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Metabolism Body Size and Age in Baby Chicks.

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The metabolic rate of homeotherms is determined by body size to such a degree that for a great variety of animals from rat to steer the daily heat production in kilocalories during fasting can be predicted by the same formula, namely, 72 $W^{3/4}$, in which W stands for the body weight in kilograms.[1]

Kleiber and Dougherty[2] have observed that the metabolic rate per $kg^{3/4}$ of abundantly fed baby chicks increased with increasing age. As a general rule the metabolism of the full fed animal parallels the fasting katabolism.[3] It was, therefore, assumed that the fasting katabolism per $kg^{3/4}$† of baby chicks increases also with increasing age which would mean a deviation from either ¾ power—or surface law of metabolism. This assumption has been confirmed by 2 series of respiration trials. In one series (30° series) 5 groups of 10 chicks per group were used, representing the ages of 12, 14, 16, 18, and 20 days. The metabolic rate was measured during 12 hours from 8 p.m. to 8 a.m., starting 24 hours after withdrawal of food. The temperature during fast and respiration trial was kept at 30°C, the humidity at approximately 50%. The apparatus used was the same as that described earlier.[2]

In a second series (35° series) 6 groups of 18 chicks represented the ages of 1, 5, 8, 12, 16, and 20 days. The metabolic rate was measured during 4 hours, 11 a.m. to 3 p.m., starting 17 hours after withdrawal of food. For the duration of the fast and respiration trial the temperature was kept at 35°C. During the respiration trial the humidity was close to saturation. (In earlier unpublished trials we had found that very wide variations in humidity did not measurably affect the metabolic rate of baby chicks at temperatures below 37°C.) The apparatus used for the measurement of the respiratory exchange has been constructed at our station for serial work with rats. It consists of 7 respiration chambers, each connected to a

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1 Kleiber, M., *Hilgardia*, 1932, **6**, 315.

2 Kleiber, M., and Dougherty, J. E., *J. Gen. Physiol.*, 1934, **17**, 714.

3 Kleiber, M., *Tierernährung*, 1933, **5**, 6.

† $kg^{3/4}$ means the unit of body weight in kilograms raised to the ¾ power.

rocking absorbing battery and a burette filled with oxygen. Water from a Mariotte bottle runs into these burettes and drives oxygen to the chambers at the same rate as it is consumed by the animal. Three chicks were put into each of 6 chambers, one chamber was used as a blank.

In 9 trials R.Q.'s higher than 0.75 were found. We omitted the data of these trials from our calculations. However, we found that the final result would have been essentially the same if it had included these data.

The daily heat production per $kg^{3/4}$ is plotted against age in Fig. 1, together with results calculated from data published by Barott and his coworkers.[4]

Fig. 1 shows that the influence of age on the metabolic rate per $kg^{3/4}$ in each series can be approximated by a straight line. These

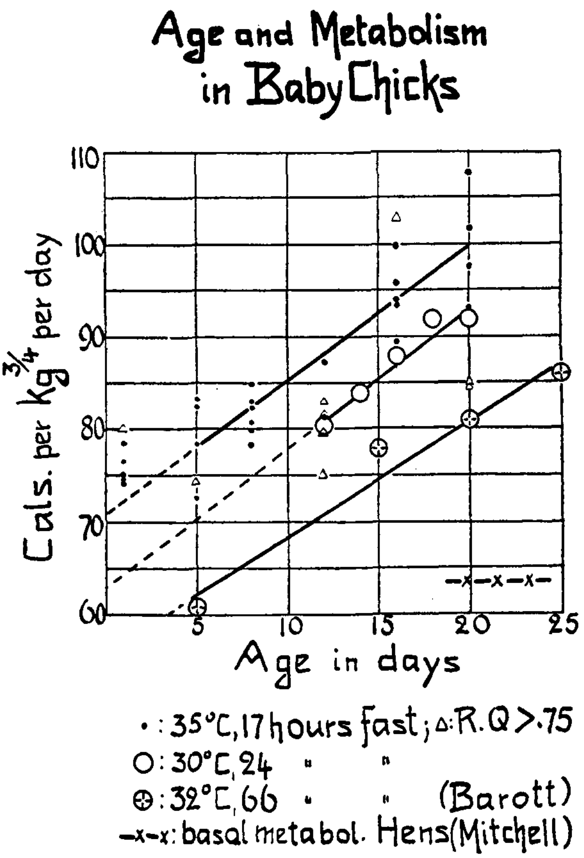

FIG. 1.

[4] Barott, H. G., *et al.*, *J. Nutr.*, 1938, **15**, 150.

lines were calculated by the method of least squares. The results at one day of age have been omitted from this calculation since they do not represent fasting katabolism on account of unabsorbed yolk as shown by Barott and his coworkers.[5]

The results of the 3 series are not directly comparable. They were obtained at different environmental temperatures, but more important than these temperature differences seem to have been the differences in the length of the fasting period prior to the respiration trial. Thus the metabolic rate of the chicks of the 35° series, that had fasted only 17 hours was higher than the rate of the chicks with longer fasting periods even though the environmental temperature for the longer fasting chicks was lower, which ordinarily tends to increase rather than decrease the metabolic rate.

The main point of interest in the comparison of the 3 series is the fact that despite the differences in the experimental conditions all 3 series show a similar effect of age on the metabolic rate per $kg^{3/4}$. In order to compare this effect in one series with that in another the metabolic rate per $kg^{3/4}$ in each series can be regarded as the sum of a theoretical rate at birth and an increment for each day increase in age proportional to the rate at birth. This formulation is expressed by the following equation:

$$B_a = B_o(1 + \alpha a)$$

in which B_a = metabolic rate per $kg^{3/4}$ at a days of age
B_o = " " " " " birth (extrapolated)
a = age in days
α = age coefficient

The age coefficient for the 3 series in Fig. 1 is 0.026 kilocalories per $kg^{3/4}$ per day for the 30° series, 0.021 for the 35° series, and 0.022 for Barott's results. The metabolic rate per $kg^{3/4}$ of fasting chicks up to 20 days of age increases thus approximately 2% of the extrapolated metabolic rate at birth, for each day increase in age. The corresponding figure for full fed chicks calculated from the data mentioned above[2] amounts to 1.5%.

This relation of age on metabolic rate cannot be extrapolated beyond the age of 25 days. A calculation based on Barott's results[4] shows a maximum of the metabolic rate per $kg^{3/4}$ at 25 days of age, and the corresponding metabolic rate of mature hens calculated from data published by Mitchell and Haines[6] amounts to only 63.8 kilocalories[1] per day per $kg^{3/4}$, which level is indicated on Fig. 1 for comparison.

[5] Barott, H. G., *et al.*, *J. Nutr.*, 1936, **11**, 191.
[6] Mitchell, H. H., and Haines, W. T., *J. Agr. Research*, 1927, **34**, 927.

TABLE I.
Relation of Metabolic Rate per Unit of Body Size to Age in Baby Chicks.

Daily metabolic rate kilocalories	per kg (weight)		per $kg^{3/4}$		per $kg^{2/3}$ (surface)	
Environmental temperature °C	30	35	30	35	30	35
Hours fast prior to resp. trial	24	17	24	17	24	17
Coefficient of correlation	.79	.23	.97	.89	.98	.91
Linear Regression:						
Extrapolated metabolic rate at birth, kilocalories	156.0	178.6	61.5	70.6	45.8	52.2
Age coefficient: Increase in metabolic rate for each day increase in age, kcal	1.50	0.32	1.60	1.47	1.40	1.45
Age coefficient in % metabolic rate at birth, %	1.0	0.2	2.6	2.1	3.1	2.8
Standard deviation of single measurement from predicted value, kcal	4.2	5.6	1.3	4.2	0.9	3.7
Standard deviation in % metabolic rate at birth, %	2.7	3.1	2.1	6.0	2.0	7.1

Table I contains the essential statistics for the influence of age on the metabolic rate per unit weight and per unit surface area in comparison with that per $kg^{3/4}$. It shows that the metabolic rate of fasting chicks increases with increasing age even if it is expressed per unit of body weight. In the 30° series this increase was quite distinct (correlation coefficient 0.8) amounting to 1% per day. The corresponding age coefficient of the metabolic rate per unit body weight in the 35° series was only 0.2% and the correlation coefficient in this case was only 0.2. In this series the metabolic rate per unit weight can therefore be summarized irrespective of age. It is 182.4 ± 1.7 kilocalories per day per kilogram body weight and the coefficient of variation of a single value from this mean is only ± 4.3%. The metabolic rate per unit surface area ($kg^{2/3}$) in the 2 series in Table I increases approximately 3% of the extrapolated rate at birth for each day increase in age.

Summary. Fasting baby chicks from 5 to 20 days of age showed an increase in metabolic rate with increasing age. This increase was 0.2 to 1%‡ per day for the metabolic rate per unit body weight, 2% per day for the metabolic rate per $kg^{3/4}$ and 3% for the metabolic rate per unit surface area. Baby chicks thus deviate systematically from the rule which is valid for the relation of body size and metabolism in mature homeotherms. This confirms an earlier deduction based on an observation on full fed baby chicks.

‡ Per cent of the extrapolated rate at birth.