

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

M. F. MILLER, *Director*

# Growth and Development

*With Special Reference to Domestic Animals*

## LIX. Resting Energy Metabolism and Pulmonary Ventilation in Growing Swine

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COLUMBIA, MISSOURI

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## FOREWORD

The special investigation on growth and development is a cooperative enterprise in which the departments of Animal Husbandry, Dairy Husbandry, Agricultural Chemistry, and Poultry Husbandry have each contributed a substantial part. The parts for the investigation in the beginning were inaugurated by a committee including A. C. Ragsdale, E. A. Trowbridge, H. L. Kempster, A. G. Hogan, and F. B. Mumford. Samuel Brody served as Chairman of this committee and has been chiefly responsible for the execution of the plans, interpretation of results and the preparation of the publications resulting from this enterprise.

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## ABSTRACT

Data are presented in tabular ("prediction table") and graphic form for pulmonary ventilation and "resting" energy metabolism (oxygen consumption and equivalent values in Calories, B.T.U., and TDN during rest but not in post-absorptive condition) in relation to body weight and age in growing swine. The "resting" metabolism data are compared with data on the same animals obtained following 24-hour fasting and with data on basal metabolism of mature animals of different species. The pulmonary ventilation rate in growing swine increases with the 0.63 power of body weight. The resting oxygen consumption (minimum maintenance energy cost under customary farm conditions) varies with the 0.90 power of body weight from birth to puberty (7 months of age), and with, approximately, the two-thirds power of body weight thereafter. When plotted in terms of Calories per square meter of surface area, the resting metabolism of swine rises from about 1300 Cal/sq. meter/day during the first month to 2300-2400 at 7 months, then declines to 1300-1600 at 24 months, depending on sex. The 24-hour fasting metabolism rises from 1000 Cal/sq. meter/day during the first month to 1600 at 8 months, then declines to near 1000 Cal/sq. meter/day at 24 months. The males have a consistently higher fasting metabolism than the females. Critical discussions are presented of the physiologic and practical significance of "basal" and "resting" metabolism, of the peculiar age changes in metabolism, and of pulmonary ventilation. These results should be of interest to students of energy metabolism, comparative physiology, nutrition, growth, to ventilating and air-conditioning engineers, and also to livestock feeders as the data are also presented in terms of maintenance cost for various live weights and ages.

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### INTRODUCTION

The phrase "basal metabolism" refers to the heat production by an animal when it is (1) completely at rest, (2) in a thermally neutral environment (at a temperature of 25-30°C. or 77-86°F., which does not, by itself, stimulate heat production above the theoretical minimum), and (3) in post-absorptive condition (digestive tract free from nutrients which may stimulate heat production).

The most debatable aspect of the problem relates to the fasting time required to attain the post-absorptive condition. In man the post-absorptive condition is considered to be attained 12 hours after the last meal. The time required to attain the post-absorptive condition in swine has not been fully determined. We hope to return to this problem of post-absorptive state in a future report. This report is concerned not with basal or post-absorptive metabolism but with "resting metabolism."

The phrase "resting metabolism," as used in this bulletin, refers to the heat production when the animal is at rest in the lying position, though not in a strictly thermo-neutral environment nor in a post-absorptive condition, but as measured before the morning feeding under customary farm conditions. This resting metabolism is identical with the maintenance energy requirements of the animal under the given conditions. The resting metabolism as thus defined is considerably above the basal metabolism; the exact value depending on the nature of the diet, on time after feeding, and on the environmental temperature. As indicated by the 24-hour fast curves in Figs. 3 to 5, the resting metabolism (heavy curves) may be double the fasting metabolism (light curves). As previously explained, 24-hour fasting does not necessarily represent basal metabolism. While the resting metabolism is less definite scientifically, it is more useful practically than the basal metabolism, as explained below.

The resting heat production of an animal is identical with its maintenance-energy cost under the given conditions. The heat production may be measured in heat units per unit time, such as in

Calories per day (24 hours), with a direct calorimeter, or, indirectly, by measuring the oxygen consumption (Fig. 1A) and/or the carbon dioxide production (Fig. 1B) since all energy in the body is obtained by oxidation, that is, by combination of oxygen with the body fuel to produce carbon dioxide. The heat equivalent of oxygen and, to a less extent, or carbon dioxide is known. Therefore, the oxygen values and/or carbon dioxide values may be converted to equivalent heat units, as Calories, or to equivalent feed units such as pounds of corn or other feed, or preferably to pounds of TDN (total digestible nutrients). The maintenance metabolism values are thus converted into maintenance feeding values. This bulletin, then, reports data on the maintenance energy needs of growing swine under conditions of morning rest before the morning feeding. The metabolism or maintenance data are related to body weight, to surface area, and to age. In this way we shall have tentative, yet very practical, maintenance-energy standards for swine of different weight and age.

The above discussion indicates that the resting maintenance energy is made up of two parts: (1) basal metabolism and (2) super-metabolism representing heat production associated with feeding, designated the "heat increment of feeding." The basal metabolism is a variable fraction of the total resting metabolism depending on the nature and on the amount of feed consumed, on the length of time after feeding that the measurement is made, on the age of animal, and on environmental temperature. Figs. 3 to 5 and Table 4 indicate that the basal metabolism level may be half the resting metabolism or maintenance level.

Of the basal metabolism energy, perhaps about one-third represents the sum of the energy expended for blood circulation or work of the heart (5 to 15% of the total), pulmonary air ventilation or work of the lungs (5 to 15% of the total), excretion or work of the kidneys (5% of the total). The remaining two-thirds of the basal-metabolism energy is less easily discussed. But it may be said, in general terms, to be expended for the support of such processes as maintaining the tone and integrity of the tissues. It is generally known that death is followed by prompt disintegration of the tissues, and it is reasonable to assume that energy is required for keeping the tissues, which are very unstable, from disintegrating. The basal metabolism also represents the energy liberated by what may be designated as purposeless enzyme activity, that is, such as is not directly related to the physiologic processes of the body, similar to enzyme activity in a yeast culture medium after the yeast cells are killed. Such enzyme activity involves much heat production.

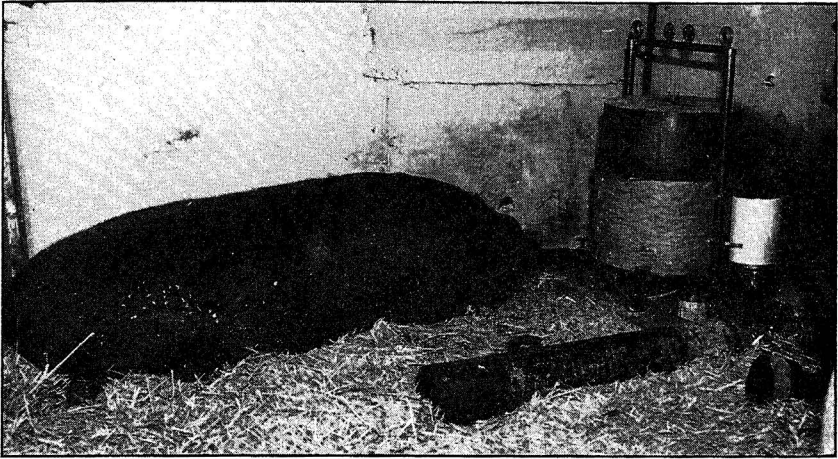


Fig. 1A.—Closed-circuit method of measuring the rates of oxygen consumption and pulmonary ventilation.

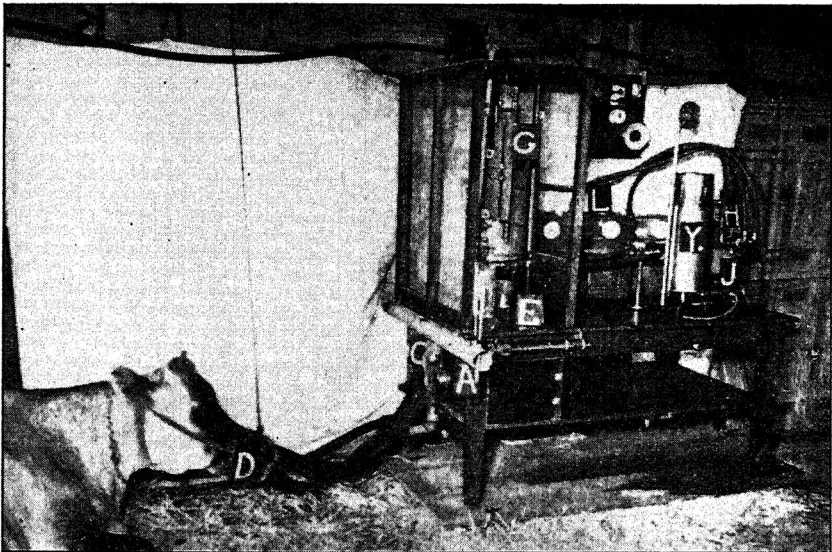


Fig. 1B.—Open-circuit method for measuring the rates of oxygen consumption and carbon dioxide production. This photograph shows how the exhaled air is collected. The exhaled air samples are then analyzed for  $O_2$  decrement and  $CO_2$  increment.

In growing animals the resting metabolism or heat production represents not only the energy cost of maintenance but also the energy expended for what may be called the "work" of growth; and if there is such an energy expense for work-of-growth, its amount must be changing with increasing age and weight. Moreover, the percentage of muscle mass in the body and the muscle tone increase rapidly during growth with corresponding change in energy expended for these tissues and processes. Then, too, the ratio of the surface area to the body weight declines rapidly during growth, a matter of considerable importance, since the body loses heat by way of the surface area; and as the cooling rate tends to decrease with the decrease in the surface area per unit weight during growth, so must the heat-production rate per unit weight tend to decrease. Furthermore, important nutritional and physiological transitions occur during growth, notably weaning and puberty, which influence the metabolic course during growth.

It is evident from the above discussion that the concept "basal metabolism," which refers to a "steady-state" metabolism, is not, theoretically at least, applicable to rapidly growing animals, such as to the pigs discussed in this report. Indeed, the rate of basal metabolism and resting metabolism in relation to body weight and even to surface area tend to change during growth, in one place, near puberty, with dramatic suddenness, indicated graphically by breaks or peaks in Figs. 2 to 4.

In addition to oxygen consumption, data are also presented on pulmonary ventilation rate (air volume exhaled or inhaled per unit time) and, inferentially, carbon dioxide production and water-vapor exhalation.

The ventilation rate data (Fig. 2) are particularly useful for the light they throw on water vaporization in such slightly-sweating or perhaps non-sweating species as swine. While there is some question concerning the degree of water saturation and temperature of the exhaled air, there is practical agreement that the exhaled air is 85% saturated with moisture at the oral temperature of the species.<sup>1</sup>

The pulmonary-ventilation data together with the oxygen-consumption data furnish the ventilating or air-conditioning engineer virtually all the data he needs: air exhalation, oxygen consumption, carbon dioxide exhalation (virtually identical by volume to oxygen con-

<sup>1</sup>While there is some difficulty in computing precisely the water vaporization from air exhalation, it can be estimated closely. The literature indicates that at the point of exhalation the air is 2° to 3° C. below that of the mouth, and about 90% saturated with respect to this exhalation temperature. In man, the usual oral temperature is assumed to be 37° C., the air at expiration 34° to 36° C., and the water content of the expired air is about 80% of that of saturated air at 37° C., containing 0.032 to 0.037 gm. H<sub>2</sub>O per liter expired air. For the literature see Newburgh, L. H., and Johnston, M. W., *Physiol. Rev.* 22, 1, 1942.

sumption), and water vaporization from the respiratory-oral system, amounting in non-sweating species to nearly all the total water vaporized.

In slightly-sweating or non-sweating panting animals, the pulmonary ventilation rate serves a dual purpose: (1) replenishing the oxygen and removing the carbon dioxide, and (2) fanning the moist mucous membranes of the pulmonary-oral surfaces, thus accelerating the moisture vaporization and, therefore, the cooling of the animal. In such species, therefore, the ventilation rate varies with the environmental temperature as well as with the metabolic rate, and it is not surprising that the variability in the ventilation rate, which includes variability due to temperature changes, is twice that in the metabolic rate.

It may be noted in this connection that swine, perhaps in common with other slightly-sweating and, therefore, highly-ventilating species, exhale air with lower oxygen decrements and carbon dioxide increments than man (a profusely sweating, non-panting species). This is indicated in the column designated "ratio of oxygen consumption to ventilation rate" (Table 1). In a personal communication, T. M. Carpenter suggested that in slightly-sweating or non-sweating animals "the water elimination from the skin is so low that in order for the heat to be eliminated by way of vaporization of the water there has to be a tremendous increase in lung ventilation," with consequent decrease in the oxygen deficit of the exhaled air.

## DATA

The data are here presented in chart form in Figs. 2 to 6 and in average numerical form in Tables 1 to 4. The characteristics of the individual animals are listed in Table A. The characteristics of the curves are given in the figure legends.

The individual data points were plotted in the charts for the resting metabolism (averaged by the heavy curves). To give some idea of the relation between basal and resting metabolism, average (light) lines, but no data, are given for the resting metabolism following 24-hour fasts. The lowest broken lines labelled No. 5 (Fig. 3) represents basal metabolism of mature animals of different species.<sup>2</sup>

Note that the metabolism data are given in various units, Calories, British Thermal Units (B.T.U.), oxygen consumption, TDN consumption. The original measurements were on oxygen consumption (Fig. 1A), as previously described.<sup>3</sup> The oxygen consumption values were

<sup>2</sup>Missouri Agr. Exp. Sta. Res. Bul. 220.

<sup>3</sup>Missouri Agr. Exp. Sta. Res. Bul. 143, pp. 6 to 15.

then converted, with the aid of the given conversion factors, into Calories and TDN values.

The ventilation rate, that is, the inhaled or exhaled air volume per minute, is computed from the amplitudes of the up-and-down movements of the oxygen bell corresponding to the inspiratory and expiratory movements of the lungs as recorded on the clock kymograph<sup>3</sup> (Fig. 1A).

We have to point out an error in the apparent resting heat production values in the later ages when the animals begin to become quite fat. This error may explain, in small part, the differences in slope of the various resting-metabolism curves following 8 months (Fig. 3). The error is associated with the conversion of the oxygen-rich carbohydrate feed (containing some 53% oxygen) into the oxygen-poor body fat (containing some 12% oxygen). Such conversion of oxygen-rich to oxygen-poor substances may be considered as decreasing the apparent oxygen consumption or increasing the R.Q. (respiratory quotient, the ratio of the volume of CO<sub>2</sub> produced to the volume of O<sub>2</sub> consumed). Under such fattening conditions, the R.Q. may rise to 1.4.

We did not measure the R.Q. but only the oxygen consumption with the apparatus shown in Fig. 1A, and assumed a constant heat value for oxygen of 4.825 Calories per liter. We should have measured both the carbon dioxide production as well as the oxygen consumption either by the method shown in Fig. 1B or with the aid of a respiration chamber.

However, the error involved in not measuring the R.Q. is, perhaps, not over 5%, that is, within the limit of the errors inherent in metabolism measurements. According to Benedict (Carnegie Inst. Pub. 489, 1937), "In all respiratory exchange measurements when the respiratory quotient is above 1.0, it is believed that the heat production can be indirectly calculated from the measured oxygen consumption with sufficient accuracy by use of the factor 5.047 Calories per liter of oxygen." This Benedict conversion factor, 5.047, is 4.6% above 4.825, the factor used by us.

This error associated with a high R.Q. should not apply to the fasting curves shown in Figs. 3 to 6.

### AVERAGING THE DATA

Voluminous data are confusing unless brought into a meaningful form, some sort of a rule, formula, "standard," or "law," which may be used for practical prediction purposes and at the same time have significant meaning.

Such a formula, previously used for relating metabolism to body weight in *mature* animals of *different species*,<sup>2</sup> is the relative growth equation.<sup>4</sup>

$$Y=aX^b \dots\dots\dots(1)$$

in which Y is metabolism at body weight X. We shall also employ it for relating the pulmonary ventilation and the oxygen consumption to body weight in growing swine.

<sup>4</sup>Missouri Agr. Exp. Sta. Res. Bul. 328.





the ventilation and metabolic rates tend to parallel each other, to be directly proportional to each other.

The scatter of the ventilation data points about the mean is not very satisfactory. The value of the standard error estimate,  $S_R$ , is high, +24%, and -20%, meaning that two-thirds of the data points are included within +24% and -20% of the average line, the area included between the broken curves in Fig. 2. These high values of the standard error of estimate may be attributed, in part, to the fact, already explained, that the resting pulmonary ventilation rate in swine is also used for body-temperature regulation, for regulating the rate of water vaporization from the respiratory and oral systems, and so varies with environmental temperature and season as well as with the need for oxygen in metabolism.

**2. Relation of Resting Metabolism (Oxygen Consumption) to Body Size and to Age in Growing Swine.**—Fig. 3 represents the metabolic data in terms of total oxygen consumption per day (actually measured, left axes), and the equivalent (computed) heat and TDN (right axes) values plotted against body weight.

The approximate ages corresponding to the given weights are indicated on the upper axes.

The heavy lines represent the equation  $Y=aX^b$  fitted to the resting metabolism data (each point represents a monthly average for one animal) by the method of least squares.

Note the presence of an apparent break in the curve (Fig. 3) at the approximate age of 7 months or at the approximate body weight of 60 kg or 130 pounds.

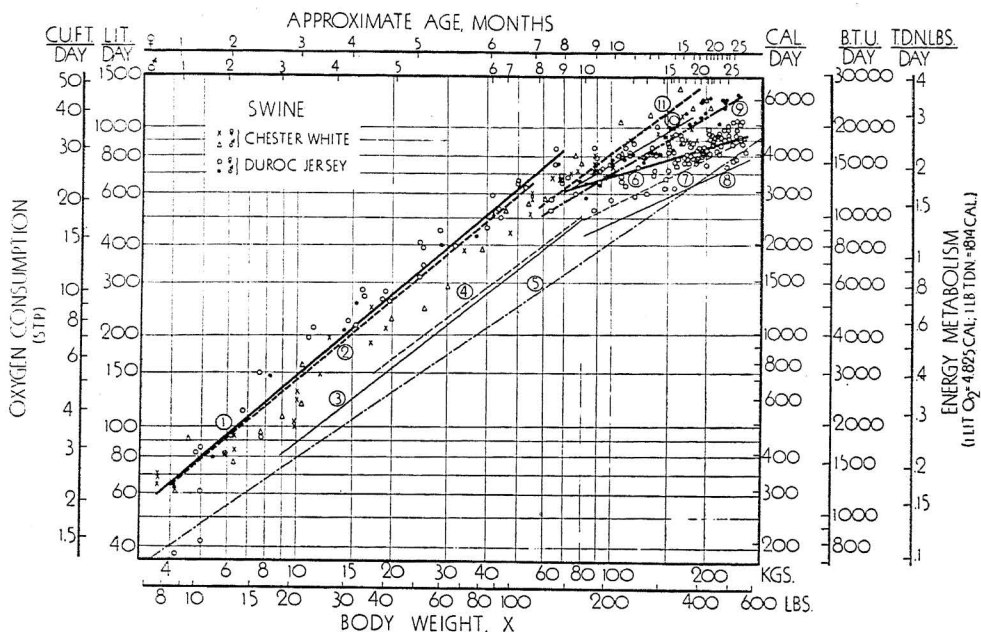


Fig. 3.—Rate of oxygen consumption (left axes) and heat production (right axes) in the given units plotted against body weight (lower axes) with ages estimated (upper axes). Curves 1 and 2 represent the "resting" (not post-absorptive) metabolism; curves 3 and 4 represent metabolism after 24-hour fasting preceding puberty (about 7 months); curve 5 represents the basal metabolism of mature animals of different species; the other curves represent data following 7 months. The curves are described in the following table.

No.	Sex	Breed	Metabolism Type	Equations		S. R. %		P
				$\bar{Y} = \text{Cal/day}$ $X = \text{Body Wt., Kg.}$	$\bar{Y} = \text{Lit/day}$ $X = \text{Body Wt., Kg.}$	+	-	
1	females	both	resting	$Y = 89.9X^{.90}$	$Y = 18.6X^{.90}$	16	14	.98
2	males	both	resting	$Y = 88.1X^{.89}$	$Y = 18.3X^{.89}$	15	13	.99
3	females	both	fasting (24 hours)	$Y = 62.8X^{.83}$	$Y = 13.0X^{.83}$	18	15	.98
4	males	both	fasting (24 hours)	$Y = 73.4X^{.80}$	$Y = 15.2X^{.80}$	14	12	.99
5	mature animals	different species	basal	$Y = 70.5X^{.73}$	$Y = 14.6X^{.73}$			
6	females	Duroc Jersey	resting	$Y = 764X^{.32}$	$Y = 158X^{.32}$	11	10	.76
7	males	both	fasting (24 hours)	$Y = 221X^{.54}$	$Y = 45.7X^{.54}$	11	10	.78
8	females	both	fasting (24 hours)	$Y = 295X^{.45}$	$Y = 61.1X^{.45}$	13	12	.70
9	males	Duroc Jersey	resting	$Y = 194X^{.62}$	$Y = 40.2X^{.62}$	12	11	.89
10	females	Chester White	resting	$Y = 228X^{.60}$	$Y = 47.2X^{.60}$	12	11	.96
11	males	Chester White	resting	$Y = 117X^{.76}$	$Y = 24.2X^{.76}$	14	12	.97

The presence of this break is, perhaps, made more dramatic in Figs. 4 and 5, representing the resting metabolism per unit surface area plotted against body weight and age respectively. It is evident

from Figs. 4 and 5 that the metabolism per unit area rises until about age 7 months and tends to decline thereafter.

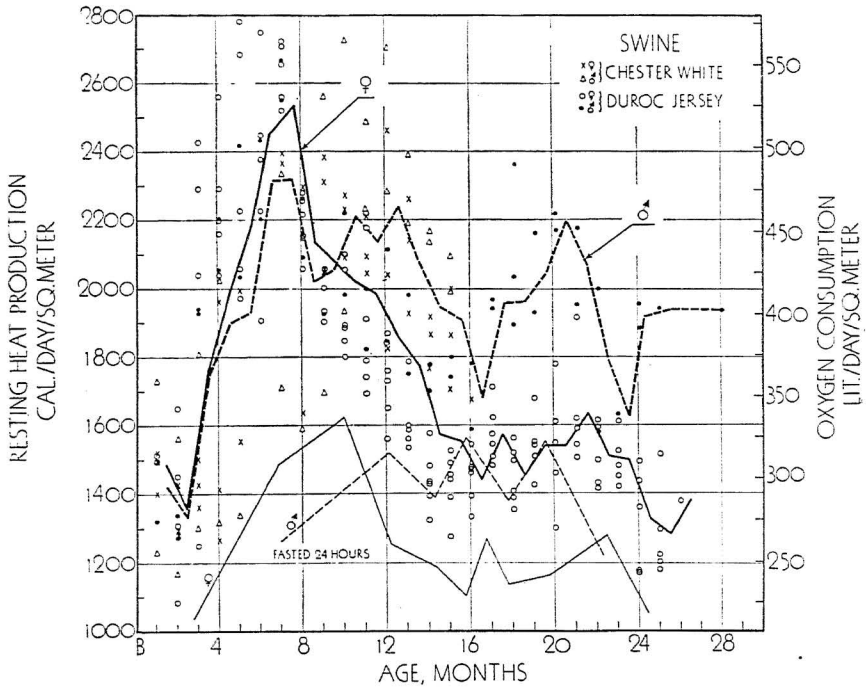


Fig. 4.—Heat production (left axes) and oxygen consumption (right axes) per square meter of surface area of the swine plotted against age. The upper heavy curves represent resting metabolism, the lower 24-hour fasting metabolism.

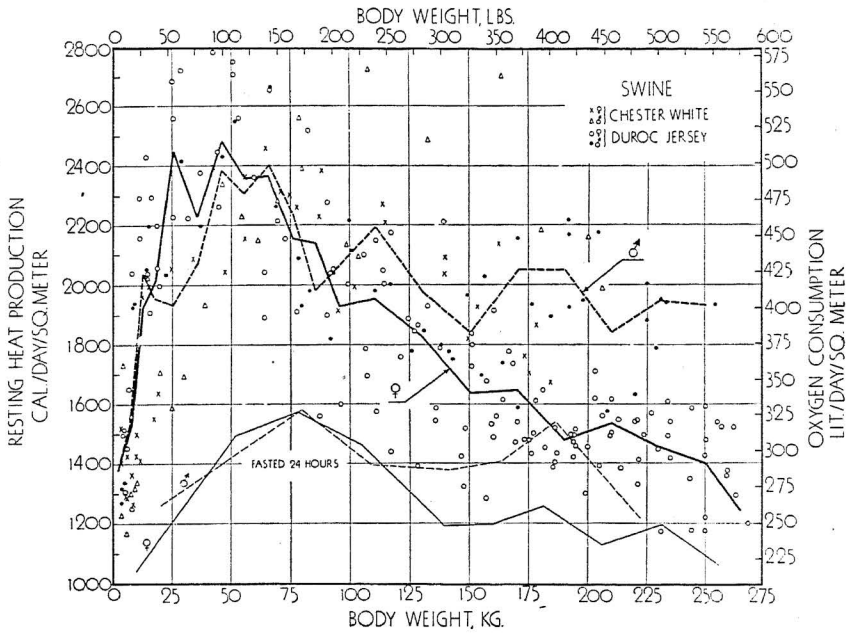


Fig. 5.—The same data as in Fig. 4 plotted against body weight.

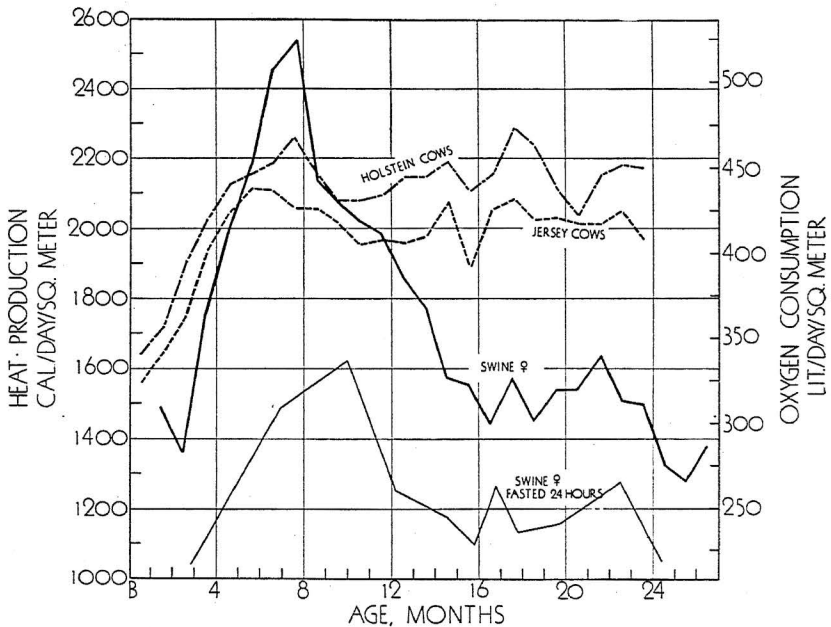


Fig. 6.—Comparison of the metabolism per unit surface area in swine and cattle plotted against age.

Physiologically, age about 7 months coincides with the onset of puberty in swine just as it does in dairy cattle (Fig. 6), with possibly a change in the nature of the growth process and, therefore, in the slope of the metabolism curve. This age of 7 months does not, however, coincide with the age of weaning in pigs as it does in cattle. The explanation of the shape of the metabolism curve can be rationalized but not scientifically explained. Let us discuss this problem in some further detail.

In Figs. 2 and 3 equal spaces represent equal *percentage* (not *absolute*) differences, and a linear distribution of data indicates that the data follow a percentage or logarithmic course as represented by the power or logarithmic equation (1), already defined.

Fig. 3 shows that up to age 7 months, approximately, the distribution of the metabolism data is linear and the slope  $b$  is 0.90; meaning that the relative, logarithmic, or percentage increase in resting metabolism or maintenance cost during this period of growth is approximately 0.9 as rapid as the corresponding relative, or logarithmic, or percentage increase in body weight. In other words, increasing body weight one per cent increases the resting maintenance cost approximately 0.9 per cent. Following this age the resting maintenance cost increases with about the 0.6 power of body weight. (Increasing body weight 1 per cent increases the maintenance-energy cost only about 0.6%.)

It is very interesting that practically the same slope values, 0.9 and 0.6, were obtained for dairy cattle.<sup>5,6</sup> This virtual identity of slope in animals so dissimilar as cattle and swine might be of considerable biologic significance since almost identical slopes (approximately 1.0 and 0.6) were also observed for growing children<sup>5</sup> with the break occurring near 3 years of age, that is, at the end of the natural weaning period; and the break also occurred at the age of natural weaning in cattle. We then<sup>5,6</sup> reasoned that natural weaning coincides with the peak on the curve relating metabolism per unit area with age (Figs. 4 to 6) and with the break on the log-log curve (Fig. 3); and that the segments on the log-log chart immediately preceding and following the break have slopes approximately 1.0 and 0.6; that is, preceding weaning the resting heat production tends to increase with simple body weight, or with the 1.0 power of body weight, and following weaning it tends to increase with the 0.6 power of body weight.

However, natural weaning in swine occurs not at 6 months as in cattle but at about 2 months. The occurrence common to cattle and

<sup>5</sup>Missouri Agric. Exp. Sta. Res. Bul. 335.

<sup>6</sup>Missouri Agric. Exp. Sta. Res. Bul. 350.

swine at 6 to 7 months, that is, at the age of the break in Fig. 3 and the peak in Figs. 4 to 6, is not weaning but onset of puberty. Hence, the metabolic breaks (Fig. 3) or peaks (Figs. 4 to 6) in swine and cattle do not have the same significance as in children at weaning.<sup>5</sup> Children show a discontinuity in the metabolism curve near the age of puberty, but it does not resemble the dramatic discontinuity shown in the curves of cattle and swine at 6 to 7 months. The dramatic metabolic peak in children occurs at age about 3 years, not long after the end of weaning. We have also investigated the age curve of metabolism in rats<sup>7</sup> and plan to extend these investigations to other species in the hope that more light will be thrown on the meaning of the peak in the curve.

It should be recalled<sup>2</sup> that *basal* metabolism of *mature* animals of *different species* tends to increase with the 0.7 power of body weight. In other words, beginning with puberty in farm animals (and age 3 years in humans) the resting maintenance-energy cost increases with, approximately, the surface area, as does the metabolism in mature animals of different species, rather than with simple weight as occurs prior to this break or peak in the metabolism curves. In other words, these data on growing farm animals substantiate the generality of the old surface law as it relates to the period following puberty in farm animals. Our emphasis, however, is not on the surface area as the major causative factor in metabolism regulation; we conceive that surface area is only one of the many factors that enter into the metabolism complex.

### SUMMARY

The abstract given at the beginning of this bulletin is also a compact summary.

Outside of the practical utility of the given data for developing feeding and metabolism standards, for computing the maintenance cost of swine of various ages, for helping to estimate the efficiency of the gains at various ages, the curves are also interesting in their similarity to like curves for cattle (Fig. 6) not merely in general shape but also in the values of slopes—0.9 prior and 0.6 following 6 to 7 months of age.

<sup>7</sup>Kibler, H. H., & Brody, S., J. Nut. 24, 461, 1942.

TABLE A—EXPERIMENTAL ANIMALS

Breed, No., and Sex	Metabolism- Measurement Period, Months	Birth Month	Age Bred Months
<b>Chester White</b>			
1-F	0.3 to 15	May	
3-F	Birth to 15	"	
4-M	0.5 to 15	"	
5-F	0.5 to 15	"	
6-M	Birth to 15	"	
<b>Duroc Jersey</b>			
33-F	6 to 25	August	24
33-M	0.8 to 25	"	....
34-F	0.8 to 19	"	17
34-M	2 to 28	"	....
36-F	4 to 26	"	25
37-F	0.9 to 25	"	24
38-F	0.9 to 25	"	24
29-F	0.8 to 25	"	24



TABLE 1.—PREDICTION TABLE FOR VENTILATION RATE OF GROWING SWINE FOR BOTH SEXES.<sup>1</sup>  
(Computed from equation in Fig. 2)

Body Weight		Approximate Age, Months		Ventilation Rate (S. T. P.)						Ratio of oxygen consumption to ventilation rate O <sub>2</sub> consumed %			
				Per minute		Per day		Air inhaled					
				Liters		Cu.ft.		Liters		Duroc Jersey		Chester White	
Kgs.	Lbs.	M	F	Total	Per Kg.	Total	Per Lb.	Per Sq. M.	M	F	M	F	
5	11.0	1.5	1.5	3.36	.67	0.118	.0107	18007	1.65	1.65	1.65	1.65	
10	22.0	3.3	3.0	5.20	.52	0.184	.0084	17970	1.87	2.00	1.87	2.00	
15	33.1	4.3	4.0	6.72	.45	0.237	.0072	17967	2.07	2.17	2.07	2.17	
20	44.1	5.0	4.7	8.05	.40	0.284	.0064	17941	2.24	2.42	2.24	2.42	
25	55.1	5.3	5.1	9.27	.37	0.327	.0059	17937	2.40	2.55	2.40	2.55	
50	110.2	7.3	6.6	14.35	.29	0.507	.0046	17906	2.90	3.05	2.90	3.05	
75	165.3	9.4	8.3	18.52	.25	0.654	.0040	17875	2.17	2.36	2.40	2.36	
100	220.5	11.0	10.0	22.20	.22	0.784	.0036	17859	2.17	2.01	2.50	2.35	
125	275.6	13.0	11.5	25.55	.20	0.902	.0033	17852	2.17	2.01	2.58	2.34	
150	330.7	14.5	13.5	28.66	.19	1.012	.0031	17843	2.18	1.89	2.64	2.30	
175	385.8	18.0	15.5	31.59	.18	1.116	.0029	17839	2.18	1.80	2.70	2.31	
200	440.9	21.0	18.0	34.36	.17	1.213	.0028	17830	2.16	1.74	2.75	2.28	
225	496.0	23.0	22.0	37.01	.16	1.307	.0026	17824	2.18	1.67	2.78	2.29	
250	551.1	25.0	25.0	39.55	.16	1.397	.0025	17820	2.16	1.62	2.83	2.28	

<sup>1</sup>Males (M); females (F).

TABLE 2.—PREDICTION TABLE FOR RESTING MAINTENANCE ENERGY COST IN GROWING CHESTER WHITE SWINE FOR BOTH SEXES.<sup>1</sup>  
(Computed from equations in Fig. 3)

Body Weight		Approximate Age, Mos.		Maintenance Energy Cost per 24 hours												Oxygen Consumption per 24 hours (S. T. P.)							
				Calories				B. T. U.				Equivalent <sup>4</sup>				Liters				Cu. ft.			
				Total <sup>2</sup>		Per Kg.		Per Sq. M. <sup>3</sup>		Total		Per Lb.		in TDN Lbs.		Total		Per Kg.		Total		Per Lb.	
Kgs.	Lbs.	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F		
5	11.0	1.5	1.5	386	386	77.2	77.2	1440	1440	1530	1530	139	139	0.2	0.2	80	80	16.0	16.0	2.8	2.8	.255	.255
10	22.0	3.3	3.0	676	724	67.6	72.4	1620	1740	2680	2870	122	130	0.4	0.4	140	150	14.0	15.0	4.9	5.3	.223	.241
15	33.1	4.3	4.0	965	1013	64.3	67.5	1790	1880	3830	4020	116	121	0.5	0.6	200	210	13.3	14.0	7.1	7.4	.214	.224
20	44.1	5.0	4.7	1254	1351	62.7	67.6	1940	2090	4980	5360	113	122	0.7	0.7	260	280	13.0	14.0	9.2	9.9	.209	.224
25	55.1	5.3	5.1	1544	1640	61.8	65.6	2070	2200	6130	6510	111	118	0.9	0.9	320	340	12.8	13.6	11.3	12.0	.205	.218
50	110.2	7.3	6.6	2895	3040	57.9	60.8	2510	2630	11490	12060	104	109	1.6	1.7	600	630	12.0	12.6	21.2	22.2	.192	.201
75	165.3	9.4	8.3	3088	3040	41.2	40.5	2070	2040	12250	12060	74	73	1.7	1.7	640	630	8.5	8.4	22.6	22.2	.137	.134
100	220.5	11.0	10.0	3860	3620	38.6	36.2	2160	2020	15320	14360	69	65	2.1	2.0	800	750	8.0	7.5	28.3	26.5	.128	.120
125	275.6	13.0	11.5	4584	4150	36.7	33.2	2220	2010	18190	16470	66	60	2.5	2.3	950	860	7.6	6.9	33.5	30.4	.122	.110
150	330.7	14.5	13.5	5230	4584	35.1	30.6	2270	1980	20870	18190	63	55	2.9	2.5	1090	950	7.3	6.3	38.5	33.5	.116	.101
175	385.8	18.0	15.5	5935	5066	33.9	28.9	2330	1990	23550	20100	61	52	3.3	2.8	1230	1050	7.0	6.0	43.4	37.1	.112	.096
200	440.9	21.0	18.0	6562	5452	32.8	27.3	2360	1960	26040	21630	59	49	3.6	3.0	1360	1130	6.8	5.6	48.0	39.9	.109	.090
225	496.0	23.0	22.0	7141	5886	31.7	26.2	2390	1970	28340	23660	57	47	3.9	3.2	1480	1220	6.6	5.4	52.3	43.1	.105	.087
250	551.1	25.0	25.0	7768	6272	31.1	25.1	2430	1960	30820	24890	56	45	4.3	3.5	1610	1300	6.4	5.2	56.9	45.9	.103	.083

<sup>1</sup>Males (M); females (F).

<sup>2</sup>The heat production was computed on the assumption that one liter of oxygen has a heat equivalent of 4.825 Calories.

<sup>3</sup>Surface area was computed from the equation, surface area in sq. meters=0.097 (weight, kg) .633. See Missouri Agr. Exp. Sta. Res. Bul. 115, p. 30.

<sup>4</sup>Computed on the assumption that one lb. TDN (total digestible nutrients) is equivalent to 1814 Cal. or 1gm. of TDN to 4 Cal.

TABLE 3.—PREDICTION TABLE FOR RESTING MAINTENANCE ENERGY COST IN GROWING DUROC JERSEY SWINE FOR BOTH SEXES.<sup>1</sup>  
(Computed from equations in Fig. 3)

Body Weight		Approximate Age, Mos.		Maintenance Energy Cost per 24 hours												Oxygen Consumption per 24 hours (S. T. P.)							
				Calories				B. T. U.				Equivalent <sup>4</sup>				Liters				Cu. ft.			
				Total <sup>2</sup>		Per Kg.		Per Sq. M. <sup>3</sup>		Total		Per Lb.		in TDN Lbs.		Total		Per Kg.		Total		Per Lb.	
Kgs.	Lbs.	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F		
5	11.0	1.5	1.5	386	386	77.2	77.2	1440	1440	1530	1530	139	139	0.2	0.2	80	80	16.0	16.0	2.8	2.8	.255	.255
10	22.0	3.3	3.0	676	724	67.6	72.4	1620	1740	2680	2870	122	130	0.4	0.4	140	150	14.0	15.0	4.9	5.3	.223	.241
15	33.1	4.3	4.0	965	1013	64.3	67.5	1790	1880	3830	4020	116	121	0.5	0.6	200	210	13.3	14.0	7.1	7.4	.214	.224
20	44.1	5.0	4.7	1254	1351	62.7	67.6	1940	2090	4980	5360	113	122	0.7	0.7	260	280	13.0	14.0	9.2	9.9	.209	.224
25	55.1	5.3	5.1	1544	1640	61.8	65.6	2070	2210	6130	6510	111	118	0.9	0.9	320	340	12.8	13.6	11.3	12.0	.205	.218
50	110.2	7.3	6.6	2895	3040	57.9	60.8	2510	2630	11490	12060	104	109	1.6	1.7	600	630	12.0	12.6	21.2	22.2	.192	.201
75	165.3	9.4	8.3	2798	3040	37.3	40.5	1880	2040	11110	12060	67	73	1.5	1.7	580	630	7.7	8.4	20.4	22.2	.123	.134
100	220.5	11.0	10.0	3378	3330	33.8	33.3	1890	1860	13400	13210	61	60	1.9	1.8	700	690	7.0	6.9	24.7	24.4	.112	.111
125	275.6	13.0	11.5	3860	3570	30.9	28.6	1870	1732	15320	14170	56	51	2.1	2.0	800	740	6.4	5.9	28.3	26.1	.103	.095
150	330.7	14.5	13.5	4342	3764	28.9	25.1	1880	1627	17230	14940	52	45	2.4	2.1	900	780	6.0	5.2	31.8	27.5	.096	.083
175	385.8	18.0	15.5	4777	3956	27.3	22.6	1870	1551	18960	15700	49	41	2.6	2.2	990	820	5.7	4.7	35.0	29.0	.091	.075
200	440.9	21.0	18.0	5163	4150	25.8	20.8	1860	1500	20490	16470	46	37	2.8	2.3	1070	860	5.3	4.3	37.8	30.4	.086	.069
225	496.0	23.0	22.0	5597	4294	24.9	19.1	1870	1440	22210	17040	45	34	3.1	2.4	1160	890	5.2	4.0	41.0	31.4	.083	.063
250	551.1	25.0	25.0	5935	4439	23.7	17.8	1860	1390	23550	17610	43	32	3.3	2.4	1230	920	4.9	3.7	43.4	32.5	.079	.059

<sup>1</sup>Males (M); females (F).

<sup>2</sup>The heat production was computed on the assumption that one liter of oxygen has a heat equivalent of 4.825 Calories.

<sup>3</sup>Surface area was computed from the equation, surface area in sq. meters = 0.097 (weight, kg) .633. See Missouri Agr. Exp. Sta. Res. Bul. 115, p. 30.

<sup>4</sup>Computed on the assumption that one lb. TDN (total digestible nutrients) is equivalent to 1814 Cal. or 1 gm. of TDN to 4 Cal.

TABLE 4.—PREDICTION TABLE FOR 24-HOUR FASTING ENERGY METABOLISM IN GROWING SWINE FOR BOTH SEXES.<sup>1</sup>  
(Computed from equations in Fig. 3)

Body Weight		Approximate Age, Mos.		Maintenance Energy Cost per 24 hours										Oxygen Consumption per 24 hours (S. T. P.)									
				Calories				B. T. U.				Equivalent <sup>4</sup>		Liters				Cu. ft.					
				Total <sup>2</sup>		Per Kg.		Per Sq. M. <sup>3</sup>		Total		Per Lb.		in TDN Lbs.		Total		Per Kg.		Total		Per Lb.	
Kgs.	Lbs.	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F		
10	22.0	....	3.0	....	434	....	43.4	....	1040	....	1720	..	78	....	0.2	....	90	....	9.0	....	3.2	....	.145
15	33.1	4.3	4.0	627	579	41.8	38.6	1160	1080	2490	2300	75	69	0.3	0.3	130	120	8.7	8.0	4.6	4.2	.139	.127
20	44.1	5.0	4.7	820	772	41.0	38.6	1270	1190	3250	3060	74	69	0.4	0.4	170	160	8.5	8.0	6.0	5.7	.136	.129
25	55.1	5.3	5.1	965	917	38.6	36.7	1300	1230	3830	3640	70	66	0.5	0.5	200	190	8.0	7.6	7.1	6.7	.129	.122
50	110.2	7.3	6.6	1689	1592	33.8	31.8	1460	1380	6700	6320	61	57	0.9	0.9	350	330	7.0	6.6	12.4	11.7	.113	.106
75	165.3	9.4	8.3	2316	2268	30.9	30.2	1550	1520	9190	9000	56	54	1.3	1.2	480	470	6.4	6.3	17.0	16.6	.103	.100
100	220.5	11.0	10.0	2654	2316	26.5	23.2	1480	1290	10530	9190	48	42	1.5	1.3	550	480	5.5	4.8	19.4	17.0	.088	.077
125	275.6	13.0	11.5	2992	2606	23.9	20.8	1450	1260	11870	10340	43	38	1.6	1.4	620	540	5.0	4.3	21.9	19.1	.079	.069
150	330.7	14.5	13.5	3281	2798	21.9	18.7	1420	1210	13020	11100	39	34	1.8	1.5	680	580	4.5	3.9	24.0	20.5	.073	.062
175	385.8	18.0	15.5	3570	2992	20.4	17.1	1400	1170	14170	11870	37	31	2.0	1.6	740	620	4.2	3.5	26.1	21.9	.068	.057
200	440.9	21.0	18.0	3860	3184	19.3	15.9	1390	1150	15320	12630	35	29	2.1	1.8	800	660	4.0	3.3	28.3	23.3	.064	.053
225	496.0	23.0	22.0	4101	3378	18.2	15.0	1370	1130	16270	13400	33	27	2.3	1.9	850	700	3.8	3.1	30.0	24.7	.060	.050
250	551.1	25.0	25.0	4342	3522	17.4	14.1	1360	1100	17230	13980	31	25	2.4	1.9	900	730	3.6	2.9	31.8	25.8	.058	.047

<sup>1</sup>Males (M); females (F).

<sup>2</sup>The heat production was computed on the assumption that one liter of oxygen has a heat equivalent of 4.825 Calories.

<sup>3</sup>Surface area was computed from the equation, surface area in sq. meters =  $0.097(\text{weight, Kg})^{.633}$ . See Missouri Agr. Exp. Sta. Res. Bul. 115, p. 30.

<sup>4</sup>Computed on the assumption that one lb. TDN (total digestible nutrients) is equivalent to 1814 Cal. or 1gm. of TDN to 4 Cal.