Montane and Piedmont Chorus Frogs (*Pseudacris triseriata*): Metabolic Rate as a Function of Temperature

The metabolic rate of montane species of anurans is higher at 5 °C than it is in piedmont species acclimated and tested at the same temperature[1]. High metabolic rate at low temperatures may represent a physiologic adaptation by permitting greater activity in relatively cold environments[1]. The study reported herein considered the metabolic performance of chorus frogs (Family Hylidae: *Pseudacris triseriata*) obtained from populations encountering contrasting thermal conditions.

Methods. Adult male chorus frogs were captured from breeding ponds in mid-May 1969. Montane frogs were obtained near Lost Lake in western Larimer Co. (Colorado) at an elevation of about 9500 ft. Piedmont frogs were captured from 2 sites near Fort Collins (Colorado) at an elevation of about 5000 ft. The montane and piedmont populations are within 60 miles of one another.

Twelve montane and 12 piedmont frogs were acclimated at a constant temperature of 10 °C in complete darkness for a minimum of 3.5 days. Another group of 16 montane and 18 piedmont frogs was acclimated for 3.5 days at 20 °C. 3.5 days is reported to be sufficient for thermal acclimation in these species[2].

Oxygen consumption of pre-weighed frogs was measured for 30 min by closed system respirometry with a Gilson differential respirometer. Metabolism of frogs acclimated to 10 °C was measured at 10 °C, and that of frogs acclimated to 20 °C was measured at 20 °C. Values for oxygen consumption reported herein have been corrected to standard conditions of temperature and pressure.

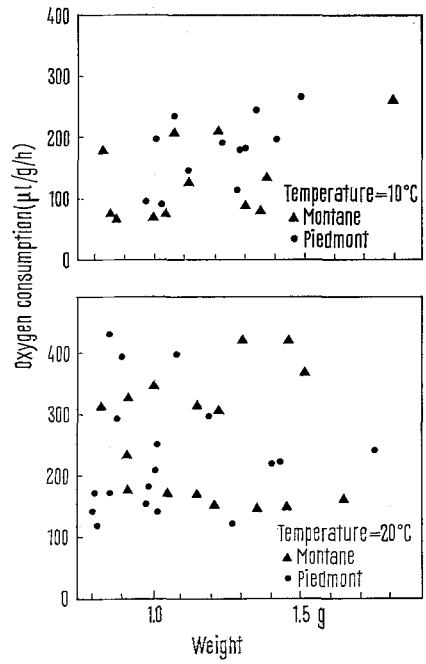
Results. A plot of oxygen consumption versus time for each frog revealed a linear uptake of oxygen during the experimental period. Thus, partial pressure of oxygen in the metabolism chambers did not decrease sufficiently as to have a suppressing effect upon metabolism.

Since oxygen consumption per unit body weight usually is a decreasing function of body weight[3,4], we first performed a regression analysis of metabolism on body weight (Figure). Interestingly, there was no apparent relationship between metabolism and body weight of frogs employed in this study; in none of the 4 experimental groups was the slope of the least squares regression line significantly different from zero ($0.05 < P$).

We then analyzed data on body weights of frogs in the 4 experimental groups by orthogonal analysis of variance. This analysis indicated that the 4 groups of frogs did not differ appreciably in body weight ($F = 1.342$ at d.f. 3, 54; $0.10 < P$; see Table I).

Since oxygen consumption per unit body weight was not a function of body size in this study, and since body weight was demonstrated not to vary among experimental groups, we were justified in performing an orthogonal analysis of variance on metabolism data (Table II). A statistically significant variation in metabolic rate among groups was indicated. All of the intergroup variation in metabolism could be assigned to effects of temperature, frogs acclimated and tested at 20 °C having higher oxygen consumptions than those at 10 °C ($\bar{x} = 238.8$ µl/g/h and 148.8 µl/g/h, respectively; $F = 14.765$ at d.f. 1, 54; $P < 0.005$). None of the intergroup variation could be attributed to site of capture ($F = 0.012$ at d.f. 1, 54; $0.10 < P$) or to an interaction factor ($F = 2.794$ at d.f. 1, 54; $0.10 < P$). Thus, montane chorus frogs did not have higher metabolic rates than piedmont chorus frogs under conditions of this study.

Discussion. We were unable to demonstrate any influence of site of capture on metabolism of chorus frogs. One interpretation of this finding is that montane and piedmont populations have come to occupy their respective habitats so recently as to preclude the occurrence of physiologic differentiation. Tacit in this argument is the assumption that thousands of years are required for the acquisition by populations of differentially adaptive characters. However, there is evidence of differentiation of populations of chorus frogs in other characters[5]; and



Scattergrams depicting weight-specific metabolism of *Pseudacris triseriata* as a function of body weight. Regression lines fitted by the method of least squares to the 4 sets of data did not have slopes that were statistically different from zero.

Table I. Body weight (g) of *Pseudacris triseriata* (mean ± S.E.)

Acclimation temperature	Montane	Piedmont
10 °C	1.161 ± 0.081 (12)[a]	1.222 ± 0.049 (12)
20 °C	1.196 ± 0.060 (16)	1.061 ± 0.062 (18)

[a] Sample size.

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evolutionary theory no longer requires that such long spans of time be invoked in the process of evolutionary differentiation of vertebrates[6–8].

We prefer to believe that certain piedmont populations of *Pseudacris triseriata* were preadapted to the cold that is associated with life at high altitudes by virtue of prior evolutionary adjustment to an early breeding schedule. Over much of the geographic range of this species breeding takes place very early in the growing year (i.e., early spring). Migration to breeding sites may occur at relatively low air temperatures, and frogs often congregate in cold, temporary pools formed by run-off from early spring rains and/or melt-water from snow. Successful exploitation of this breeding schedule presumably involved differential survival and reproduction favoring those individuals capable of maintaining higher metabolism at low temperatures, thereby preadapting these frogs for subsequent dispersal into cool, montane environments[9,10].

Table II. Oxygen consumption (µl/g/h) of *Pseudacris triseriata* (mean ± S.E.)

Acclimation temperature	Montane	Piedmont
10 °C	125.8 ± 19.5 (12)[a]	171.7 ± 16.9 (12)
20 °C	256.1 ± 26.4 (16)	223.5 ± 23.0 (18)

[a] Sample size.

Zusammenfassung. Die Stoffwechselraten von Fröschen (*Pseudacris triseriata*) aus Tiefland- und Bergpopulationen wurden bei 10 °C und 20 °C bestimmt. Die beiden Populationen unterschieden sich nicht signifikant in der Stoffwechselrate bei den 2 Testtemperaturen.

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[9] We wish to thank Dr. J. P. Jordan for encouragement and support of this research. Mr. J. Hess provided some of the frogs employed in the study.
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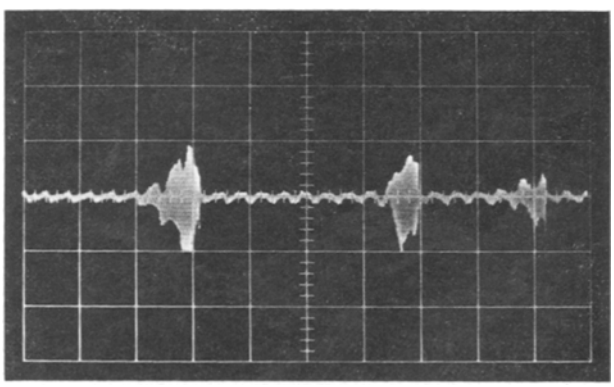
Unkreaktion mit Befreiungsruf beim Weibchen der Kreuzkröte *Bufo calamita*[1]

Die von Flindt und Hemmer[2] analysierten Befreiungsrufe männlicher Bufonen sind mit an ein Husten erinnernden Flankenbewegungen verbunden, die auch die ♀♀ zeigen, wenn sie ausser Paarungsbereitschaft axial umklammert werden. Bei der Erdkröte *Bufo bufo* ♀ erfolgen diese «Unkreationen»[3] immer stumm. Dennoch erschien es als wahrscheinlich, dass die stumme Unkreation der ♀♀ und die mit dem Befreiungslaut verbundenen Unkreaktionen der ♂♂ ethologisch identische Bewegungen, also homolog sind[4].

Die Homologie der bei ♂♂ und ♀♀ auslösbaren Flankenbewegungen wird nun dadurch bestätigt, dass bei Kreuzkröten *Bufo calamita* auch beim ♀ diese Bewegungen gelegentlich mit Befreiungsrufen verbunden sind: Am 3.5.1969 nahm ich Befreiungsrufe eines *Bufo calamita* ♀ von Gossau, Zürich, das in der Nacht zuvor gelaicht hatte, bei 22 °C mit einem Aiwa-Tonbandgerät auf und analysierte sie auf einem Speicheroszillographen Tektronix 549[5]. Die Laute sind leiser als bei den ♂♂, bestehen aus einem explosive erfolgenden, impulsartigen Klang von 30–50 msec Dauer und werden zu Serien gereiht (Figur). Bei dieser hohen Aufnahmetemperatur folgten die Einzellaute mit Abständen von 80–200 msec aufeinander, so dass 4–5 Laute/sec ertönten.

Nicht bei jeder Flankenbewegung kommt es zur Lautäusserung; man hat den Eindruck, das ♀ bringe den Ton nur mühsam heraus. Die meisten ♀♀ bleiben auch bei längeren Serien von Flankenbewegungen stumm. Ob es sich dabei um eine Frage der intraindividuellen «Bahnung» zum Beispiel in Abhängigkeit vom Hormonspiegel handelt oder ob die Unterschiede zwischen den Individuen definitiv sind, ist nicht bekannt.



Befreiungsrufe eines Kreuzkröten-♀ (*Bufo calamita*). Netzweite auf der Abszisse: 50 msec (Oszillogramm).

Summary. The release call which is uttered by Bufo ♂♂ in connection with specific movements can also be evoked in the ♀♀ of *Bufo calamita*. This is indicative of homology of the male release call and the usually silent release movements of the ♀♀.

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