CHAPTER 4

VARIATIONS IN THREE ENERGY PROVIDING METABOLITES *VIZ.* CARBOHYDRATE, TOTAL LIPID AND PROTEIN IN MALE AND FEMALE JUNGLE BABBLERS.

INTRODUCTION ~

Animals obtain all their required energy from the food they eat. Their diet consists of various biological components *viz.* carbohydrate, lipids and protein; the proportion of which depends on the type of the diet consumed and the nature of the food available throughout the year. Depending on the type of the activity they perform during the different seasons of the year requirement of the energy would vary. One of the most cost effective, energy requiring activity is reproduction, crowded in a very short favourable period of the year in majority of birds benefiting both young ones and the parents (Immelmann, 1971; Phillips *et al.,* 1985). The different energy costing reproductive activities performed by the breeding birds include courtship, nest building, egg laying, incubation and feeding the brood (Perrins and Birkhead, 1983).

One of the important biomolecules which makes the maximum part of the feed is the carbohydrate- polysaccharides (starch in plant

tissues converted to glycogen in animal tissues). Because of its instant readiness to supply energy to the tissues and thus allowing them to perform at their best, glycogen has been recognized as a versatile organic compound for a variety of biological systems (Mayes, 2000). It is readily and rapidly synthesized from all available nutrients and is easily broken down when energy demand of the body increases.

The excess amount of the carbohydrate absorbed by the avian intestine is converted to fat for to its use as a reserved energy source (Griminger, 1986). Fat is then released from the depots in the form of non – esterified or free fatty acids which enters the blood stream and circulates in body loosely complexed with plasma albumin. The only dietary requirement of lipids by birds and other higher animals are of relatively small amounts of those few fatty acids that cannot be synthesized by the organism (Griminger, 1986). However birds are capable of utilizing appreciable quantities of dietary fats. Depending on the eating habits, fat intake among non domestic species varies widely (Griminger, 1986). The fats are most variable metabolites among the major body constituents proportion of which varies with species, sex and age. It is also strongly affected quantitatively as well as qualitatively by nutrition (Griminger, 1986).

Proteins play both structural as well as metabolic roles in the body. While the metabolic role of the proteins is exemplified by enzymes and plasma proteins; they also provide energy in their due course of degradation thus having a functional role of energy supply

after carbohydrates and lipids (Griminger and Scanes, 1986). Excess dietary amino acids are not excreted out but are converted to common metabolites that are precursors of glucose, fatty acids and ketone bodies and are therefore metabolic fuels (Voet *et al.,* 1998). Thus, there is an inter-relationship between carbohydrate, lipid and protein metabolism (Chart 1).

The liver, major metabolic organ in the body is greatly under the influence of the dietary intake of the metabolites and their demand by the body. One of the major functions of liver is the ability of the hepatocytes to store glucose in the form of glycogen for storage of energy. Glucose production and secretion is dependent on extent of glycogen stores and on the rate of glycogenolysis in the liver (Banhegyi *et al.,* 1996). Liver shows metabolic adaptations to deal with the nutrients (proteins, fats or carbohydrates) predominantly brought in through the diet. In the euryphagous birds, the liver has to show a high viability in dealing with all types of nutrients brought by the diet which varies according to the availability (Pilo *et al.,* 1975). In birds, with liver the kidney may also take up the compensatory role via gluconeogenesis in metabolic homeostasis depending on the diet and requirement of the metabolites by birds (Pilo and Mehta, 1985; Hazelwood, 1986). Watford (1989), also reports that chicken kidney is the major site of gluconeogenesis from substrates other than lactate and thus plays an important role in maintenance of glucose homeostasis. The dietary protein levels regulate the in vitro

lipogenesis which is inversely related to the dietary protein (Rosebrough *et al.,* 2002). By the evaluation of organ specific glucose release, it has been shown that renal glucose is of the same order as hepatic glucose (Cano, 2001). Thus, the kidney is now recognized as playing a key role in inter organ glucose metabolism. In birds, kidney is a major gluconeogenic organ, whereas the liver is a specialized lipogenic organ and thus forcing kidney to become the predominant gluconeogenic tissue (Watford, 1985).

From the available evidence it seems probable that the avian intestine also, under certain altered hormonal and dietary regimes plays a role not only in the uptake of sugars but also of fatty acids, glycerides an cholesterolic compounds serving to the changing energy needs of the birds.

Presence of glycogen in various cellular elements of testis (Free, 1970) and ovaries (Bjersing, 1977) are known facts. The glycogen has been associated with energy requirement for various gonadal activities may that be the synthesis of steroid hormone or growth and multiplication of germ cells. Intense localization of PAS+ve carbohydrates has been reported in the nuclei of the sertoli cells and the germ cells of breeding testis of Indian robin, *Saxicoloides fulicata* (Rajvanshi *et al.,* 1985). From these references, it is clear that the location and distribution of glycogen follow certain definite patterns complimentary to the process of spermatogenesis and development of ovarian follicles and oocytes. The presence of glycogen in the sertoli

cells is related to its role in providing optimum supply of glucose for maintaining the efficiency of the testis and for nourishment to developing spermatogenic cells (Free, 1970; Rajvanshi *et al.*, 1985). Ovaries also have different types of cells which change according to stages of development of the follicles and the production of the ovarian hormones (Zuckerman, 1962). It is therefore likely that the carbohydrate metabolism could vary in the ovary at different phases of reproductive cycle.

In the present chapter variations in the glycogen, lipid and protein in the liver, intestine and kidney with the same in gonads of breeding and non-breeding male and female Jungle Babblers along with the helper females are discussed.

MATERIALS AND METHODS ~

Birds were procured from a local bird supplier and sacrificed as early as possible to avoid effects of caging. A part of liver, small intestine (duodenum), kidneys and gonads were taken out, blotted free of tissue fluids and were taken for estimations of glycogen, total lipid and protein contents as follows.

Glycogen

The parts of the tissues taken were weighed to the accuracy of 0.1 mg on single pan mettler balance and then added to a test tube containing 2 ml 30 % KOH. Part of intestine was split open, rinsed in cold saline to remove the intestinal content and then utilized for estimation. Test tubes with tissues were kept in boiling water bath till the tissues inside the tubes were completely digested. 2.0 ml of absolute alcohol was added to the tubes to precipitate glycogen. The contents were mixed thoroughly and kept in fridge for about 30 minutes to allow the precipitous of glycogen to settle. The tubes were then centrifuged at 3000 rpm and the supernatant was decanted. The process was repeated once more and finally the pellets collected at the bottom of the tubes were dissolved in known volume of distilled water. Different dilutions were taken for the estimation of glycogen by the Anthrone method of Seifter *et al.,* (1950). Anthrone reagent in concentrated H_2SO_4 hydrolysis glycogen into glucose which reduces

the yellow anthrone to green colour which is read at 620 nm on spectrophotometer.

Total Lipid

The total lipid contents were extracted by the method described by Folch Lee *et al.,* (1925), in 6ml 2: 1 (v / v) chloroform: methanol mixture. Fresh tissues were crushed in the test tubes with the help of a glass rod and mixed thoroughly with addition of chloroform: methanol mixture, later 0.2% $CaCl_2$ was added to remove the water content from the tissue and the test tubes were allowed to stand overnight. The upper layer (aqueous part) was removed and clear supernatant was decanted in the separate graduated tubes. Aliquots of 2 ml were taken in preweighed lipid tubes and evaporated to dryness by keeping the tubes in an air – oven maintained at 60 ° c. Total lipid content was calculated gravimetrically.

Protein

Protein estimation was carried out by the method described by Lowry *et al.,* (1954). Homogenates of the tissues were made in chilled clean mortar pestle with chilled 1 ml distilled water. From this homogenate 0 .1 ml of the aliquotes was taken in test tubes and to this 0.9 ml of distilled water was added. To these tubes 5 ml of reagent C (Reagent A: 2% Na_2CO_3 in 0.1 N NaOH + Reagent B: 0.5% $CuSo_4$ in 1% Na-K Tartarate) was added and allowed to stand at room

temperature for 10 minutes. Later 0.1 ml diluted Folin-phenol reagent was added with immediate stirring. After 30 minutes the color intensity developed was read at 750 nm on a spectrophotometer. In this the protein reacts with Folin-phenol reagent to give a coloured complex which is formed due to the reaction of the alkaline copper with protein and the reduction of phosphomolybdate by tyrosin and tryptophan present in the protein. It is expressed as mg protein/ 100 mg of tissue weight.

Table: 1 Glycogen content in some tissues of male and female Jungle Babblers

	MALE		FEMALE		
	BREEDING	NON-BREEDING	BREEDING	NON-BREEDING	HELPERS
LIVER	0.122 ± 0.012*	0.088 ± 0.013	0.126 ± 0.018***	0.028 ± 0.008	0.156 ± 0.017@@@
INTESTINE	0.067 ± 0.008**	0.041 ± 0.007	0.076 ± 0.012**	0.041 ± 0.005	0.056 ± 0.011
KIDNEY	0.062 ± 0.007	0.051 ± 0.007	0.056 ± 0.017	0.057 ± 0.007	0.047 ± 0.005
GONADS	0.047 ± 0.009*	0.028 ± 0.006	0.06 ± 0.010**	0.027 ± 0.008	0.056 ± 0.004@@

* Non-breeding birds Vs Breeding birds * P <0.05 ** P <0.005 *** P <0.0005

@ Non-breeding females Vs helpers @ P <0.05 @@ P <0.005 @@@ P <0.0005

Table 2: Total lipid contents in some tissues of male and female Jungle Babblers

	MALE		FEMALE		
	BREEDING	NON-BREEDING	BREEDING	NON-BREEDING	HELPERS
LIVER	5.66 ± 0.638	5.44 ± 0.584	5.03 ± 0.30	5.036 ± 0.645	5.64 ± 0.70
INTESTINE	5.22 ± 0.688	4.98 ± 0.852	5.23 ± 0.381	5.965 ± 1.21	6.25 ± 0.78
KIDNEY	6.37 ± 0.935	5.61 ± 0.836	4.75 ± 0.692	4.01 ± 0.128	3.37 ± 0.47#
GONADS	4.76 ± 0.295***	11.6 ± 1.057	4.9 ± 0.27***	11.33 ± 1.02	5.21 ± 0.20@@@

* Non-breeding birds Vs Breeding birds * P <0.05 ** P <0.005 *** P <0.0005

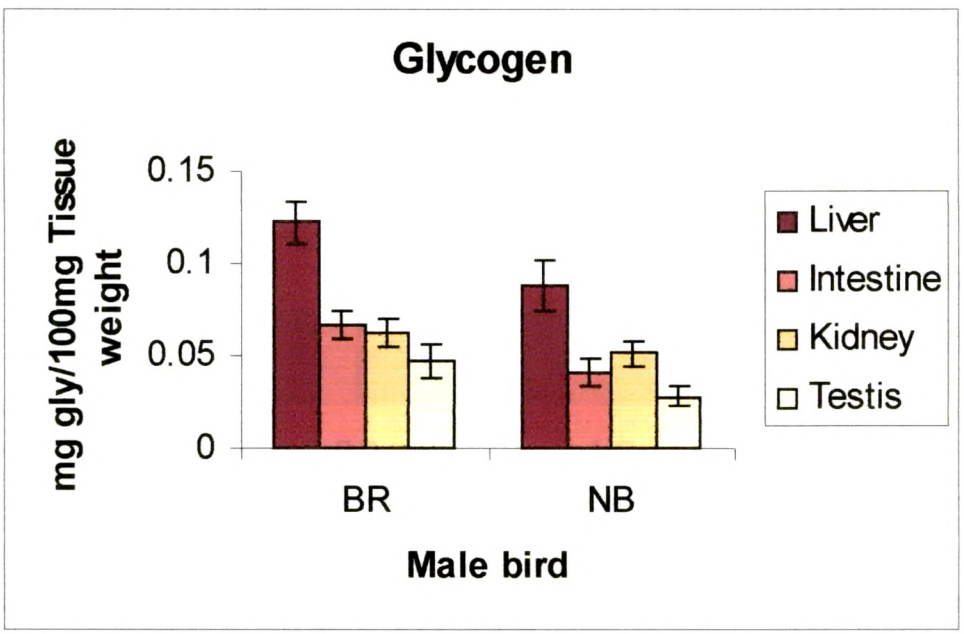
@ Non-breeding females Vs helpers @ P <0.05 @@ P <0.005 @@@ P

Table: 3 Protein content in some tissues of male and female Jungle Babblers

	MALE		FEMALE		
	BREEDING	NON-BREEDING	BREEDING	NON-BREEDING	HELPERS
LIVER	16.82 ± 1.33	18.72 ±1.08	17.72 ± 2.35**	10.31 ± 1.88	15.65 ± 0.74
INTESTINE	12.14 ± 0.56***	16.85 ± 0.88	13.04 ± 0.82**	16.46 ± 1.01	11.78 ± 0.43@@@
KIDNEY	13.89 ±1.50	13.54 ±1.30	15.22 ± 1.78**	11.93 ±1.50	12.77 ± 0.40

* Non-breeding birds Vs Breeding birds * P <0.05 ** P <0.005 *** P <0.0005

Figure 1: **Glycogen content of gonadal and extra-gonadal tissues of breeding and non-breeding male and female Jungle Babblers along with helper females.**



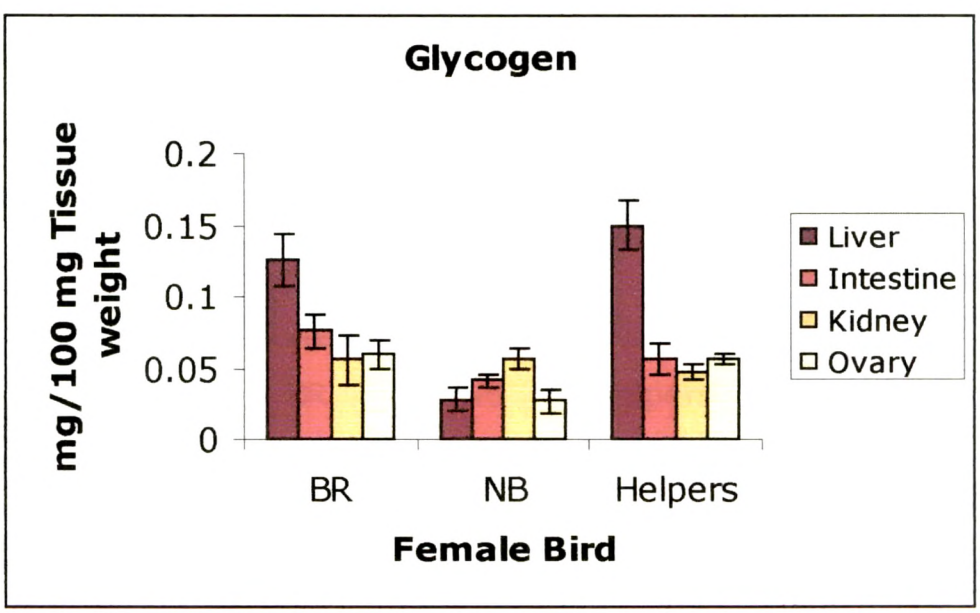
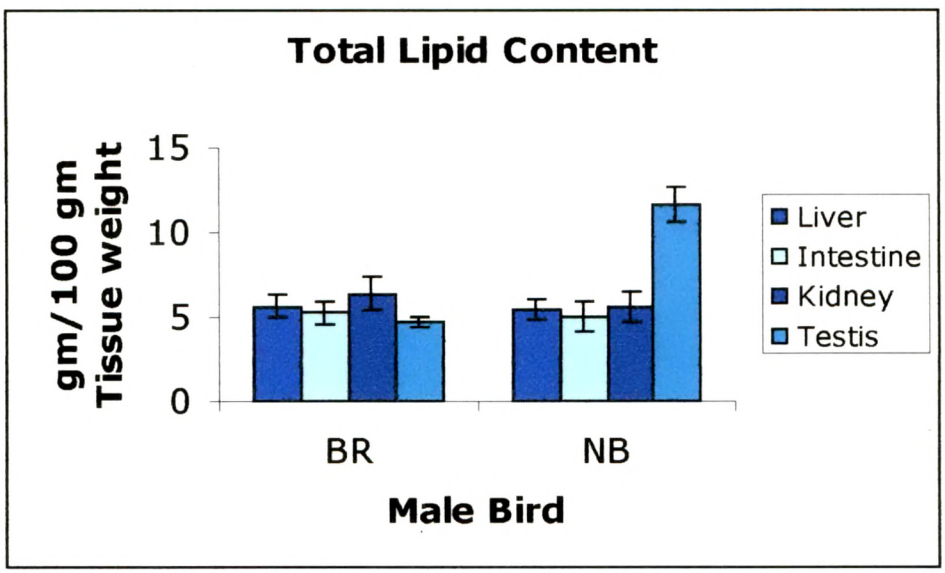


Figure 2: **Total lipid content of gonadal and extra-gonadal tissues of breeding and non-breeding male and female Jungle Babblers along with helper females.**



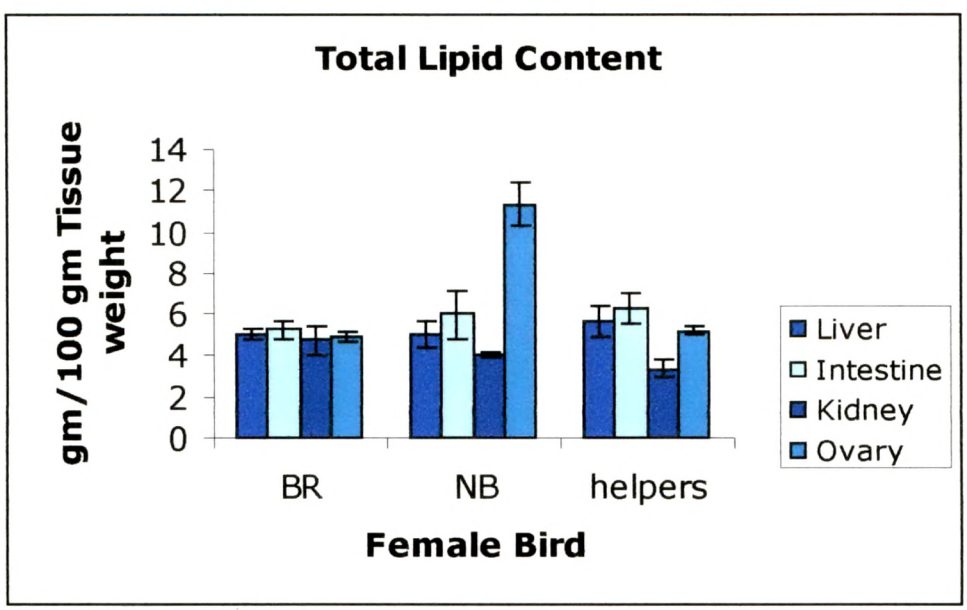
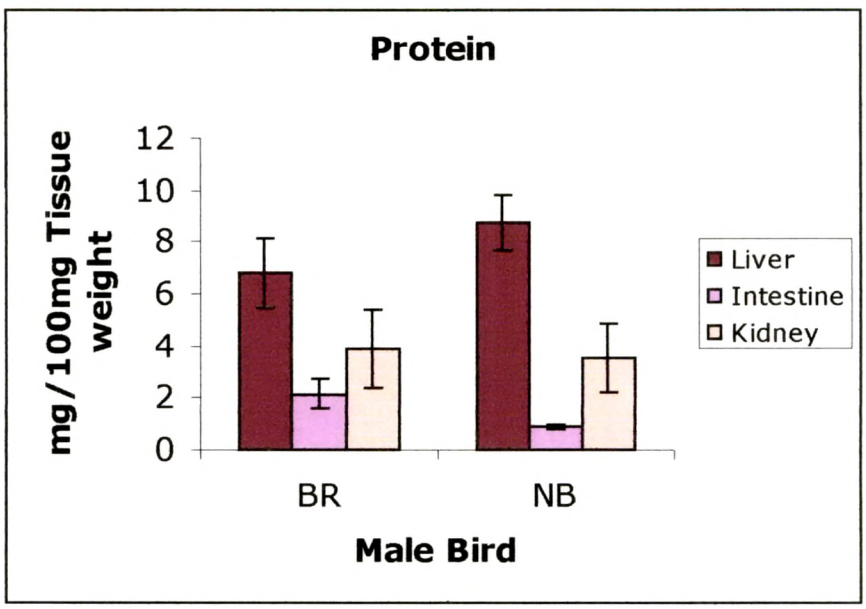
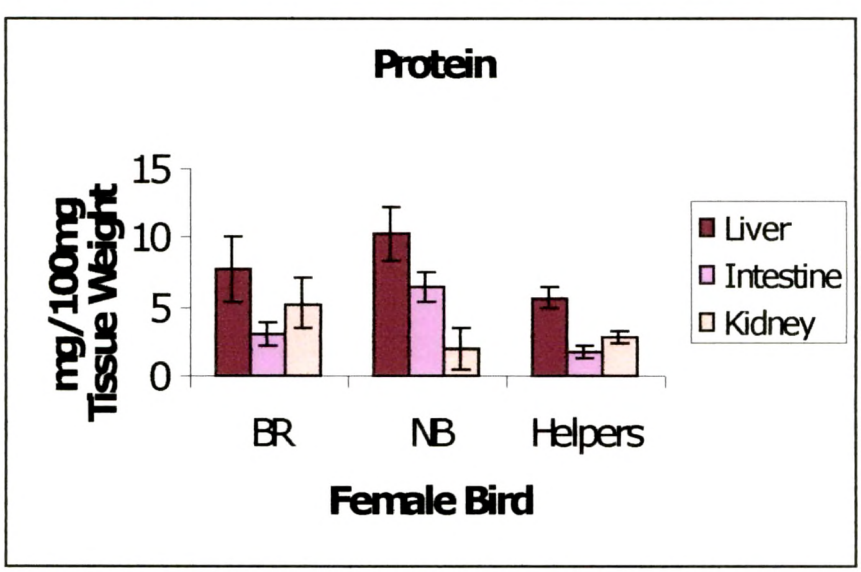


Figure 3: Protein content of extra-gonadal tissues of breeding and non-breeding male and female Jungle Babblers along with helper females.





RESULTS ~

The comparative metabolic status of different tissues studied for glycogen are presented in Table 1, Fig. 1, for total lipids in Table 2, Fig 2 and for proteins in Table 3, Fig 3.

Glycogen (Table 1 and Fig. 1)

From Table 1 & Fig. 1, it can be seen that the content of glycogen present in liver of non-breeding male Jungle Babblers is low at 0.088 $\pm$ 0.013 mg glycogen/100 mg tissue wt which increased significantly in the breeding males to 0.122 $\pm$ 0.012 mg. In breeding females the hepatic glycogen content was 0.12 $\pm$ 0.018 mg which decreased significantly in the non-breeding females to 0.028 $\pm$ 0.008 mg and in case of helper females it was non-significantly higher compared to the breeding females at 0.15 $\pm$ 0.017 mg glycogen/100 mg tissue weight.

The renal glycogen content was low in the non-breeding male at 0.051 $\pm$ 0.007 mg glycogen/100 mg tissue wt which in the breeding males increased non-significantly to 0.062 $\pm$ 0.007 mg. In breeding females the renal glycogen was low at 0.056 $\pm$ 0.017 mg which increased non-significantly in the non-breeding females to 0.057 $\pm$ 0.007 mg. In helper females the renal glycogen content was non-significantly low at 0.047 $\pm$ 0.005 mg glycogen/100 mg tissue weight.

Intestine showed the similar pattern of glycogen content to that of liver in case of males which was low in the non-breeding males at 0.041 $\pm$ 0.007 mg glycogen/100 mg tissue wt and significantly high in

the breeding males at 0.067 ± 0.008 mg. In females also the similar trend is observed in intestine which was significantly high in the breeding females at 0.076 ± 0.012 mg compared to the non-breeding females at 0.041 ± 0.005 mg, while in helper females the intestinal glycogen content was non-significantly high in the non-breeding females at 0.056 ± 0.011 mg glycogen/100 mg tissue wt.

Testis showed higher glycogen content in the breeding males at 0.047 ± 0.009 (mg glycogen/100 mg tissue wt) which decreased in the non – breeding males to 0.028 ± 0.006 mg. Ovaries of the breeding females had 0.06 ± 0.010 mg glycogen while that in the helper females was non – significantly low at 0.056 ± 0.004 mg. In the non –breeding females the glycogen levels were at 0.027 ± 0.008 mg glycogen/100 mg tissue wt.

Total Lipids (Table 2 and Fig 2)

As seen in Table: 2 & Fig. 2, no difference is noted in the total lipids contents of the liver of the breeding and non-breeding male Jungle Babblers which had 5.66 ± 0.63 gm and 5.44 ± 0.58 gm total lipid/100gm tissue wt respectively. Same was the case observed for females wherein hepatic total lipids were maintained in breeding and the non – breeding females at 5.03 ± 0.30 gm and 5.03 ± 0.64 gm respectively. In helper females the total lipids were insignificantly higher at 5.64 ± 0.70 gm. The intestinal lipids in breeding males were higher at 5.22 ± 0.68 gm which decreases non-significantly in the non

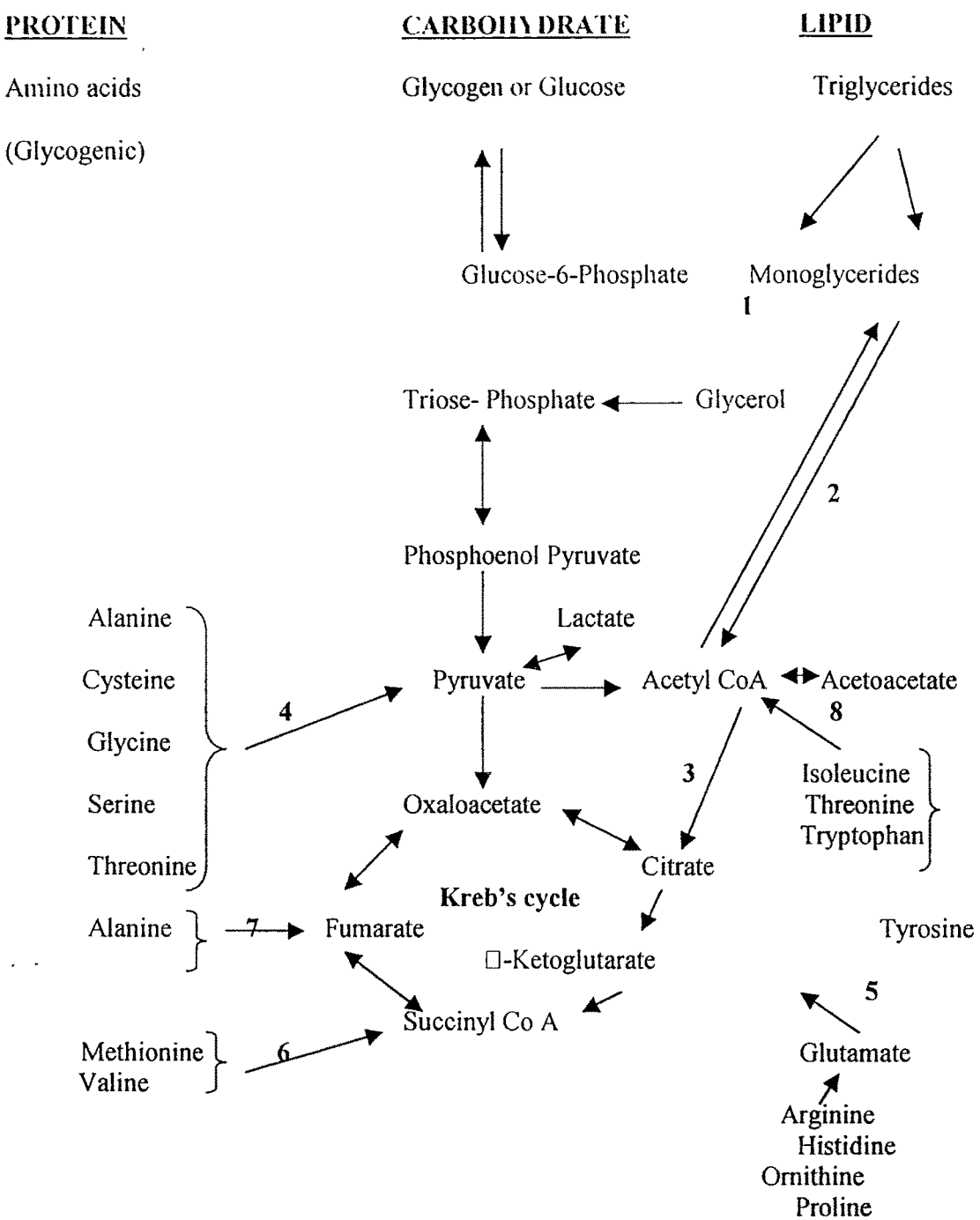
- breeding males to 4.98 ± 0.85 gm. In case of breeding females intestinal total lipid content was 5.23 ± 0.38 gm which increases in the non-breeding as well as in the helper females to 5.96 ± 1.21 gm and 6.25 ± 0.78 gm /100gm tissue wt respectively.

The breeding male kidney had higher total lipid at 6.37 ± 0.93 (gm total lipid/100gm tissue wt) when compared to the non - breeding males at 5.61 ± 0.83 gm. While in the females, the renal total lipid content was insignificantly high in the breeding female at 4.75 ± 0.69 gm compared to the non - breeding females at 4.01 ± 0.12 gm and was further low at 3.37 ± 0.47 gm in the helper females. Total lipid present in testes was significantly higher in the non - breeding male at 11.6 ± 1.05 gm which decreased significantly in the breeding males to 4.76 ± 0.29 gm. The ovarian total lipids present in the breeding females were non - significantly lower at 4.9 ± 0.27 gm while in the helper females it was non-significantly higher at 5.21 ± 0.20 gm. In the non - breeding females ovaries had significantly higher lipid accumulation at 11.33 ± 1.02 gm total lipid/100gm tissue wt.

Protein (Table 3 and Fig 3)

As seen in Table 3 and Fig 3, the protein content in the liver of the non-breeding males was non-significantly higher than the breeding males at 18.72 ± 1.08 mg and 16.82 ± 1.33 mg protein/ 100 mg of tissue weight respectively, while that in the female non-breeders was significantly low compared to breeding females. Maximum hepatic

contents were noted in the breeding females at 17.72 ± 2.35 mg followed by the helper females at 15.65 ± 0.74 mg and in non-breeding females at 10.31 ± 1.88 mg. The intestinal proteins in the non-breeding males were significantly higher at 16.85 ± 0.88 mg compared to the breeding males at 12.14 ± 0.56 mg. Among the females, the non-breeding females had highest intestinal levels at 16.46 ± 1.01 mg followed by the breeding females at 13.04 ± 0.82 mg and helper females having 11.78 ± 0.43 mg. Kidney of breeding and the non-breeding males showed nearly equal levels at 13.89 ± 1.50 mg and 13.54 ± 1.30 mg protein respectively. High levels of proteins were noted in the kidney of breeding females followed by helper females and with a non-significant decrease in the non-breeding females. The values being 15.22 ± 1.78 mg, 12.77 ± 0.40 mg and 11.93 ± 1.50 mg / 100 mg of tissue weight respectively.



Steps **1, 2** and **3**: Principle Gluconeogenic pathways for Fat as substrate
Steps **4** and **5**: Principle routes of entry of amino acids for Gluconeogenesis
Steps **4, 5, 6** and **7**: Also indicate entry of individual "Glycogenic amino acids"
Step **8**: Indicates entry of "Ketogenic amino acids"

DISCUSSION ~

As the reproductive activities are crowded in a short favorable period of the year (Lofts and Murton, 1973; Perrins and Birkhead, 1983), the energy required by different tissues in breeding birds would vary according to the status of their reproductive activities. Endocrine factors influencing reproduction usually bring about altered metabolic and physiological effects which are of enormous significance to birds especially before the onset of breeding activities (Nalbandov, 1970). These should result into quantitative fluctuations in the levels of metabolites and their related enzymes. With reference to this it was thought worthwhile to study the relation of breeding status to that of quantitative differences in the glycogen, total lipid and protein levels in different tissues *viz.* Liver, Intestine, Kidney and, testis and ovaries of breeding and non-breeding males and females along with the helper females of the Jungle Babbler. The liver plays a central role in energy metabolism via glycogenesis, glycogenolysis and gluconeogenesis; the intestine is the route of the dietary sources of energy whereas kidney though an excretory organ influences carbohydrate metabolism via gluconeogenesis especially in birds.

The significantly high ($P<0.01$) hepatic and intestinal glycogen content in breeding Jungle Babblers of both the sexes suggest higher uptake of carbohydrates in the diet leading to its storage in liver for instant energy needs. In the non-breeding birds where demand for the energy is low, both liver and intestine show lower glycogen levels. In

case of helper females, which share some of the breeding activities, except egg laying and courtship, intestinal glycogen level is intermediate whereas hepatic glycogen content is highest indicating comparatively low utilization of carbohydrate for energy purpose compared to breeding birds and that the carbohydrates consumed by these birds are extensively stored in the liver. The glycogen deposition is highest in the liver of grain eaters (Pilo *et al.,* 1975). The diet of graminivore birds mostly contains carbohydrate and negligible amounts of lipids. Jungle Babbler is having a long breeding season, where at least some pairs show breeding activities, from April to November, wherein many cereal crops are grown. Jungle Babblers are known to feed on sorghum, pearl millet and Bajra (Parasharya, 1988; Rana, 1972) and during summer about 60- 70 % of its diet consists of food grains (Gaston, 1978; Dhindsa *et al.*, 1994) in North India. Jungle Babblers do not show sexual dimorphism and are known to remain in a flock of 7-8 birds. Here all the members do not feed at the same time (Chapter 1) and thus probably the difference in the food consumption in sexes in relation to difference in the energy demands according to the breeding status. This difference needs to be investigated separately.

The massive build up of fat prior to breeding which involves many activities like courtship display, nest building, mating incubation and feeding the brood which require a large amount of energy supplied through the consumption of carbohydrate as well as lipid and to a

lesser extent proteins serve as a source material for lipogenesis. Earlier reports (Padate, 1990) from our laboratory showed that the male and female Brahminy myna show high levels of hepatic glycogen during the non-breeding phase, suggesting the possible accumulation of glycogen which is also supported by the levels observed in the intestine leading to maximum absorption of carbohydrates coming through the diet, which could be used later during the breeding phase. Brahminy myna is an individual hole nester, in which all the breeding activities are performed by the breeding pair which is cost effective, therefore the accumulation of glycogen whereas in Bank myna, a colonial hole nester, males and females show high hepatic glycogen during the breeding phase suggesting simultaneous accumulation and utilization of glycogen. Least hepatic glycogen levels seen in Jungle Babblers can be due to sharing of all the breeding activities by all the members of the flock. Hence, no predeposition of glycogen required, while intestinal levels are highest suggesting maximum absorption of available carbohydrates from the diet.

Renal glycogen content was non-significantly high in Jungle Babblers, suggesting possible involvement of kidney during breeding to suffice the energy requirement in the breeding birds. The avian kidney, in addition to its excretory functions, shares with the liver the major gluconeogenic role in the body (Krebs and Yoshida, 1963). The non-significantly higher glycogen content of kidney of both the sexes in the non – breeding birds compared to the breeding birds and the

helper females indicate the possible involvement of gluconeogenic or lipogenic pathways. The total renal lipids were significantly higher ($P < 0.01$) in breeding males whereas total renal protein contents were significantly higher in the non-breeding females. Here sex specific differences seem to be operating in accordance to breeding activities. The total lipid content present in the kidney is significantly higher in the breeding birds than in the non – breeding birds of both the sexes. Neill and Bannister (1986), reported in domestic fowl, the incorporation of lactate or glucose into triglycerides (lipogenesis) is relatively low as no fatty acid synthase (FAS) activity is detected. Pilo *et al.*, (1975), reported that the increased influx of carbohydrate necessitates the inhibition of gluconeogenesis and activation of lipogenic pathways.

Pilo & Mehta (1985), suggested that kidney of omnivore birds do not have a high rate of lipid metabolic activity *i.e.* lipid synthesis or lipid mobilization. The kidney of Jungle Babbler which is largely graminivore during summer did not show significant difference in the lipid metabolic activities as their diet invariably brings in adequate amount of carbohydrate. The constant level of glycogen content of kidney of male and female Jungle Babblers along with helper females may indicate that the tissue makes no apparent attempt to store carbohydrate. Pilo and Mehta, (1985) suggested that the diet forces a tissue to adapt / orient its metabolism. However no difference is found in the hepatic lipid contents of male and female breeding and non-

breeding as well as helper females. No fluctuation occurs in the body weight of the Jungle Babblers (Chapter 2). Hence Jungle Babbler, a social bird with a very long favorable breeding season, shows typical avian adaptation of no accumulation of fat, to decrease the body weight. Jungle Babbler is not a strong flier, takes short flights and generally climbs at elevated level with short hopping flights and takes a long gliding flight, hence probably does not require energy stores. The energy required for breeding activities in case of Jungle Babbler mainly comes from the carbohydrates and proteins consumed as evinced by the increased intestinal glycogen (carbohydrate) content resulting into increased hepatic glycogen in the breeding and the helper females compared to non-breeding birds. Being a social bird the energy demand is less and the energy expenditure is shared.

The maximum number of birds found in non-breeding state was between November- February coinciding with the cultivation period of kharif crops like Pigeon pea and Chick pea grown in winter and known to be heavily infested with *Helicoverpa armigera* larvae. Jungle Babblers have been reported to feed on these larvae by Gokhale, (1992); Parasharya, (1988) and by the personal observation (Chapter 1). This is reflected by the highly significant increase in the intestinal proteins in the non-breeding birds. The high protein demand by the breeding females for egg production is reflected by increased protein levels in liver as well as kidney on one hand, and decreased proteins in intestinal tissue indicating a faster uptake from the same. The helper

female which do not lay eggs show lower intake of proteins compared to breeding and non-breeding females reflected in lower hepatic and renal protein levels too. Kidney does not seem to get influenced in both breeding and non-breeding males however in breeding females' protein levels in liver and kidney suggest probable accumulation of proteins.

Gonads of wild birds undergo cyclic physiological changes through the breeding and the non-breeding states of their reproductive cycle (Nalbandov, 1970) which mainly includes fluctuations in the levels of storage of lipids and glycogen (carbohydrates). Accumulation of lipids in different testicular and ovarian components during the non-breeding state has been reported by Lofts and Murton (1973), in pigeon (*Columba livia)* Ambadkar and Kotak (1976), Prasad and Guraya (1982), Patel and Ramachandran (1987), in rat, Sangha and Guraya (1989), in Bank Myna, *Acridotheres ginginianus* and Brahminy Myna, *Sturnus pagodarum,* Padate (1990). Almost all the seasonally breeding vertebrates depict a seasonal lipid decrease during active spermatogenesis and steroidogenesis *i.e.* during the breeding state and its increase in the inactive or the non-breeding state which has also been shown by all the above workers.

Testicular and ovarian lipids reflect accumulation in the non – breeding male and female Jungle Babblers too. This suggests that there appears a change in the metabolic pattern of testis and ovaries indicating non – utilization of lipids and its subsequent accumulation distinctly during its

non breeding state. The depletion of lipids which is seen during the breeding activity is indicative of an increased utilization of lipids as a precursor for steroidogenesis and for the process of spermatogenesis which requires tremendous energy as well as structural lipids for the development of sperms. Such accumulation of lipids is noted in the non – breeding Jungle Babblers.

In female birds lipids are synthesized in the liver and then transported into ovarian follicles in the form of yolk granules, in Japanese quail (Furuse *et al.,* 1991), in rat ovary by Sangha and Guraya (1989) and in house crow, *Corvus splendens*, common myna, *Acridotheres tristis*, and in house sparrow, *Passer domesticus* by Prasad and Guraya (1982) depending on sexual maturity. Furuse *et al.,* (1991), observed that labeled fatty acids in the follicle increased linearly as the birds become sexually mature. Formation of egg and its laying requires large quantities of lipid, so possibly lipid via the blood circulation is destined towards the reproductive structures *viz.* ovaries.

Ovarian lipids show significant decrease in the breeding Jungle Babblers which could be attributed to their utilization for the synthesis of estrogens and progesterone as well as for oogenesis. The accumulation of lipids in the non – breeding Jungle Babblers indicating low biogenesis of female sex hormones. The helper females showed lipid accumulation in ovarian as well as extra-ovarian tissues equal to that of the breeding females suggesting equal participation of helper females in the breeding activities except for egg laying.

The non-significant difference in the total lipid content of liver, intestine and kidney in the breeding as well as non-breeding birds along with the helper females same which accounts for the flocking nature of the Jungle Babblers where along with the breeding pair, helpers are also involved in care taking of eggs as well as the youngones and that the burden of parenting is shared equally by both the sexes.

The presence of glycogen in testes and ovaries has long been demonstrated in pigeon, *Columba livia* by Patel and Ramachandran (1987), Indian Robin, *Saxicoloides fulicata* by Rajvanshi *et al.,* (1985), in Bank Myna, *Acridotheres ginginianus* and Brahminy Myna, *Sturnus pagodarum* by Padate (1990). The glycogen content in testis as well as ovaries is significantly higher, $p<0.01$ in the breeding Jungle Babbler males and $p<0.001$ in breeding Jungle Babbler females than in the non – breeding birds. In Indian Robin males, the glycogen stores increased with the progression of spermatogenesis (Rajvanshi *et al.,* 1985). Glycogen is the source of energy for total sperm output and for expenditure during biosynthesis of steroids (Rajvanshi *et al.,* 1985). Ovaries also show high concentration of glycogen during breeding which is utilized as energy for various cost effective activities.

From the glycogen and total lipid contents of the extra-gonadal tissues of the breeding and the non-breeding male and female Jungle Babblers along with the helper females it could be said that these birds don't store glycogen and total lipids in the form of reserve energy

which is also reflected in their body weights where no significant difference among the breeding and the non-breeding birds is observed and that they rely on their daily food supply which could be seen in their foraging behavior wherein they spend their maximum time in search of food.

CONCLUSION ~

In summary it can be said that the liver of the omnivore bird, the Jungle Babbler is probably having more flexible metabolic adaptations. The liver of these birds show adaptations of both insectivores and graminivores depending on the type of the diet. The main function of the kidney is excretion but by and large, the organ is also capable of performing metabolic activities. It is a prominent tissue but kidneys of omnivorous birds *viz.* Jungle Babblers show less gluconeogenic or lipid metabolic activities.

Being a social bird, the energy expenditure is shared by all the individuals of the group and hence the fluctuations in the metabolites in various tissues of breeding and non-breeding and helper females are minimum.