STANDARD METABOLISM COMPARISONS BETWEEN ORDERS OF BIRDS

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The relationship between standard metabolic rate ($M =$ kcal/bird-day) and body weight ($W =$ kilograms) may be expressed as

$$M = aW^b \pm \text{SE of } M, \text{ or}$$

$$\log M = \log a + b \log W \pm \text{SE of } \log M$$

where SE of M is the standard error of estimate involved in predicting M from W, and SE of log M is the standard error of estimate involved in predicting log M from log W. In the more readily used logarithmic form, b is the slope and a is the Y-intercept of the linear regression line.

Lasiewski and Dawson have recently reassessed this relationship utilizing data from nearly 100 species (Condor 69:13, 1967), but reporting probable errors rather than standard errors of estimate (Lasiewski, personal communication). They point out that regression lines calculated separately for passerine and nonpasserine species have statistically similar slopes, but very different elevations or Y-intercepts. This indicates that passerine species metabolize at much higher levels than nonpasserine species of the same weight, although the rate of change in standard metabolism with weight is the same in both groups.

I have used their data to determine among which avian orders differences in the metabolism-weight relationship may occur. The computed regressions were nonsignificant ($P > 0.10$) for orders with data for three or fewer species, but all other regressions reported in table 1 are highly significant ($P < 0.001$, except for Falconiformes where $0.001 < P < 0.005$). By analysis of covariance (Snedecor, Statistical Methods, Iowa State Univ. Press, Ames, 1956:394), the slopes of the significant regression lines were compared with each other, and whenever there was no significant difference between slopes, the Y-intercepts (elevations) were compared. The slopes of all the regression lines tested are statistically indistinguishable from one another ($P > 0.05$), except for the extreme b values where Columbiformes are different from Falconiformes ($0.01 < P < 0.05$) and from Anseriformes ($0.005 < P < 0.01$). This indicates great constancy of response of standard metabolism on weight in the class Aves.

Impressive differences exist between the elevation of the passerine and the nonpasserine regression line ($P < 0.001$) as well as between Passeriformes and Apodiformes, Strigiformes, Columbiformes, Galliformes, or Falconiformes ($P < 0.001$), between Passeriformes and Ciconiiformes ($0.001 < P < 0.005$), and between Passeriformes and Anseriformes ($0.005 < P < 0.01$). Significant differences also exist for Falconiformes vs. Anseriformes ($0.001 < P < 0.005$), Falconiformes vs. Ciconiiformes and Apodiformes vs. Columbiformes ($0.005 < P < 0.01$), and for Strigiformes vs. Anseriformes, Galliformes vs. Anseriformes, and Galliformes vs. Ciconiiformes ($0.01 < P < 0.05$). None of the three passerine families studied differed significantly in slope or elevation from any other. As data of this type for more species are obtained, such differences as reported here may be better substantiated and hypotheses may emerge concerning their relation to phylogeny, ecology, and behavior.

The above equations express metabolism as kcal/bird-day and weight as kilograms. Some authors, however, may present such equations using different units of measurement (*e.g.*, metabolism as cal/bird-day or cal/bird-hr, or weight as grams). But, even if their original data are not available, one can express their equations with the above (or any other) units of measurement by simple conversion factors (Zar, BioScience 17:818, 1967).

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TABLE 1. Empirical statistics for the standard metabolism (kcal/bird-day) vs. body weight (kg) regressions.

Group	Number of data points	a	log a	b	SE of M	SE of log M
Apodiformes	9	114	2.06	0.769	0.201	0.0558
Strigiformes	7	66.4	1.82	0.692	11.1	0.0989
Columbiformes	10	92.1	1.96	0.858	2.68	0.0491
Galliformes	13	72.6	1.86	0.698	15.3	0.0904
Falconiformes	5	65.3	1.82	0.648	45.3	0.108
Anseriformes	9	95.8	1.98	0.634	23.4	0.0524
Ciconiiformes	7	86.9	1.94	0.737	22.0	0.0464
Passeriformes	48	129	2.11	0.724	8.71	0.0806
Corvidae	8	126	2.10	0.709	23.3	0.147
Ploceidae	17	164	2.21	0.794	1.40	0.0808
Fringillidae	19	125	2.10	0.714	1.02	0.0473
All Nonpasserines	72	78.5	1.90	0.723	42.8	0.111
All Species	120	86.3	1.94	0.668	52.8	0.133