Laboratory measurements of metabolized energy in some passerine nestlings.—Many aspects of nestling energetics have been investigated, but no studies have been made of the relative energy requirements of growth and maintenance (Ricklefs 1968). Measurements of the components of nestling energetics may be important for the understanding of the evolution of clutch size, nestling growth rates, secondary productivity of avian populations, and a variety of other phenomena. The following report describes one method of analyzing nestling energetics and presents some preliminary results.

Gross energy intake is the number of calories ingested by the young bird per unit time, excretory energy is calories egested, and metabolized energy is the difference between the two. Assimilation efficiency (%) is metabolized energy/gross energy intake × 100. The cost of growth is that quantity of energy involved in the production of new tissues and deposition of fat by the developing nestling.

Published studies of nest temperatures (Baldwin and Kendeigh 1932, Kendeigh 1940, Huggins 1941, Irving and Krog 1956) indicate that 34–37°C approximates the average temperature for a normal passerine nest. In the present study, nestlings of six species were taken from natural nests and maintained in a constant temperature cabinet at 37 ± 1°C, and a photoperiod of 14L:10D. At half-hour intervals all nestlings that begged were hand-fed mealworms or a ground-meat egg mixture fortified with a commercial chow. Nestlings were weighed each morning shortly before the light period began. Throughout the tests nestling behavior appeared normal, and growth rates were generally within the lower half of natural ranges (Table 1).

The dry weight of food given each bird was calculated from the percentage dry weight of aliquots from the common supply. Caloric content of food and feces was determined in a nonadiabatic bomb calorimeter. The mealworms had a caloric content of 6.608 ± 0.042 kcal/g (mean ± SE), the meat mixture contained 5.782 ± 0.068 kcal/g, and both foods had a protein content of 49 percent on a dry weight basis.

Gross energy intake, excretory energy, metabolized energy, and assimilation efficiency were calculated daily from the weights of food and feces and their respective caloric contents. The cost of producing one gram of nestling of a particular age is equal to the slope of a linear regression equation for metabolized energy vs.

TABLE 1

RANGES OF WEIGHT AND GROWTH OF NESTLINGS IN NATURAL NESTS AND THE LABORATORY

Species	Age (days)	Weight (g)		Growth (g/day)	
		Field	Lab	Field	Lab
Carolina Wren	4–6	7.6– 9.8	7.5– 9.2	0.9–1.5	0.6–1.5
	6–8	9.0–13.2	9.3–11.7	1.4–1.8	0.6–1.0
Brown Thrasher	1–3	7.7–13.9	6.7– 9.2	1.1–2.4	0.9–1.7
Mockingbird	1–3	——	7.7–13.9	——	0.9–2.7
Robin[1]	1–3	6.0–12.0	4.8– 6.2	3.3–4.3	1.5–2.1
Starling[2]	4–8	25.0–44.2	38.7–43.0	2.9–8.0	1.6–3.6
	8–10	36.5–62.0	49.2–57.4	3.4–5.9	0.8–5.0
	10–12	39.2–72.9	52.4–58.2	1.0–4.2	0.7–2.3
Common Grackle[3]	8–12	41.4–73.9	59.7–69.7	2.4–7.3	1.0–5.5

[1] Field data calculated from Howell 1942.
[2] Field data calculated from Hudek and Folk 1961.
[3] Field data calculated from Willson et al. 1971.

weight gained. This calculation is similar to that used by Owen (1970) for adult Blue-winged Teal, *Anas discors*, and is based on the assumption that the cost of maintenance and activity is similar for birds of the same species, age, and size.

The relationship of metabolized energy (ME) in kcal/bird-day, to nestling weight (W) in grams, and weight gained during growth (WC) in grams for all nestlings tested (N = 78) is: $ME = 0.45\ W + 1.51\ WC + 0.87 \pm 4.65$ (multiple correlation coefficient, $R = +0.93$), where W is the mean of two consecutive morning weights, and WC is the difference between these weights. Standard partial regression coefficients indicate that weight (0.859) is 3.2 times more important than weight change (0.264) to the prediction of ME.

The energetic cost of growth ranged from 1.41 kcal/g wet weight for 8–12 day-old Common Grackles, *Quiscalus quiscula*, to 3.57 kcal/g wet weight for 10–12 day-old Starlings, *Sturnus vulgaris*, and tended to increase with the age of the nestling. These values may be related to the weight-specific energy content of the nestlings. Ricklefs (1967) found that the energy content of nestling Barn Swallows, *Hirundo rustica*, and Red-winged Blackbirds, *Agelaius phoeniceus*, increased from about 0.6 to 2.1 kcal/g wet weight during development. Kale (1965) found a similar increase of 0.83 to 1.87 kcal/g in nestlings of the Long-billed Marsh Wren, *Telmatodytes palustris*.

Energetic cost of growth was usually less than 35% of metabolized energy and was greater in young nestlings. It may be significant that the Brown Thrasher, *Toxostoma rufum*, which requires about the same number of days to fledge as the smaller Mockingbird, *Mimus polyglottos* (Bent 1948), is able to utilize a greater portion of metabolized energy in growth.

Assimilation efficiency tends to be low in newly hatched passerines, but increases with age. The average of all determinations is 75.3 percent (N = 78). A low but statistically significant correlation ($r = +0.39$) exists between weight change and assimilation efficiency for nestlings older than 4 days. The caloric content per gram of excrement in newly hatched passerines is high and in some cases exceeded the caloric content of the food given them. Low assimilation efficiencies of very young nestlings may be due either to inability to assimilate fats, or to use of energy-rich egg materials remaining in their digestive tracts and its replacement by water and protein in new tissues.

The above analyses, although fragmentary, suggest that nestling size and stage of development may be more influential energetically than growth. The cost of

TABLE 2

METABOLIZED ENERGY AND THE COST OF GROWTH OF SOME PASSERINE NESTLINGS

Species	Age (days)	N	Metabolized energy (kcal/ bird-day)	Cost of growth (kcal/g)	Percent metabolized energy used in growth
Carolina Wren	4–6	8	5.55 ± 1.37	1.46 ± 0.23	23.7
	6–8	8	5.65 ± 0.64	1.95 ± 0.17	20.7
Brown Thrasher	1–3	5	5.16 ± 0.50	2.12 ± 0.52	61.6
Mockingbird	1–3	5	7.96 ± 1.98	1.66 ± 0.30	43.8
Robin	1–3	4	6.90 ± 0.31	2.40 ± 0.38	73.0
Starling	4–8	10	29.04 ± 1.05	1.82 ± 0.28	16.3
	8–10	15	26.94 ± 2.03	2.52 ± 0.53	20.6
	10–12	15	30.71 ± 3.44	3.57 ± 0.62	12.8
Common Grackle	8–12	8	33.81 ± 3.68	1.41 ± 0.54	15.8

growth as determined by this technique appears to vary throughout development, and tends to be greater than the caloric value of individual passerine nestlings reported in the literature. Future laboratory investigations of the energetics of nestling development from hatching to fledging might well consider aspects of metabolized energy as well as standard metabolism and caloric content of the nestlings.

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Breeding attempts by juvenile Great Blue Herons.—Although most North American herons probably do not attempt to breed for the first time until the breeding season of their second year, records of breeding by Black-crowned Night Herons (*Nycticorax nycticorax*) (Gross 1923), Green Herons (*Butorides virescens*) (Meyerriecks, *in* Palmer 1962), and Little Blue Herons (*Florida caerulea*) (Palmer 1962) in juvenal plumage indicate that in these species a few individuals attempt breeding at about 1 year of age. Owen (1959) reported breeding that he considered exceptional by yearling Grey Herons (*Ardea cinerea*) in Great Britain. Millstein et al. (1970) found breeding attempts by yearling Grey Herons to be common at the Willoughby Wood heronry in England in 1967. The Cattle Egret (*Bubulcus ibis*) also sometimes breeds at the age of 1 year (Palmer 1962).

So far as I can determine, breeding by juvenile Great Blue Herons (*Ardea herodias*) has not been reported previously. I saw two nesting attempts by Great Blue Herons in juvenal plumage during a 6-year study at the heronry at Audubon Canyon Ranch in central California. In this heronry the Great Blue Herons nest