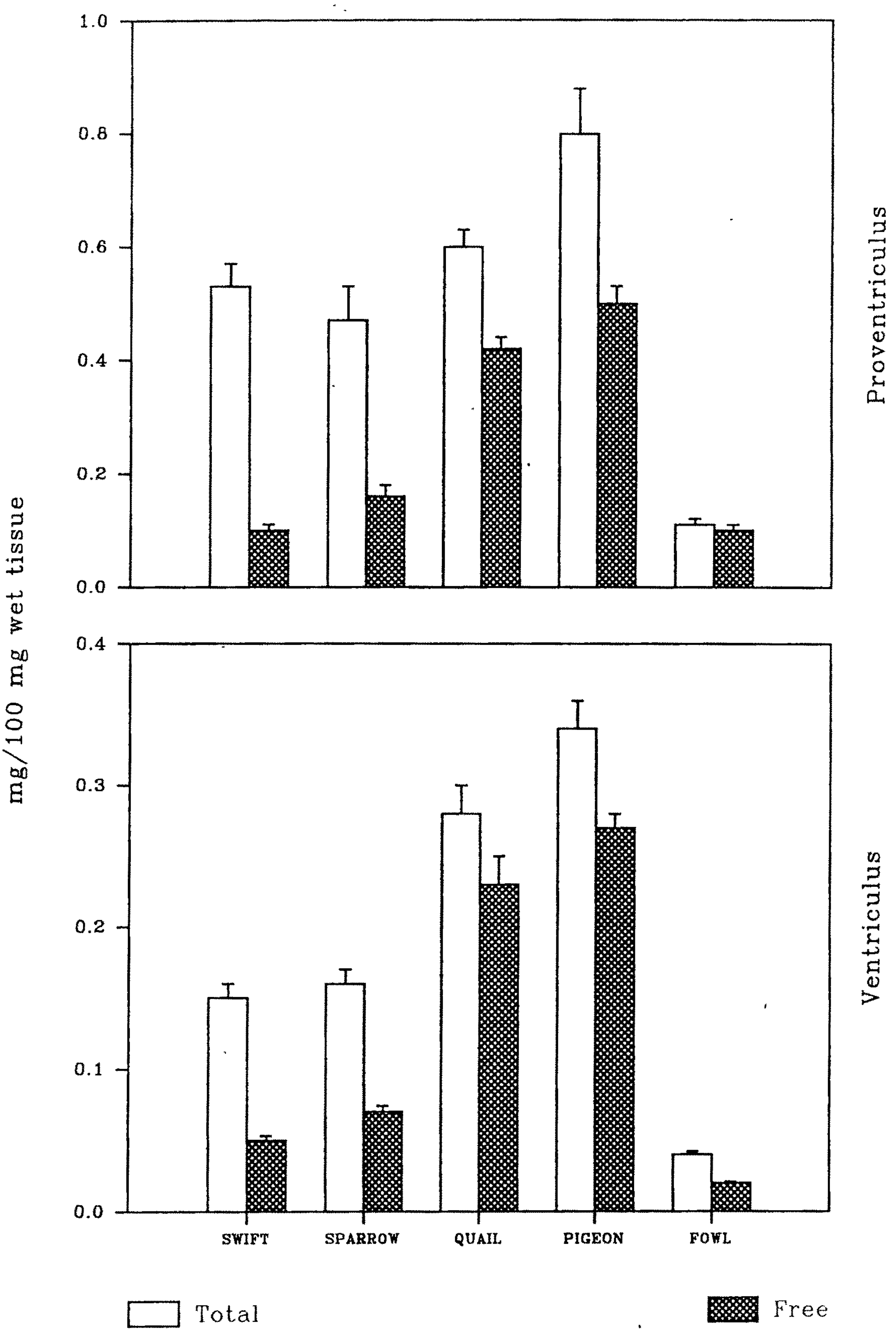


Fig 5. Levels of cholesterol in adult birds.



fluctuations were noted in the free cholesterol content with high levels on days 5, 20 and in adult.

Cholesterol content in adult Birds (Table 6; Figure 5).

Proventriculus: Total cholesterol content was noted to be maximum in the proventriculus of pigeon followed by quail, swift and sparrow with the minimum content of the same in fowl. However, free cholesterol content was maximum in pigeon, preceded by quail, sparrow, swift and fowl.

Ventriculus: The total and free cholesterol content in ventriculus too followed the same trend as that of proventriculus with maximum amount in pigeon followed by quail, sparrow and swift while fowl registered a very low level of total and free cholesterol content.

DISCUSSION

The present studies on the quantitative analyses of glycogen and phosphorylase tend to indicate the fact that the stomach complex of fowl and quail, during the early days of development depend upon glycolytic metabolism. This contention appears to be favoured when one visualizes the concentration of this metabolite which was moderately high on the day of hatching, showed a gradual decline on day 5 in both proventriculus and ventriculus of fowl and quail. At the same time, the concentration of phosphorylase registered an increase during the above mentioned days of development. A continuous process of glycolytic metabolism in the developing pigeon gizzard was reported by Shah and Panicker (1974) and Panicker and Shah (1980 a). So the concurrent decline of glycogen in the initial days of development of these organs is in good correlation with the suggestion of a predominant carbohydrate metabolism in these birds. The metabolic necessities during the initial days of development of these organs are of a low order; nevertheless, the proventriculus is in a higher metabolic status compared to ventriculus, and therefore shows an enhanced capacity for the utilization of glucose for the production of energy.

To the above observation, lipid catabolism appears to be significant only during the later part of development in these birds. Though apparent decrease in the lipid concentration could be observed in the proventriculus and ventriculus of fowl, the decrease was very slow and gradual in case of quail. Nevertheless, an increase in lipid concentration noted on day 10 in proventriculus and day 5 in ventriculus cannot be explained at the present juncture except when the basic growth data of these birds (chapter II 2) are considered. It may thus be inferred that the stomach complex of these birds during the initial days of development, though depends upon carbohydrate, also stores at least some amount of lipids.

The trend of continued decline in glycogen content in the stomach complex was evident even on day 10 of post natal development in these birds with the proventriculus still showing a slightly higher concentration of the metabolite. In the same period, the phosphorylase was at its lowest ebb (42.91 and 51.73 μg P/mg protein/10 minutes) in the proventriculus of fowl and quail whereas in case of ventriculus, the quail showed the lower ebb (62.14 μg P/mg protein/10 minutes) and the fowl showed a lowest concentration of 59.91 μg P/mg protein/10 minutes (which was slightly higher than the lowest concentration of 47.67 μg P/mg protein/10 minutes observed on day 30). This sharp decline of glycogen with the minimal level of phosphorylase noted on this day with apparently no lipid catabolism appears to be in good correlation with the concomitant spurt in the morphometric development of these organs marked by an increased rate of proliferation and differentiation of the components of these organs (chapter II). Such a correlation between the concentration of metabolites like glycogen and lipids and the enzymes concerned with the metabolism of these has been reported by Shah and Panicker (1974 and 1976) and Panicker and Shah (1980 b) in developing pigeon gizzard and indicated the possibility of complete oxidation of glycogen through TCA cycle for the liberation of energy.

Days 20 and 30 are marked by an increase in all the structural components of proventriculus and ventriculus (see chapter II). Interestingly enough, this is the period when the muscularity of the ventriculus and the functional competence of the proventriculus have attained the maximum level. The slow depletion of glycogen content and a concomitant increase in the phosphorylase level in the proventriculus and ventriculus of fowl and quail with a decline in the lipid concentration in the proventriculus of fowl clearly indicate an active lipid catabolism; at the same time a low level glycogen utilization also cannot be ruled out. In the ventriculus of fowl and quail a reverse trend was observed with the lipid showing an increase. These observations are highly noteworthy here and signify the ability of the mucosal tubules to utilize glycogen/glucose for energy requirement for koilin synthesis and active cellular proliferation and several researchers have attributed the prevalence of glycogen to such functions (Bradfield, 1950; Montagna and Ellis, 1958; Shah and Chacko, 1967 and Shah and Panicker, 1974).

The period between 10th and 30th days of development is marked by an increased rate of lipid depletion in the proventriculus of fowl and quail as recorded by the quantitative analysis. During the same period, the ventriculus of fowl and quail recorded an increase in the amount of lipid content on day 20, followed by a reduced level on day 30. Incidently, it may be noted from the basic growth data (chapter II) that the proventricular growth rate at this period is at the maximum level in case of fowl and quail, whereas the ventricular growth rate is slightly delayed to reach the maximum in adult. When the carbohydrate metabolism fails to satisfy the energy necessities of the fast developing stomach complex the energy demand is supplemented by the active participation of lipids as noted in the present study.

The transitional period from 30th day to adult could be considered as one when finer and final changes are at work. As far as fowl and quail are concerned, this period is characterized by an increase in glycogen content and decrease in phosphorylase level. This observation lends credence and support to the earlier observations that when the proventriculus and ventriculus have attained their full structural and functional maturity there is a significant low demand for metabolic necessities.

When the developmental process is completed with the attainment of adulthood, the metabolic necessities also seem to be very much reduced as could be observed from the slightly reduced content of lipids in ventriculus and a slightly conditioned level of the same in the proventriculus, mainly to settle down towards the characteristic adult pattern. In the wake of above observation, it is reasonable to conclude that the lipid synthesis, by far, outweighs the degree of its utilization. As the ventriculus is chiefly constituted of smooth muscles, it has poor capacity to store metabolites. Also the functions of stomach involves slow and sustained contractions, a ready and instant supply of fatty acids made available through blood might serve very useful and economical and as such the energy for the relatively slow but sustained contractions of smooth muscle is derived from the oxidation of fatty acids (White *et al.*, 1964).

An important and significant aspect that has been brought out by the studies on the metabolic features of skeletal muscles is that, whereas the slow, tonic contractile fibres, (red) are chiefly dependent on the lipid catabolism, the quick, tetanic contractile fibres (white) are better adapted for carbohydrate metabolism (George and Naik, 1959; Ogata and Mori, 1964 and Nene and George, 1965). Based on this scheme of biochemical characterization of muscles, the expectance of a moderate and uniform incidence of lipid catabolism as observed in the present study in the stomach complex (particularly ventriculus) of all types of birds appears to be reasonable and tenable as the stomach complex could be functionally associated with the process of slow and sustained contractility. However, the utilization of carbohydrate, even to a low level, seems to gain justification not only from the fact that there is always a minimal level of carbohydrate catabolism in all the animal tissues, but also from the fact that the proventriculus and ventriculus at times might have to engage itself in quick, tetanic mode of contraction to evacuate the contents further to the succeeding parts. It could be noted that though all types of ventriculus are capable of lipid catabolism the extent of its utilization appears to show a gradation as per the specific type of food ingested by various groups of birds. In this respect the ventriculus of graminivores (pigeon, quail and fowl) appears to be more dominant as the food consists of grains which are comparatively much harder and tough, thus demanding active muscular action. The omnivore and insectivore (sparrow and swift respectively) tends to be in a lower grade as far as the muscular activity is concerned and the texture of the food materials consumed by them also appears to be of an intermediary nature between the hard and soft ones.

The pattern of concentration of glycogen and phosphorylase in adult representative birds showed variations. When the modes of development (precocial and altricial) or dietary preferences were taken as parameters, there was much overlapping in the concentration of glycogen and phosphorylase. The highest level of glycogen was seen in proventriculus of sparrow (altricial, omnivore) followed by quail (precocial, graminivore) with the remaining three *viz.*, pigeon (altricial, graminivore), fowl (precocial, omnivore) and swift (altricial, insectivore) showing the lowest but identical levels of glycogen. The phosphorylase level was highest in pigeon thereby showing a high level of glycogen degradation. The other birds under study have shown almost identical levels of phosphorylase. This, when related to the observed value of glycogen, clearly indicates that these birds are differently adapted to utilize glycogen for energy purpose. The ventriculus, on the other hand, had a lower concentration of glycogen and correspondingly a lower phosphorylase level. Here again, the pigeon, as evidenced by a higher concentration of phosphorylase is equipped with an efficient machinery for degradation of glycogen, with apparent low level of glycogen in swift, fowl and quail when related to the observed concentration of phosphorylase, clearly indicates that the glycogen degradation is of a high threshold than in sparrow where the concentration of both glycogen and phosphorylase is almost identical. Perhaps, these similarities and differences may be due to the preferential utilization of diet. The birds grouped in omnivores (sparrow and fowl) are primarily adapted for grains and secondarily adapted to taking insects or other types of food. So the variations in the glycogen and phosphorylase concentration are undoubtedly based on the type of consistency of the food.

The use of cholesterol in the body is to form cholic acid in the liver and this cholic acid is conjugated with other substances to form bile salts which promote digestion and absorption of fats. So a possible correlation is established between the amount of cholesterol and the degree of metabolism of fat. Approximately half the cholesterol of the body arises by the synthesis and the remainder is provided by the average diet. The effect of dietary cholesterol on cholesterol synthesis has been extensively studied in humans and in a variety of animals (Dietschy and Wilson, 1970; Ho and Taylor, 1970 and Lutton, 1991). For a given species, the sensitivity with which the cholesterol metabolism is modulated varies from one tissue to another and for a given tissue, the variation between the species is remarkable (Zhang *et al.*, 1994). The hepatic cholesterogenesis is reduced considerably if the diet is rich in cholesterol while in extra hepatic tissues such as small intestine such synthesis is less affected (Jeske and Dietschy, 1980). Further, the entry of dietary cholesterol into the circulation, besides other factors, controls the plasma cholesterol concentration.

In the proventriculus of developing fowl and quail the concentration of total cholesterol was moderate on the day of hatching, thereafter it registered a decline till day 20 with an increase on day 30 followed by a decline in adult. Whereas in the ventriculus of fowl the level of total cholesterol noted on the day of hatching showed fluctuations during the subsequent days of development and a very low level of cholesterol was noted in the adult. In case of quail a moderate level of cholesterol was the notable feature during the different days of development and in adult. On a comparative basis, the cholesterol level was lower in the ventriculus of quail than in the proventriculus. The fluctuations noted in the concentration of cholesterol in the proventriculus and ventriculus of developing and adult fowl and quail is related to the possible use of this in the synthesis of bile salts which promote the digestion and absorption of fats. In proventriculus and ventriculus of fowl and quail during the different days of development a moderately high incidence of lipid metabolism is noted as mentioned earlier and the presently noted level of cholesterol is in conformity with this observation. Further, in the proventriculus and ventriculus of adult birds with different feeding habits, the level of cholesterol did not show any conclusive pattern, rather showed individual peculiarities. Probably the differences in the dietary cholesterol level were as per the specific types of food these birds consume and a clear and conclusive understanding could be had only if a detailed study is carried out in the stomach complex of these birds.