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Distribution pattern of succinic dehydrogenase in the myocardia of some vertebrates

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Abstract. A comparative study on the myocardial SDH levels in certain representative vertebrates revealed interesting variations. The *Cybium* myocardium exhibited relatively lesser SDH levels, whereas *Rana*, despite its diving habits, had a higher level with significant variations between the two ventricular halves. *Calotes*, an active terrestrial form, showed the highest enzyme level among the reptiles. The SDH activity of the avian myocardia are quite high, with *Columba* having a greater level than *Gallus*. The myocardia of the actively flying forms (*Columba* and *Pteropus*) exhibited higher enzyme levels in the right ventricle than the left ventricle.

Keywords. Succinic dehydrogenase; vertebrate myocardia; myocardial metabolism; oxygen requirements; chamberwise variations; activity levels; flying habit; diurnal dormancy.

1. Introduction

The vertebrate heart is a multi-chambered organ, exhibiting specific regional variations in its contractile performance facilitated by various factors (Rubel 1968). The morphology of the heart of several vertebrate groups has been observed to be correlated to the specific functional adaptation of each animal (Johansen and Hansen 1968; Randall 1968; White 1968, 1976). Considerable attention has been focussed on the biochemical basis of cardiac function in mammals (Balasubramanian *et al* 1973; Dhalla *et al* 1972, 1974; Tomlinson and Dhalla 1973). However, relatively little information is available on the biochemical adaptation of the vertebrate myocardia to diverse physiological conditions. Specific chamberwise variations with regard to mitochondrial activity and other parameters in the myocardia of several mammals have been reported (Laguens 1971; Alexander 1975; Sordahl 1976). The present study is an attempt to elaborate some aspects of the enzymic variations in the different chambers of the myocardia of some representative vertebrates having varied ecological conditions and activity levels, with special reference to one of the key enzymes of cardiac metabolism, namely succinic dehydrogenase.

2. Material and methods

The myocardia of nine vertebrates belonging to various classes and activity levels have been chosen for the present study. A list of animals with their habitat is given in table 1. Healthy adult animals were collected from their natural habitats and myocardial samples of the various chambers of these vertebrates were carefully excised. A tissue homogenate was prepared in double distilled water at 4°C. SDH activity was estimated by the colorimetric method of Kun and Abood (1949). The reaction was carried out in phosphate buffer at pH 7.4 using 0.4 M sodium succinate as substrate and 0.1% solution of triphenyl tetrazolium chloride as the electron acceptor.

3. Results

The data obtained for the SDH activity of the various chambers of the myocardia of the vertebrates investigated are given in table 2.

Relatively a lower level of the SDH activity is discernible in the myocardia of *Cybium* than that of *Rana*, but it is greater than that of the myocardia of the chelonians. The SDH activity of the left atrium and left ventricle of *Rana* is significantly higher than that of the right atrium and right side of the ventricle respectively. Among the reptiles, higher enzyme level is observed in the myocardia of *Calotes* with preponderance of the SDH activity in the right ventricle than the left ventricle. The difference in the enzyme activity of the two ventricular halves of *Lissemys* is negligible. The avian myocardia also exhibit higher SDH activity, and among the two birds investigated, a higher enzyme level was observed in the myocardia of the actively flying form *Columba*. With regard to mammals, the atria of *Pteropus* possess a relatively higher SDH activity than that of *Capra*. The right half of the myocardia of *Columba* and *Pteropus* show a greater SDH activity than the left.

4. Discussion

Succinic dehydrogenase being an oxidative enzyme has considerable relavance in the energy metabolism of the cardiac muscle. Irrespective of the source of the fuel, oxidative metabolism takes place in the mitochondrion through the citric acid cycle. In fact data on SDH would facilitate a better insight into the metabolism of the cardiac muscle of the various animals investigated.

Table 1. Animals used and their habitats

Class	Animal	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)
	Domestic fowl	*Gallus domesticus*	Terrestrial (very poor flier)
Mammalia	Goat	*Capra* sp.	Terrestrial
	Bat	*Pteropus giganteus*	Terrestrial (flying)

The SDH activity of the myocardium of *Cybium* is lower than that of some of the warm blooded vertebrates. The oxygen requirements for the fish is generally a fraction of those for higher vertebrates (Nicol 1960). The lower SDH activity of the myocardium of *Cybium* may possibly be indicative of this. Between the two myocardial chambers of *Cybium*, the atrium has a higher activity than the ventricle. Randall (1968) has attributed a more significant role to the atria, based on the similarity of the atrial and ventricular volume of fish, in the ventricular filling and the higher SDH level of *Cybium* may be attributed to the specific haemodynamic demands of the chamber.

Interestingly enough the heart of *Rana* has a relatively higher SDH activity. In frogs, the skin, in addition to the lungs, serve as a respiratory surface. The total gaseous uptake through the lungs and skin might provide an ample supply of oxygen to the myocardial tissue. This oxygen uptake may be sufficient for the higher oxidative metabolism of the cardiac muscles of *Rana*, as indicated by the SDH activity. Significant variations have been observed between the two atria and between the two halves of the ventricle. Such a specific variation, though the ventricle of *Rana* is single chambered, is interesting. Johansen and Hansen (1968) have reported a trabecular network in the ventricle of amphibians, which runs in an

Table 2. Distribution pattern of SDH in the myocardia of various vertebrates (μ gm of formazan/min/gm of wet tissue)

	Atrium		Ventricle	
	Right	Left	Right	Left
Cybium guttatum	28.36 (0.89)		16.79 (0.66)	
Rana tigrina	32.99 (1.81)	49.74 (3.05)	40.67 (3.23)	56.05 (3.94)
Lissemys punctata	10.51 (0.56)	12.36 (0.21)	16.18 (0.86)	17.27 (0.79)
Geomyda trijuga	18.81 (0.95)	13.12 (0.94)	11.27 (0.64)	15.86 (1.04)
Calotes versicolor	60.28 (2.03)	67.23 (2.23)	97.23 (2.09)	89.11 (4.08)
Columba livia	78.27 (2.22)	65.88 (5.63)	109.18 (8.61)	90.79 (7.85)
Gallus domesticus	40.27 (2.75)	49.64 (4.43)	59.46 (4.33)	66.87 (5.25)
Capra sp.	15.78 (1.25)	20.91 (0.69)	27.28 (2.57)	36.04 (3.28)
*Pteropus giganteus**	59.16 (3.48)	46.55 (2.57)	27.98 (1.61)	17.29 (0.89)

(Values are the mean of ten assays, 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 chambers ($p < 0.01$)

* samples were taken during day time only due to practical difficulties.

antero-posterior direction, maintaining a right and left compartmentalisation. The variation in the SDH activity in the two halves of the ventricle may possibly be due to this phenomenon.

Among the reptiles investigated, *Calotes* myocardia exhibit relatively higher levels of the SDH activity indicating a higher oxiditive metabolism than those of *Geomyda* and *Lissemys*. *Calotes* is a terrestrial reptile with access to plenty of atmospheric oxygen and has relatively more active habits, the higher energy demands can be efficiently met only by an increased level of oxidative metabolism. Significant chamberwise variations are also noticed. The left atrium has a higher enzyme level than the right, and the right half of the ventricle has a higher enzyme activity than the left half.

The myocardia of the two chelonians studied exhibited only relatively low SDH activity. *Geomyda* is an extremely sluggish form whereas *Lissemys* is a relatively active diving form. However, during submergence, *Lissemys* is exposed to limited supply of oxygen. Our studies on the fuel reserves (unpublished data) have shown a very high level of glycogen in the myocardia of *Lissemys*. Hence quite probably during diving, its myocardia may depend more on anaerobic glycolysis. In the case of *Geomyda*, on account of its extremely sluggish activity pattern, the total circulatory demand may be reduced. Presumably this might have induced a lower energy demand in the myocardia of *Geomyda* which is reflected by a lower level of SDH activity.

The birds by virtue of their higher metabolic rate have relatively higher SDH activity, with *Columba* myocardia having a greater level than that of *Gallus*. Talesera and Narang (1979) have also reported a higher SDH activity in the cardiac muscles of *Columba* (7.68) as compared to that of *Gallus* (5.08). However, these values are for the whole-heart, rather than for the different myocardial chambers. The present study reveals interesting chamberwise variations. The right atrium and right ventricle of *Columba* exhibit higher SDH levels than those of the left atrium and left ventricle, indicating a higher metabolic activity in the right half than the left. It may be noted here that the right half, *viz.*, the right atrium and the right ventricle, is concerned with the pulmonary circulation. The active flying habits of *Columba* necessitates a greater demand of oxygen which can be met to a certain extent by an increased blood supply to the lungs. Hence the higher metabolic activity of the right myocardial half may possibly be due to this specific vascular demand.

Among the mammals investigated, lower values have been obtained for the myocardia of *Capra*. Laguens (1971) reported a higher numerical and volumetric density of mitochondria in the left ventricle of the rat than the right ventricle. In the present study also, SDH, a key mitochondrial enzyme did reveal a significant variation between the two ventricles of *Capra* with left ventricle showing a higher value than the right.

A comparative study on the myocardial SDH levels of some birds and mammals have revealed a higher enzymic level in the heart of bat *Pipistrellus* sp. (11.60) as compared to that of pigeon, chicken and rat (Talesera and Narang 1979). However, in the present study the myocardia of *Pteropus* exhibited lower SDH level than *Columba*. According to Kulzer (1967) a reduction in heart rate occurs in the daily torpor of bats. *Pteropus* also exhibits diurnal dormacy and probably the lower SDH level may be reflection of the metabolic adaptation of its myocardia to diurnal dormancy. The chamberwise distribution pattern of SDH in the myocardia of

Pteropus shows a similarity to that of *Columba*. In both cases a greater level of SDH activity is observed in the right myocardial half than the left, which may be an adaptation in correlation to the greater cardiovascular demands due to their flying habit.

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