Seasonal variation of myoglobin in the northern red-backed vole

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MORRISON, PETER, MARIO ROSEN Mann, AND JOHN A. SEALANDER. Seasonal variation of myoglobin in the northern red-backed vole. Am. J. Physiol. 211(6): 1305-1308. 1966.—A marked increase in myoglobin concentration was observed in thigh muscle (1.3 ± 3.2 mg/g) and masseter (4.7 ± 10.1 mg/g) from northern red-backed voles (Clethrionomys rutilus dawsoni) during winter (Jan.-Feb.) as compared with the minimum summer values (July-Sept.). Heart-Mb showed a more modest change (4.3 ± 5.7 mg/g). Because the life span in this species is synchronized to the year, with growth ceasing in fall and resuming in spring, the concentration increase during the fall was by synthesis of Mb, but the decrease during the spring represented dilution of Mb by growth.

acclimatization; muscle; heart; masseter; Alaska; cold

MYOGLOBIN, the pigmentary constituent of muscle, varies in its distribution among mammals, both in different muscles and in different species. Environmental correlation in diving (2) and high-altitude forms (5) have been found, and recently a striking seasonal response has been observed in one species, the Alaskan snowshoe hare, which experiences severe fluctuations of light and temperature during the year (6). Whereas the snowshoe hare is exposed to the full impact of the climate with extremes from below −50 C to above 30 C, smaller subarctic mammals largely use subterranean or subsurface habitats with ranges of as little as 20 C (−10 to +10 C) instead of 80 C above ground (4). The present study examines seasonal changes in the level of myoglobin in one such small rodent, the northern red backed vole (Clethrionomys rutilus dawsoni). These observations may provide insight into a) the generality of the seasonal change in Mb; b) the influence of climatic extremes in mediating the Mb response; and c) the influence of body size (15 vs. 1,500 g) on the Mb level and response, a well-ordered sequence of many physiological activities and concentrations being observed as a function of body size. In the latter regard, the higher critical temperature between the zones of “physical” and of “chemical” thermoregulation could oppose the moderating influence of the microclimate on the small voles.

EXPERIMENTAL PROCEDURE

Clethrionomys rutilus is perhaps the most numerous and most widely distributed mammal in Alaska. The individuals used in this study were live trapped in the vicinity of College, Alaska (Aug. 1963-Aug. 1964) for use in a broad descriptive study of a seasonal change in number of morphological and some chemical factors being conducted by one of us (JAS). Details as to local habitat, capture, and handling are given elsewhere (8). An average of 15 individuals was measured each month with juveniles in immature pelage excluded (June-Sept.). Samples were taken from each individual immediately after sacrifice using: a) pooled thigh muscles; b) both masseter muscles; and c) the entire heart freed of blood. The weighed samples were immediately frozen and held at −90 C, and the Mb and Hb content subsequently determined from the absorption values at 5,380 and 5,680 A after pulverization, extraction, clarification, and saturation with CO (6).

After coding and punching, the data were analyzed using a computer program devised to give the ordinary statistical terms and also to eliminate aberrant values. The procedure involved: a) the successive omission of the value with the largest deviation; b) the recalculcation of the standard deviation; and c) the determination of the deviation of the excluded value from the new mean, the ratio c/b determining whether the value was retained or thrown out. The “throw-out” level was conservatively
FIG. 1. Monthly variation in leg Mb with standard error, standard deviation, and range of values indicated. Dashed curve shows body weight. Circled values show points not included in average.

set at a deviation equal to four times that for which there was a probability of \(1/n\). This very useful procedure provides a constant and objective basis for rejecting values that fall away from the main distribution and, indeed provides a more accurate description of a data group than does the blind inclusion of all values no matter how aberrant. The values rejected (13 of 353) are shown in Figs. 1 and 2.

RESULTS

The concentrations of Mb in thigh muscle are given in Fig. 1 and demonstrate a striking increase of almost 2.5-fold in the monthly means (1.3 → 3.2 mg/g). The increase was largely accomplished within the first 2 months of fall, but the decline occurred more or less linearly over 5 months (Feb.–July). In the fall, animals may be divided into two groups by weight (bimodal distribution) to segregate the older individuals who die off before winter from the younger, more vigorous group. Differences in Mb level were not observed between these two weight groups, although there were fewer of the small individuals in the September–October series. In a similar manner, segregation by sex disclosed no difference.

Heart Mb (Fig. 2) contrasted by showing no change through the spring (Feb.–June) followed by a modest but significant decline (May–June/Aug. = 1.3; \(t = 5.9\)). However, the mean concentration was more than twice that in the thigh. During the spring (Feb.–June) the voles increased steadily in size (avg 13.6 → 24.2 g) but the heart fraction fell almost correspondingly so that there was little change in actual heart weight (avg 151 → 163 mg). Accordingly, the amount of Mb in the heart remained constant (avg = 0.06 mg) during this growth phase. By August, with the influx of young animals into the population, mean values for body weight, heart weight and Mb concentration were all lower so that the average Mb content of the heart was 0.63 mg.

A striking concentration of Mb was observed in the masseter (Fig. 2) but the proportional reduction to less than one-half between February and July closely paralleled the reduction in thigh Mb. The concentration of Mb in masseter was twice that in the heart in February, but less than in the heart in July. Because of differences in muscle weight the mean Mb content of masseter in July was little more than a third that in February (0.50 vs. 1.40 mg).

DISCUSSION

The seasonal change in Mb in the red-backed vole closely follows the pattern in the snowshoe hare (6) and to this degree confirms a common pattern among northern mammals irrespective of microclimatic protection. The same maximum increases were observed in both species for leg muscle (2.3–2.5 X) and for heart 1.3–1.4 X). In the vole, however, absolute values for Mb were lower for leg (max = 3.2 vs. 4.1 mg/g) and higher for heart (max = 5.7 vs. 4.1 mg/g), changes which ap-
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Between February and June the Mb level in thigh fell from a maximum of 3.16 to 2.02 mg/g, whereas the mean muscle mass of the animal increased from 9.1 to 12.8 g (JAS). If we take thigh as representative of the body muscle, the mean Mb mass would not have decreased significantly over this period (29 → 26 mg). In other words, the decrease in Mb concentration represented a dilution by growth rather than a net loss of pigment. In the next 2 months, with the introduction of young individuals, both weight and Mb level decreased so that the comparable “mean Mb mass” was less than half. There was, however, no correlation between body weight and thigh Mb in this mixed summer population. During the fall and winter, growth is suspended (3) so the increase of 18 mg/g in Mb concentration represents the synthesis of new pigment.

The special functional implication of the very high Mb concentration in masseter and its increase in winter are of considerable interest. Although no direct association can be made now, we may note several factors of possible special involvement: (a) the importance and specialization toward chewing in rodents; (b) the continuously repetitive nature of chewing; (c) the poorer nutritional quality and greater durability of the frozen vegetation in winter; and (d) the increased nutritional requirement due to thermoregulation in winter. The seasonal increase in masseter Mb was greater in the vole than in the hare (2.2X vs. 1.5X) and the minimum summer concentration observed was somewhat higher (4.3 vs. 3.5 mg/g).

The general question of the functional need or advantage served by an increase in Mb in winter as first raised in relation to the snowshoe hare (6) still remains unanswered, although a relation to an increased demand for oxygen is an attractive suggestion. Increases in Mb concentration have been produced experimentally in rats (4) by exercise but we have no information on seasonal levels of activity in either the vole or the hare in nature. Hart, Pohl, and Tener (1) have recently described seasonal acclimatization in the snowshoe hare as involving insulative rather than metabolic changes. Peak metabolic values, however, were not measured. Their observations also indicate that shivering may be more efficient—regarded as cubic centimeters of oxygen per mean microvolt output—in the winter animals, if non-shivering thermogenesis is not involved. If myoglobin is involved in the increased metabolic output of muscles through shivering, the higher levels in masseter are appropriate to the preferential function of this muscle in shivering. Slonin (10), for example, describes for the rat the greater increase in electrical activity with cold “in the masseter muscle and muscles of the neck than in the muscles of the back and thigh.” The similar response in the rabbit is described as “even more distinct.”

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References

