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MYOGLOBIN LEVELS IN THE MYOCARDIA OF SOME REPRESENTATIVE VERTEBRATES

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ABSTRACT

Studies on the myocardial myoglobin levels of some representative vertebrates were carried out. The lowest myoglobin level has been observed in the myocardia of *Rana*. The ventricular myocardia of *Cybium*, *Calotes* and *Geomyda* exhibit higher myoglobin levels than their respective atria. The myocardia of flying forms *Columba* and *Pteropus* have higher levels than the less active forms. *Pteropus* myocardia show a uniquely high myoglobin level. The active flying forms exhibited a preponderance of myoglobin in the right ventricle than the left.

INTRODUCTION

MYOGLOBIN is concerned with the storage and transport of oxygen at the cellular level in the muscular tissue. Functionally it is an oxygen carrier facilitating oxygen diffusion into the cell[1]. Myoglobin plays an important role in the adaptation of animals to diverse physiological conditions. Grote[2] suggested that in tissues with critical oxygen supply, there is the possibility of an increased myoglobin concentration. The role of myoglobin in adaptation to high altitude had been reported by various investigators[3,4]. Similarly, programmed treadmill running was also found to induce a higher concentration of myoglobin in skeletal muscles of rats[5]. According to Catlett *et al.*[6] there exists a higher myocardial myoglobin level in the flying forms of *Columba* than the non-flying forms. Differential distribution pattern of myoglobin in the various myocardial chambers of some vertebrates has also been reported[7,8]. However information regarding the distribution pattern of myoglobin in the various chambers of vertebrates belonging to diverse habitats and activity levels is lacking. The present study has therefore been undertaken to elaborate the distribution pattern of myoglobin and its possible significance in the myocardia of some representative vertebrates belonging to diverse habitats and activity levels.

Abreviations: RA—Right atrium; LA—Left atrium; RHV—Right half of ventricle; LHV—Left half of ventricle; RV—Right ventricle; LV—Left ventricle.

MATERIALS AND METHODS

The list of nine vertebrates investigated and their respective habitats are given in table 1. The myocardial tissue from different chambers were carefully excised and the myoglobin content was estimated employing the method of Tappan and Reynafarjee[3].

RESULTS

Myoglobin levels in the various chambers of the myocardia of the vertebrates investigated are given in table 2. The data are represented as histograms (figure 1), showing the distribution pattern of myoglobin among the various animals and in the different chambers.

TABLE 1

Table showing the list of animals and their habitats

Class	Animals	Full name	Habitat
Pisces	Seer fish	*Cybium guttatum*	Marine (actively swimming)
Amphibia	Frog	*Rana tigrina*	Amphibious
Reptilia	Turtle	*Lissemys punctata*	Fresh water (diving)
	Tortoise	*Geomyda trijuga*	Terrestrial, moist surroundings
	Garden lizard	*Calotes versicolor*	Terrestrial
Aves	Pigeon	*Columba livia*	Terrestrial (actively flying)
	Fowl	*Gallus domesticus*	Terrestrial (very poor flier)
Mammalia	Goat	*Capra* sp.	Terrestrial
	Bat	*Pteropus giganteus*	Terrestrial (flying)

A significantly higher myoglobin content has been observed in the ventricle of *Cybium* as compared to that of atrium (atrium—3.93, ventricle—6.47). *Rana* has a comparatively lower myoglobin level (RA—1.05, LA—0.78, RHV—3.17, LHV—1.72).

Myoglobin levels of reptilian forms investigated show a definite increase over those of other lower vertebrates. In *Calotes* myocardial myoglobin levels are RA—4.17, LA—5.01, RHV—7.67 and LHV—6.51; those of *Geomyda* myocardia are RA—3.43, LA—5.24, RHV—7.27 and LHV—9.47 and the values for *Lissemys* are RA—6.56, LA—5.19, RHV—8.33 and LHV—6.94.

Among the birds, the *Columba* myocardia has a higher myoglobin content than that of *Gallus*. The values for *Gallus* myocardia are RA—3.58, LA—4.33, RV—5.28 and LV—3.54 whereas those of *Columba* myocardia are RA—11.09, LA—8.17, RV—8.83 and LV—7.07.

The highest myoglobin level in the present series has been obtained for the myocardia of *Pteropus*, with values RA—22.98, LA—47.32, RV—31.52 and LV—18.41. Comparatively much lower values are obtained for the myocardia of *Capra* (RA—3.72, LA—2.14, RV—4.62 and LV—5.29).

TABLE 2

*Table showing the distribution pattern of myoglobin in the various chambers of the vertebrate myocardia investigated (expressed as mg/g of wet tissue)**

Full name	Atrium		Ventricle	
	Right	Left	Right (RHV)	Left (LHV)
Cybium guttatum	3.93 (0.14)		6.47 (0.31)	
Rana tigrina	1.05 (0.04)	0.78 (0.03)	3.17 (0.05)	1.72 (0.02)
Lissemys punctata	6.56 (0.21)	5.19 (0.17)	8.33 (0.18)	6.94 (0.28)
Geomyda trijuga	3.43 (0.21)	5.24 (0.18)	7.27 (0.15)	9.47 (0.21)
Calotes versicolor	4.17 (0.16)	5.01 (0.15)	7.67 (0.13)	6.51 (0.20)
Gallus domesticus	3.58 (0.14)	4.33 (0.23)	5.28 (0.23)	3.54 (0.21)
Columba livia	11.09	8.17	8.83	7.07
Capra sp.	3.72 (0.20)	2.14 (0.14)	4.62 (0.15)	5.29 (0.10)
Pteropus giganteus	22.98 (0.97)	47.32 (1.35)	31.52 (1.13)	18.41 (0.91)

*(Values are the mean of assays conducted on ten animals each, with standard error in brackets).

Analysis of variance was carried out and the F ratio was calculated to test the significance of variations. Significant variations were observed between animals ($p < 0.01$) and between the chambers ($p < 0.01$).

DISCUSSION

Myoglobin is functionally similar to haemoglobin and plays a salient role in facilitating the supply of oxygen at the molecular level in the muscle. It has a relatively higher oxygen affinity than haemoglobin and hence can combine with, and dissociate from oxygen with great rapidity.

The ventricle of *Cybium* has a higher myoglobin content than the atrium. This may probably facilitate a relatively greater diffusion of oxygen into the ventricular myocardium and augment the pumping efforts which distribute blood to the various regions of

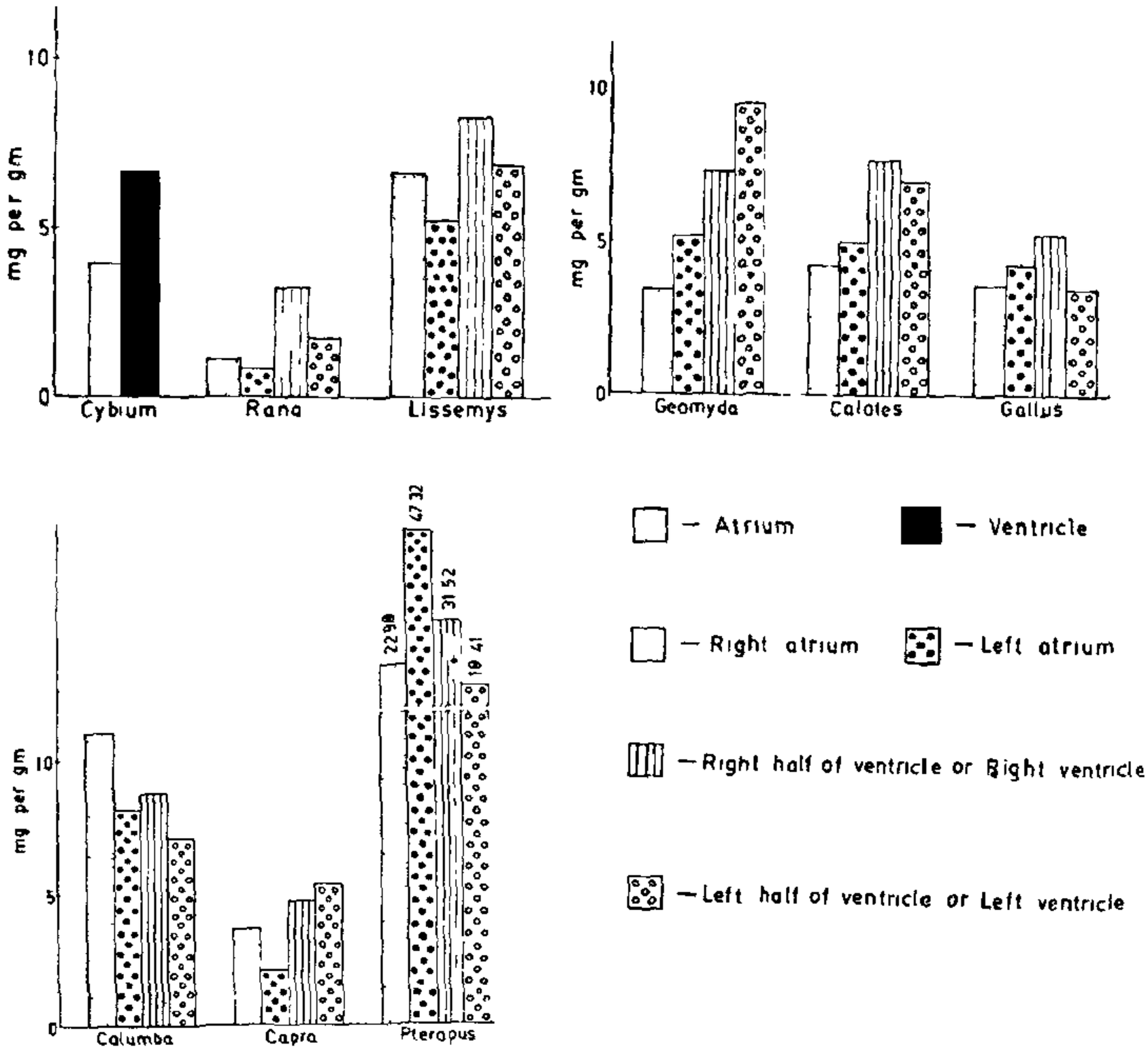

Figure 1. Showing the distribution pattern of myoglobin among the various animals and in the different myocardial chambers.

the body. As compared to the myocardia of *Cybium*, the *Rana* myocardium has only relatively lower myoglobin level which may possibly be due to the sluggish habits of *Rana*. However a relatively higher level of myoglobin is observed in the ventricle of *Rana*, than in the atria. Moreover the ventricles of *Rana* do not reveal any significant variation in their myoglobin levels.

Among the reptiles investigated, significant variations have not been observed in the myoglobin levels between animals. Besides, variations exist in the different chambers of the animals concerned. In *Calotes*, although marked differences are not discernible between the two atria, and between the two ventricular halves, the ventricles showed a significantly higher myoglobin content than the atria. *Geomyda* exhibits significant variations between the myocardial chambers, with greater myoglobin concentrations being observed in the ventricles. The left half of the ventricle of *Geomyda* has a higher myoglobin content than the right half. Although *Lissemys* is a diving form, its myocardial myoglobin level did not vary much from those of *Calotes* and *Geomyda*. However variations are observed between the two atria and between the two ventricles. Further, the ventricular myocardial myoglobin level of *Lissemys* is greater than its atrial myoglobin level.

Although the reptilian heart has only a single ventricular chamber, specific variations in myoglobin levels are discernible between the right and left halves, probably indicative of a functional separation. Interestingly enough, White[9] has suggested a functional specialisation of the ventricle of the reptilian heart, whereby the mixing of the arterial and venous blood is avoided in the ventricle.

Among birds, the myoglobin content of the *Columba* heart has been found to be significantly higher than that of *Gallus*. This can be correlated to the fact that *Columba* is an active flier whereas *Gallus* is a very poor flier. A comparative study has been made by Catlett *et al.*[6] on the flying and non-flying forms of *Columba*. The flying forms had 4.34 mg/g and non-flying forms had 3.13 mg/g of myoglobin in their myocardia. These values are lower than the values obtained during the present study. However Deshpanade[10] has reported greater level of myocardial myo-

globin in the domestic duck *Anas platyrhynchos* (RV—14.76 and LV—20.45), Coot,*Fulica atra* (RV—16.84 and LV—25.74), and dabchick *Podiceps ruficolis* (RV—19.25 and LV—31.38).

In both the birds investigated, myocardial myoglobin levels of the right ventricle are greater than those of the left ventricle, which indicates a greater oxygen demand in the myocardial metabolism of the right ventricle. Probably, this may help in accentuating the respiratory shunt to cope up with the higher oxygen demands of the body as a whole. However data by Deshpande[10] show a contrasting situation wherein the left ventricular myoglobin level is higher than that of the right ventricle of *Anas platyrhynchos*, *Fulica atra* and *Podiceps ruficollis*.

The myoglobin levels of the left atrium of *Columba* was lower than that of the right atrium. A similar pattern of reduced left atrial myoglobin content was reported in few mammals by Alexander[8]. This has been attributed to the probable diffusion of oxygen into the atrial walls from oxygenated blood which gets collected in the left atrium. Quite probably a similar phenomenon may also exist in the left atrium of *Columba*. However significant variations have not been observed between the two atria of *Gallus*.

Interestingly enough, the bat *Pteropus* exhibits a remarkably high level of myoglobin in all its myocardial chambers and to the best of our knowledge these values are one of the highest ever obtained for the cardiac muscles of vertebrates. In an earlier study, it has been reported that some of the hibernating mammals of North America had a higher level of myoglobin in their cardiac muscles, with 13—lined ground squirrel, *Citellus tridecimlineatus* having 14.14 mg/g and woodchuck, *Marmota monax* having 11.15 mg/g[11]. Further, Alexander[8] reported higher values for *Homo sapiens* (RA—6.59, LA—4.64, RV—9.24 and LV—11.43). Wachtlova *et al.*[12] had reported that 24% of the capillaries of the bat heart were either inactive or occluded and that the density of the myofibrils per unit area was also higher. This suggests that there is a reduction in the availability of oxygen through capillary circulation. In fact quite probably the uniquely high myoglobin content met within the myocardia of the bat studied (*Pteropus giganteus*) might possibly facilitate the tiding over the resulting oxygen debt during flight. Further, this will augment the oxygen storing capacity and enhance the oxygen diffusion to the myofibrils. An interesting correlation has been observed in the myocardial myoglobin distribution of *Pteropus* and *Columba*. Similar to *Columba* myocardia, a higher myoglobin has been observed in the right ventricle than the left, of *Pteropus*. The myocardial myoglobin level of *Capra* is relatively low, which might probably be due to its lower activity level. Moreover, in contrast to *Pteropus* ventricles, the left ventricle of *Capra* had slightly higher level than the right.

The distribution pattern of myocardial myoglobin in vertebrates varies with the activity levels of the animals and their specific functional demands. No marked variation along the phylogenetic levels of the animals concerned has been observed. However, interesting chamberwise variations could be discerned.

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