GROWTH AND DEVELOPMENT

With Special Reference to Domestic Animals

XXXIV. Basal Metabolism, Endogenous Nitrogen,
Creatinine and Neutral Sulphur Excretions
as Functions of Body Weight

SAMUEL BRODY, ROBERT C. PROCTER AND URAL S. ASHWORTH

(Publication Authorized September 18, 1934)

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 plans for the investigation in the beginning were inaugurated by a committee including A. C. Ragsdale, E. A. Trowbridge, H. L. Kempster, A. G. Hogan, 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.

F. B. MUMFORD,
Director Agricultural Experiment Station

TABLE OF CONTENTS

ABSTRACT

1. An analysis of a very large body of basal (energy) metabolism data of mature animals of different species ranging in weight from 0.02 to 4000 kg (mice to elephants) shows that basal metabolism tends to vary with the 0.73 power of body weight. The general equation is $Q = 70.5\ M^{0.734}$ in which Q is heat production (basal metabolism in kilo-calories per day) for body weight, M, in kilograms.

2. An analysis of a smaller, but respectable, body of data on minimum (endogenous) urinary nitrogen excretion by mature animals ranging in weight from 0.02 to 500 kilograms (mice to cattle) shows that the endogenous urinary nitrogen excretion tends to vary with the 0.72 power of body weight. The general equation is $N = 146\ M^{0.72}$ in which N is mgs per day of endogenous urinary nitrogen excretion for body weight, M, in kilograms.

3. An analysis of a relatively small body of data on neutral sulphur excretion by mature animals ranging in weight from 0.1 to 800 kg. shows that the neutral sulphur excretion tends to vary with the 0.74 power of body weight. The general equation is $NS = 6.85\ M^{0.74}$ in which NS is mg per day of neutral sulphur for body weight, M, in kilograms.

4. It appears that the differences in the numerical values of the exponents between equations 1, 2 and 3 above are within the limits of experimental errors; that, therefore, with the limits of experimental errors, basal metabolism, endogenous nitrogen and neutral sulphur excretion all increase, or at least tend to increase, in the same proportion with increasing body weight of mature animals of different species; that, therefore, the ratios of $\dfrac{\text{endogenous nitrogen,}}{\text{Basal metabolism}}$ and $\dfrac{\text{neutral sulphur,}}{\text{basal metabolism}}$ tend to remain constant.

5. The creatinine excretion for animals of the same species tends to vary directly (linearly) with body weight; but in the case of mature animals of different species this excretion tends to vary with the 0.90 power of weight ($Cr.N = 12.7\ M^{0.896}$). It follows, in the latter case, that the creatinine coefficient tends to decrease with increasing body weight; that in either case the ratio of creatinine excretion to basal metabolism increases with increasing live weight; that, in either case, the percentage ratio $\dfrac{\text{Creatinine N}}{\text{Endogenous Urinary N}}$ increases with increasing body weight. Creatinine nitrogen is therefore not a directly proportional index of either endogenous nitrogen or of basal metabolism. These conclusions refer to mature animals only. Corresponding data for growing animals are not sufficient for drawing conclusions at this time.

6. Prediction tables are presented for: basal metabolism, endogenous urinary nitrogen, creatinine nitrogen, neutral sulphur, protein equivalents of the endogenous nitrogen, calories in the form of protein of endogenous nitrogen, the ratios between these variables. Feeding standards for maintenance are suggested on the basis of the equation of $Y = AM^{0.73}$ in which Y is digestible feed requirement for maintaining body weight M.

GROWTH AND DEVELOPMENT

With Special Reference to Domestic Animals

XXXIV. Basal Metabolism, Endogenous Nitrogen, Creatinine and Neutral Sulphur Excretions as Functions of Body Weight.

Samuel Brody, Robert C. Procter and Ural S. Ashworth

I. INTRODUCTION

Definitions.—Basal metabolism and endogenous nitrogen represent respectively the minima of energy and of nitrogen expenses for maintenance. Creatinine and neutral sulphur excretions are thought to be comparable to basal metabolism and endogenous nitrogen in their constancy, and so the excretions of these substances are likewise considered to represent roughly irreducible expenses of the life process. This common characteristic of irreducible minimum for these four kinds of metabolism makes it desirable to consider them together. The object of this bulletin is to present the results of a study of the quantitative relations of each of these four classes of metabolism with increasing body weight, and incidentally with each other, and to suggest feeding standards for maintenance based on these data.

Plan; Data.—The plan of this research consisted in formulating equations relating each of these kinds of metabolism with body weight and to present the results in graphic and tabular forms. Since it is desirable to formulate the conclusions on as broad a basis as possible, it is therefore necessary to make use of as many data as possible. We have therefore supplemented generously whatever data we had with data taken from the literature. All the data with their sources are given in the appendix of this bulletin (Tables 1 to 4). It will there be seen that the Missouri data constitute a very substantial part of the whole as regards basal metabolism, especially in the upper live-weight brackets (sheep, swine, cattle, horses, elephants); less with regards to endogenous nitrogen and creatinine; none with regards to neutral sulphur. The method of securing the Missouri data and their sources are given in the publications cited in the foot notes to the tables in the appendix.

Practical Applications.—In the formulation of feeding standards it is first of all necessary to determine the irreducible costs of maintenance. The relations of basal metabolism and of endog-

enous nitrogen to body weight given in this bulletin, supply the necessary information concerning the minimum costs of maintenance for energy and for nitrogen for animals of different live weights. Such known relations should have practical applications, for by indicating the necessary nitrogen *spent* by animals of different live weights, they also indicate the amount of protein *required*. The given relation of creatinine to body weight indicates that creatniine can not be taken as a directly proportional index of either the minimum energy or of the minimum nitrogen expense of maintenance.

Theoretical Implications.—It is generally believed that surface areas of animals vary with the 2/3 power of their body weights and that basal metabolism varies directly with surface area; that therefore basal metabolism likewise varies with the 2/3 power of body weight. This "surface law", as it is often called, has been a subject of extensive study and lively debate for almost a century. This "law" tacitly assumes that the surface area of animals is the limiting factor in their energy metabolism as might be inferred from Newton's law of cooling. We have previously shown (Missouri Research Bulletins 89 and 115) that surface area, basal metabolism, weight of the visceral organs (kidneys, stomach, intestine, liver) all vary with the 2/3 to the 3/4 power of body weight; it was shown by Dreyer [Proc. Royal Soc. B, **82**, 545 (1910) and **86**, 39, 56 (1912-13); Phil. Trans. B, **201**, 133 and 191; Lancet, **2**, 227 (1919)] that the area of the aortic cross section, the area of the tracheal cross section, vital capacity, likewise tend to vary with the 2/3 to 3/4 power of body weight. The "surface area law" thus seems to be merely one example of a broader law, which might be termed the 2/3 to 3/4 power law. It seems that the sizes and activities of the vital organs tend to vary with 2/3 to 3/4 power of body weight because the skeletal, or the purely supporting, organs must increase in size more rapidly than the body weight as a whole. This bulletin goes a step further by showing that urinary endogenous nitrogen and neutral sulphur excretions likewise follow this general law. Creatinine excretion tends to vary almost directly with body weight rather than with endogenous nitrogen excretion, thus indicating that it represents the muscular mass, and therefore the principal active mass, of the body. A special feature of this bulletin is the wide range of live weights of animals on

which the generalizations are based. The equation relating minimum energy expense to body weight (Fig. 1) is based on animals ranging in live weight from 0.01 kg. mice to 4000 kg. elephants, i. e., a range of 1 to 400,000; the equation relating endogenous urinary nitrogen to body weights (Fig. 2) is based on animals ranging in body weight from 0.02 to 500 kg. i. e., a range of 1 to 25,000. This range in magnitudes gives the generalizations a rather unusual breadth of validity.

Literature.—As may be inferred from the selected references given in the footnotes for tables 1 to 4, there is a tremendous literature on the quantitative aspects of energy and nitrogen metabolism. However, the papers by Terroine and his pupils and the research by Smuts (Ph.D. Thesis, University of Illinois, Urbana, 1932), carried out under H. H. Mitchell's direction, bear most directly on the problem under consideration and therefore need detailed review.

Terroine and Sorg-Matter [Arch. Internat. de Physiol., **29**, 121 (1927) and **30**, 115 (1928); also Sorg-Matter, ibid., **30**, 126 (1928)] investigated the quantitative relations between basal metabolism and total (including fecal) endogenous nitrogen excretion in mice, rats, pigeons, chickens and rabbits, and found the N/Cal. ratio constant. In the first of the aforecited papers they summarized their results by the following table:

Animal	Mg. of total endog. N per kg-hr.	Cal. of basal metabolism per kg-hr.	Mg. N. per Calorie
Mouse	34.8	12.0	2.90
Rat	18.8	7.8	2.41
Pigeon	18.8	6.5	2.89
Chicken	10.6	4.6	2.30
Rabbit	9.0	3.4	2.65
Dog	6.7	2.4	2.80
Man	2.2	0.933	2.32

They generalized this table by saying that "Dans toute la série des homéothermes, la dépense azotée minima de l'adulte, par unité de poids, est rigoureusement proportionnelle à l'intensité minima de sa dépense d'énergie".

In the second of the aforecited papers Terroine and Sorg-Matter reported results indicating that changes in external temperature have the same proportional influence on total endogenous nitrogen excretion as on basal metabolism; and that therefore the

minimum nitrogen excretion is attained only at thermal neutrality. They summarized their results by the following table:

Animal	Body wt. gm.	Mg. end. N. per kg-hr.	Cal. energy metabolism per kg-hr.	Mg. N. per Cal.
Mice at 25°C.	17	34.2	17	2.02
	16	34.7	17	2.03
	15	35.7	17	2.10
	16	38.8	17	2.28
	17	37.0	17	2.18
Mice at 30°C.	15	26.95	12	2.24
	15	28.13	12	2.34
Pigeon at 0-2°C.	320	26.32	12	2.20
	365	28.58	12	2.38
	300	27.46	12	2.29
	270	29.43	12	2.45
Pigeon at 15-16°C.	340	18.43	9	2.06
	300	18.54	9	2.06
	260	19.40	9	2.15
Pigeon at 28-29°C.	330	13.66	6.5	2.10
	380	13.92	6.5	2.14
	330	12.81	6.5	1.97

They summarized this table by concluding that "Chez tout homéotherme, à toute variation de température extérieure entraînant une augmentation de la dépense énergétique, correspond une augmentation proportionnelle de la dépense azotée endogène. En conséquence, la dépense azotée minima ne peut être atteinte qu'a' là neutralité thermique".

In the third paper Sorg-Matter showed that the nitrogen to energy ratio remains the same for animals of different sizes of the same or different species as shown by the following table:

Animals	Body wt. gm.	Endog. N. per kg-hr. mg.	Basal metabolism per kg-hr., Cal.	Mg. N. per Cal.
Rats	50	26.3	5.4	2.20
Rats	100	23.0	5.4	2.30
Rats	200	15.8	5.4	2.30
Chickens	720	13.7	5.4	2.53
Chickens	740	13.5	5.4	2.40
Chickens	760	13.7	5.4	2.55
Chickens	800	13.2	5.4	2.44
Chickens	1800	10.5	4.6	2.30
Chickens	1000	11.3	4.6	2.43

Sorg-Matter concluded the paper by the statement that "La loi d'apès laquelle la grandeur de la dépense azotée endogène, aû niveau du métabolisme de base, est entièrement soumise à celle de la dépense énergétique et rigoureusement proportionnelle à cette dernière, est donc valable à la fois intraspécifiquement et interspécifiquement."

Smuts, in the aforecited dissertation, criticised Terroine and Sorg-Matter because in computing their N/Cal. ratios they used total rather than urinary nitrogen, inasmuch as the endogenous fecal nitrogen is more variable than the endogenous urinary nitrogen; and because Terroine and Sorg-Matter did not determine the basal metabolism of the animals for which the endogenous nitrogen was measured, but used instead average basal metabolism determinations obtained at different times, perhaps under different conditions, and on different series of animals, thereby ignoring individual peculiarities of animals with tendencies to have especially low or high metabolic rates for energy or for nitrogen or for both. Smuts accordingly measured both the energy metabolism and urinary nitrogen excretion on the same animals and under conditions giving strictly minimum, (or "basal") values in both cases. Smuts' excellent data are included in Tables 1 to 3. The range in live weights of Smuts' animals is seen to be very much wider (from 20 gm. mice to 79 kg. pigs) than the range of Terroine's animals (from 15 gm. mice to 1600 gm. chickens).

Smuts confirmed the fact found by Terroine and Sorg-Matter that the ratio of endogenous nitrogen to basal metabolism is remarkably constant for animals of different live weights. Smuts found the following ratios for mg. urinary nitrogen to basal metabolism: mice, 1.92; rats, 2.00; rabbits, 2.04; pigs, 2.10; average of all measurements 1.99. If one recalls that Terroine reported the ratios in terms of total (including fecal) nitrogen to calories, while Smuts reported his data in terms of urinary nitrogen to calories, then the differences between the N/Cal. ratios of these two investigators probably disappear. The "Terroine—Sorg-Matter law" as the Terroine-—Sorg-Matter conclusions were referred to by Bonnet [in Arch. Internat. Physiol., 37, 104 (1933)] is thus completely confirmed by Smuts. Incidentally, Bonnet (loc. cit.) found that the N/Cal. ratios of frogs and of tortoises remain constant at different environmental temperatures ranging from 2° to 30° C; that is, both, endogenous nitrogen and basal metabolism, rise and fall together in constant proportion with temperature

changes. In the frog the average of this ratio was 7.2; in tortoises, 2.8—very near that found by Terroine and Sorg-Matter for homeotherms. Within each of these species, however, this ratio remained constant for different environmental temperatures. Bonnet suggests that reptiles are probably in an intermediate class (biochemically and physiologically) between homeotherms and poikilotherms.

Terroine et al [Bull. Soc. Chim. Biol. Vol. 15, pp. 23, 42, 230, 260 (1933)] discussed the problem of the interrelationships between the various nitrogen components of the endogenous urinary nitrogen. They found that the creatinine changes with increasing body weight are independent of the changes in urinary nitrogen; that creatine tends to disappear completely with the increase of time on the N-free diet; that the ammonia output is, as is well known, a species characteristic (e. g., low for the rabbit, high for the rat) even more than a dietary characteristic, but that within the species it probably varies on the N-free diet in the same way as does the total endogenous nitrogen; that the allantoin tends to vary directly with the basal metabolism and endogenous nitrogen excretion; that the urea and amino acid excretions on a N-free diet tend to be proportional to the total urinary endogenous nitrogen. Of course, the body of data on which the above conclusions of Terroine et al are based is relatively small as compared to the data on total urinary nitrogen plotted in Fig. 2; but they are nevertheless important and significant.

Finally note may be made of Ashworth & Brody's attempts [Missouri Research Bulletins 189 and 190 (1933)] to determine for *growing* rats the relation (among others) between (1) time on N-free diet and nitrogen excretion; (2) relation between endogenous nitrogen and basal metabolism; (3) relation between creatinine nitrogen and total endogenous nitrogen. The unexpected conclusion was reached that the minimum urinary nitrogen levels were attained any time between 4 and 28 days on the N-free diet, and that, therefore, the values of endogenous nitrogen, as obtained empirically by simply keeping the rats on N-free diets for several days, are variable, not reproducible, and usually too high. Likewise, the ratios of endogenous N/basal metabolism are too high. In this work the lowest N/Cal. ratio (as determined from the time curves on N-free diet) was found to be 1.4 mg. N per Cal. rather than 2.0 as found by Smuts; and under some conditions it was found to be as low as 0.70 for very young rats.

These data, together with more recent unpublished data on nitrogen excretion in rats, were plotted in Fig. 2 where they appear to be below the curve of the general equation. However, the nitrogen excretion by these rats on the fourth day on the N-free diet, is seen in Fig. 2 to approach quite closely to the general curve. It is reasonable to assume that the endogenous nitrogen, quite like basal metabolism, represents a relative rather than an absolute level, attained only under well defined conditions. It is generally known that the basal metabolism declines for many days following the attainment of the post-absorptive condition; the same appears true as regards endogenous nitrogen. But obviously this problem needs to be re-investigated especially as regards growing animals.

To avoid complications, this bulletin is concerned principally with mature animals of different weights and with metabolism data as conventionally obtained. This problem as it concerns growing animals will be discussed elsewhere in more detail by Asnworth.

II. RESULTS

The results are presented in a series of charts based on the data in Tables 1 to 4 in the appendix.

Basal Metabolism as a Function of Body Weight.—These data, including a range in live-weight from 0.01 kg mice to 4000 kgs elephants, are presented in Fig. 1 based on the data in Table 1. The encircled numbers in Fig. 1 refer to the serial positions of the original data, and to their sources (given in the footnotes of Table 1.)

The metabolism of the elephant was measured by the same method as used for cattle and previously described in Missouri Res. Bull. 143; a rubber sleeve was slipped over the elephant's trunk similar to the mask over the cow's muzzle. The basal metabolism is seen in Fig. 1 to increase with the 0.734 power of body weight, and the equation relating metabolism to body weight is $Q = 70.5 \ M^{0.734}$ in which Q represents Calories (i. e. kilo-calories) per day for body weight M in kgs. The equation was fitted to the data by the method of least squares. The data represented by crosses were not included in fitting the equation to the data. Practically all the data points are within $\pm 20\%$ of the curve of the equation. It is interesting to note that previously we have found the same equation to represent a much smaller group of data (cf. p. 93, Missouri Res. Bull. 166). This chart makes us confident that this equation approaches closely the "true" relation between basal metabolism and body weight of mature mammals of different species.
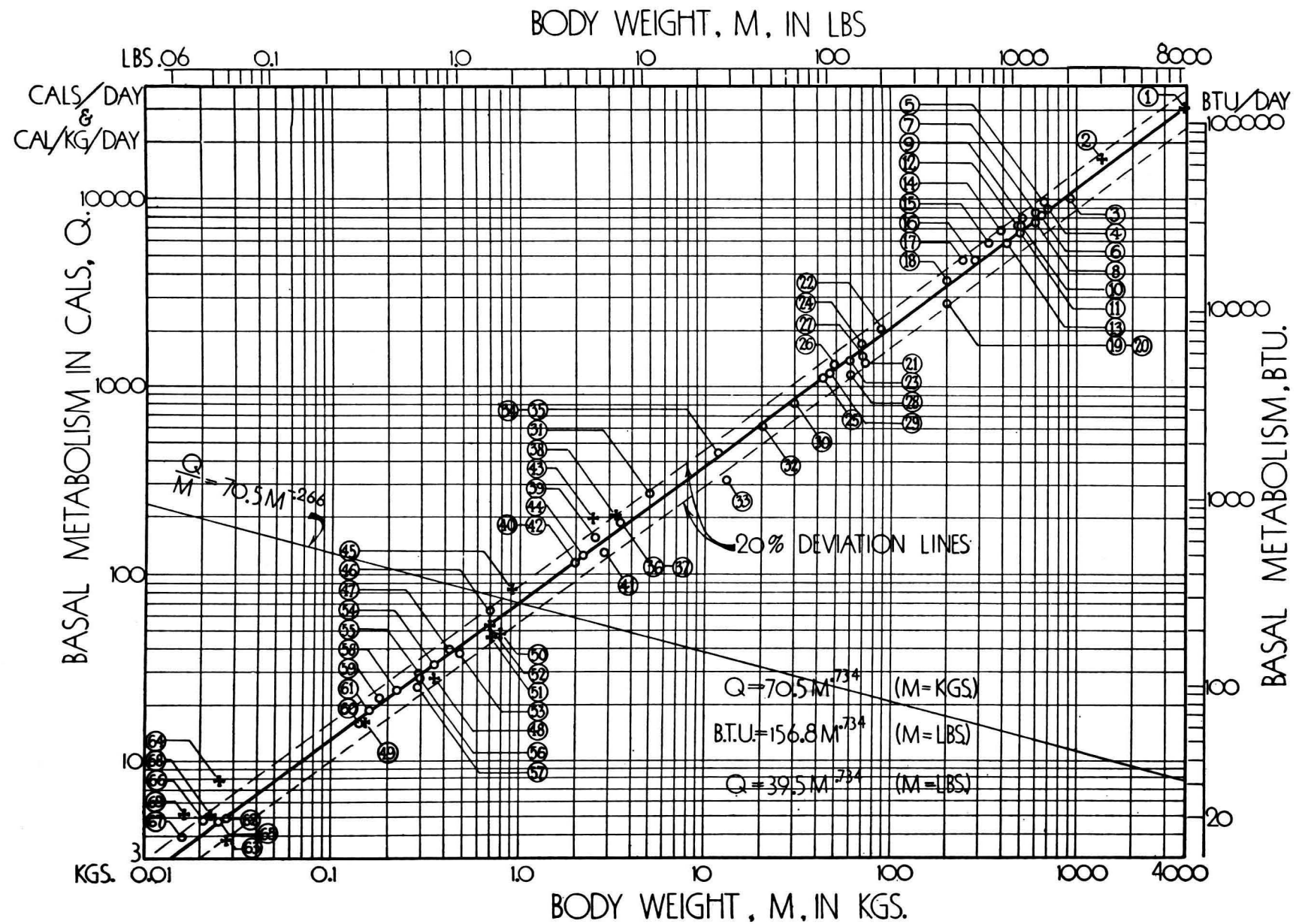
Fig. 1.—Basal metabolism, Q, plotted against body weight, M, on a logarithmic grid. The numbers enclosed in circles refer to the positions of the corresponding values in table 1 in the appendix. The data points represented by crosses were not included in fitting the equation to the data on account of the empirical corrections shown in the footnotes in Table 1. The metabolism per unit weight, Q/M, is given by the declining line.

Endogenous Urinary Nitrogen as a Function of Body Weight.
—These data, including a range in live weight from 0.02 kg. mice
to 500 kg. cattle, are presented in Figs. 2 and 2a based on data in
Tables 2 and 2a in which the sources of the data are also given.
Fig. 2 and table 2 are seen to include data from different sources,
and to five subgroups of these data separate equations were fitted
by the method of least squares. With the exception of Mitchell's
data on growing rats (which represent averages, while our plan
for fitting equations to the data in Fig. 2 called for individual data
points), Smuts' data on mice (which are off the general curve),
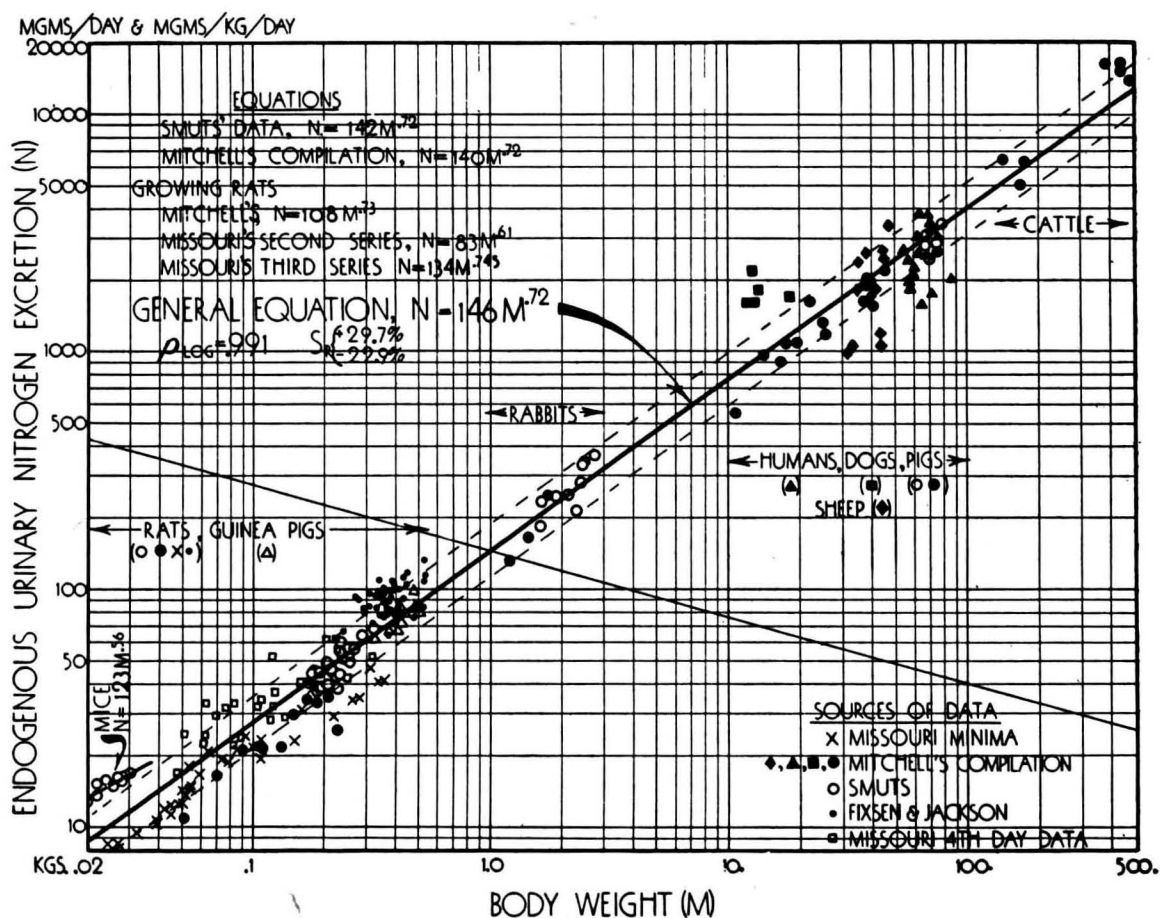
Fig. 2.—Endogenous urinary nitrogen data plotted against body weight.
The general equation is based on Smuts' data (excepting his mice), Mitchell's
compilation, Missouri data, but it does not include Mitchell's growing rat data,
nor the Missouri 4th day data. The broken lines on each side of the general
equation represent the values of the standard error of estimate, Sr, which are
+29.7% and —22.9% from the average curve. The numerical data, and their
sources, are given in Table 2 in the appendix.

and the Missouri 4th day data, all these data were included in the
general equation ($N = 146 \ M^{0.72}$ in which N stands for milligrams
per day endogenous urinary nitrogen for body weight M in kg.).
The index of correlation ρ between the logarithms of nitrogen and

logarithms of body weight is seen from Fig. 2 to be .991 (the precise significance of this high correlation between the **logarithms** of the variables is not altogether clear to the writers). The standard error of estimate, Sr, is +29.7% and −22.9% (which means that 2/3 of the data points are between +29.7% and −22.9% of the average curve, if the data constitute a normal distribution). The broken lines on each side of the average curve in Fig. 2 represent these deviations.*

It will be seen from the variations in the values of the exponents of the subgroups, and from the probable errors of the exponents given in the appendix, that the values of the exponents are sensitively responsive to the lay of the data, and that a difference of one or two units in the second place may be due to experimental errors. As the difference between the exponents of the basal metabolism and endogenous nitrogen weight curves is only one to two units in the second place, we may therefore formulate the exceedingly important conclusion that, within the limits of experimental errors, *the endogenous urinary nitrogen increases at the same rate with increasing body weight as does the basal metabolism.* Concretely, this means that increasing the body weight by 100% increases the minimum nitrogen (or protein) cost of maintenance not by 100%, but only by about 70%; likewise, the minimum energy cost of maintenance is increased by the same percentage, so that the ratio of the minimum nitrogen cost of maintenance to the minimum energy cost of maintenance remains prac-

---

*FORMULAS FOR DERIVING THE STANDARD ERROR OF ESTIMATE AND COEFFICIENT OF CORRELATION

$$S^2_{\log Y} = \frac{\Sigma \log^2 Y - \log A \Sigma \log Y - B\Sigma \log X \log Y}{N-1}$$

$$S_r = \text{antilog } S_{\log Y}$$

$$\rho^2 = \frac{\log A \Sigma \log Y + B\Sigma \log X \log Y - NM^2_{\log Y}}{\Sigma \log^2 Y - NM^2_{\log Y}}$$

$S_{\log Y}$ = Standard error of estimate of log Y

S_r = Standard error of estimate in ratio form

ρ = Index of correlation

Y = Nitrogen Variable

X = Body weight variable

A = Constant, 146

B = Slope constant, 0.72

N = Number of observations

$M^2_{\log Y}$ = Mean of log Y's squared

tically constant (about 2 mg. urinary N or about 2.4 mg. total N. per Calorie) for all body weights for this enormous range in live weight under consideration. This later conclusion, of course, confirms the results of Terroine and Sorg-Matter, and of Smuts.

An examination of the data in Table 2 showed that the data by Terroine *et al* for endogenous urinary nitrogen is, on the average, higher (by about 30%) than the other data in the table. In order to avoid confusion, we have therefore plotted the urinary as well as the total nitrogen data by Terroine *et al* on a separate chart, in Fig. 2a. The urinary nitrogen data for Fig. 2a are given in Table 2, while the total (including fecal) nitrogen for Fig. 2a are given in Table 2a. The exponent for the total nitrogen curve
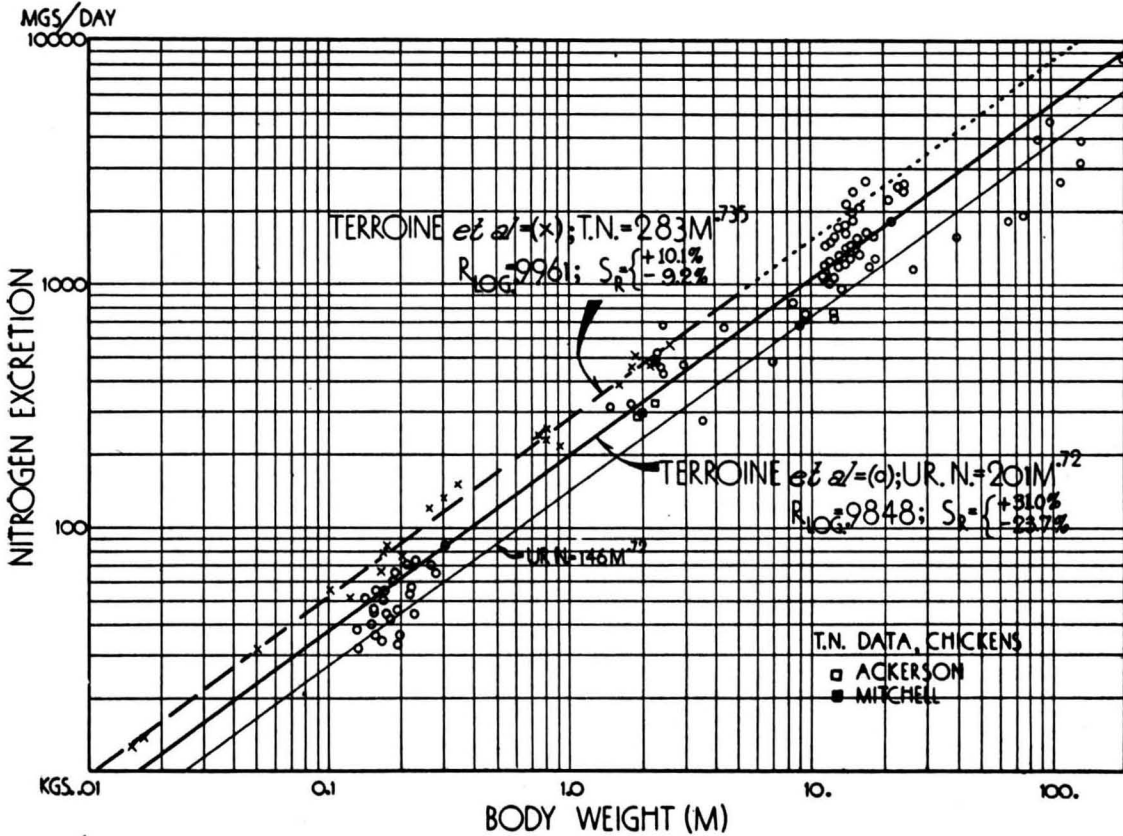
Fig. 2a.—Endogenous nitrogen plotted against body weight. The heavy solid line represents Terroine's urinary nitrogen data; the upper broken line Terroine's total (including fecal) nitrogen data; as indicated by the data in Table 2a. The lower light line is a reproduction, for purposes of comparison, of the general curve in Fig. 2 including endogenous urinary nitrogen other than Terroine's data. The percentage difference at body weight of 1 kg. between Terroine's urinary nitrogen and the general equation for urinary nitrogen is 38% (i. e. $\frac{201-146}{146}$ x 100); between Terroine's total nitrogen and Terroine's urinary nitrogen it is 41% (i. e. $\frac{283-201}{201}$ x 100); between Terroine's total nitrogen and the general equation for urinary nitrogen it is 94% (i. e. $\frac{283-146}{146}$ x 100).

in Fig. 2a differs from the urinary nitrogen curve by only 0.015; therefore, within the limits of experimental errors, the curves are parallel. But the general level of the total nitrogen curve is about 40% above the general level of the urinary nitrogen curve. The endogenous nitrogen in the feces is thus about 40% of the endogenous nitrogen of the urine (under the given conditions for the given range in live weight and for the given species of animals). (See the appendix for additional discussion of the relation between endogenous, fecal, and urinary nitrogen.)

For purposes of comparison, the average, or general, curve for urinary-nitrogen in Fig. 2 (not including the data by Terroine *et al*) is reproduced in Fig. 2a (the lower light line). This curve has the same exponent for its equation as the heavy curve in the center representing the data by Terroine *et al*, but Terroine's curve is about 38% higher.

Terroine's data (presented in tables 2 and 2a) represent averages of 7 to 10 days; if instead of these averages, the lowest 2-day averages are chosen from Terroine's data, then the general level of the resulting curve is lowered by about 20% (from Ur. $N=201$ $M^{0.72}$ to Ur. $N=182$ $M^{0.72}$); but this lowered curve is still above the average curve in Fig. 2 (Ur. $N.=146$ $M^{0.72}$). The chicken data for total nitrogen by Mitchell, and by Ackerson, while plotted on Fig. 2a, were not included in the general equation.

By way of summary it may be said that the endogenous urinary nitrogen of mature animals of different species increases with about the 0.73 power of live weight, which is, within the limits of experimental errors, of the same order of magnitude of increase as the power for the rate of increase of basal metabolism of mature animals of different species with increasing live weight. However, the general level of the endogenous urinary nitrogen curve (indicated by the coefficient in the power equation, or by the point in the chart where the curve crosses body weight of 1 kg.) is not as well defined as the general level of the basal metabolism curve. The average value of the coefficient of the nitrogen equation in Fig. 2 is seen to be 146, but it may be as low as 140, and on the other hand, as indicated by Fig. 2a, it may be as high as 200 (that is, for body weight of 1 kg., the endogenous urinary nitrogen excretion may be as low as 140 mg., or as high as 200 mg). The endogenous fecal nitrogen, for the given data under the given conditions, as indicated by the data in Fig. 2a., is about 40% of the endogenous urinary nitrogen. However, as pointed out by Smutts,

the numerical value of the endogenous fecal nitrogen is rather ill defined quantitatively on account of its variation with the nature and amount of the non-protein diet. It is very possible that other factors, such as structure of the digestive tract, etc., are important influencing factors.

Creatinine Nitrogen as a Function of Body Weight.—It is generally believed that creatinine nitrogen is a constant fraction of the endogenous urinary nitrogen. Both Terroine [cf. Terroine, Bonnet, Danmanville and Mourot, Bull. Soc. Chimie Biologique, **14**, 12 (1932); **14**, 47 (1932); **14**, 68 (1932)] and Smuts (loc. cit.) questioned this notion. Now we have plotted in Fig. 3, based on data in Table 3, a large body of data on creatinine nitrogen excretion for animals ranging in weight from 0.02 to 800 kg. which gives a
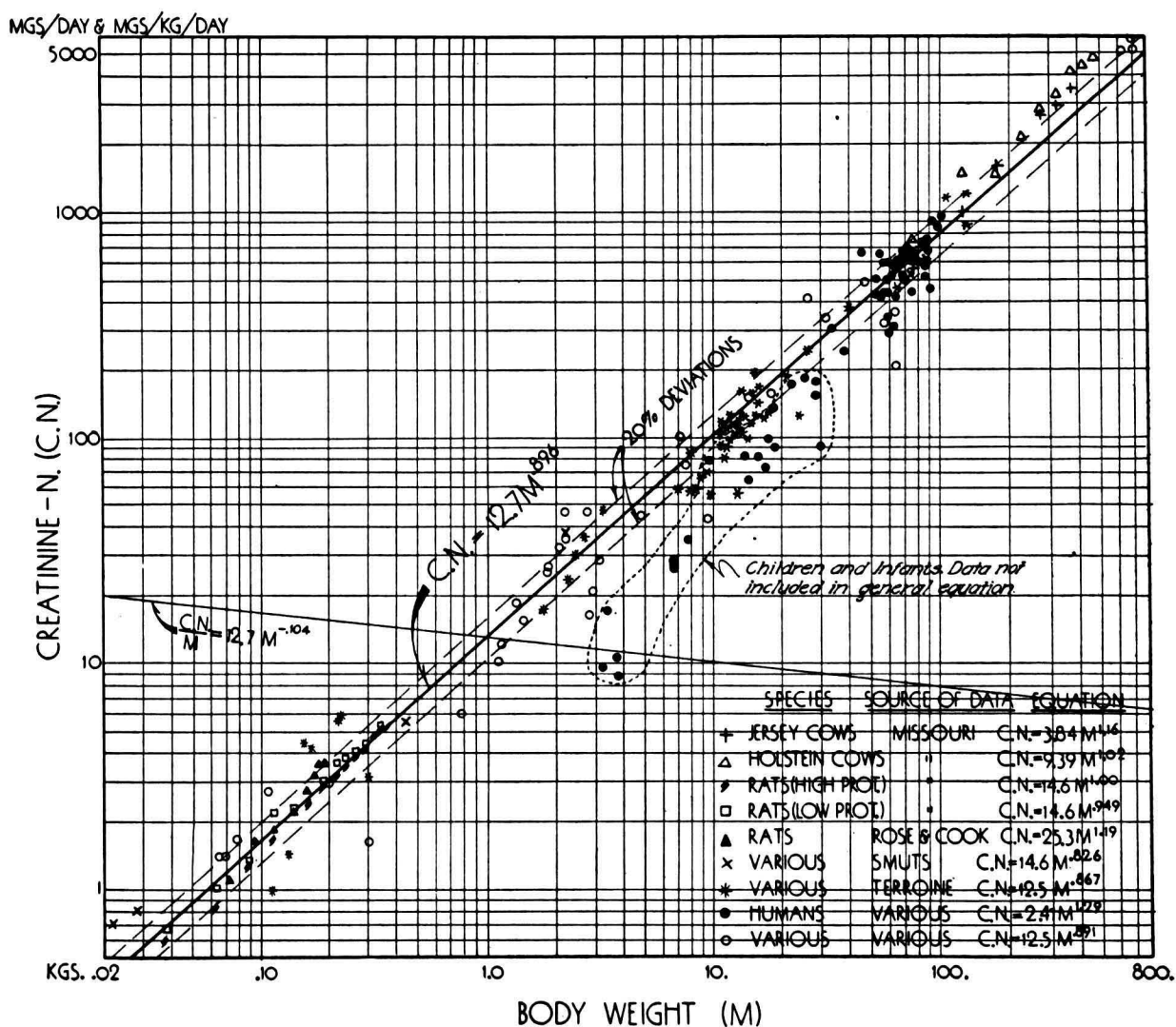
Fig. 3.—Creatinine nitrogen plotted against body weight. The data are in Table 3 in the appendix. The equation for the subgroups are given in the lower right-hand corner of the table. The declining curve represents the creatinine nitrogen per unit weight, CN/M.

broad basis for generalizing. It appears from Fig. 3 that for the Missouri data, which represent growing animals, and for animals of different size of the same species, the creatinine excretion is directly proportional to body weight (the exponent in the power equation is nearly unity). For humans of different weight the creatinine excretion increases even more rapidly than body weight (the exponent is 1.29). But for mature animals of different species the creatinine excretion increases with the 0.83 to 0.89 power of body weight. Since the endogenous nitrogen increases with but the 0.72 power of body weight, it therefore follows that the creatinine nitrogen percentage in the endogenous urinary nitrogen must increase with increasing body weight. Creatinine nitrogen, therefore, does not vary directly (i. e., linearly) with either endogenous nitrogen metabolism, or with basal metabolism, but rather with body weight.

Neutral Sulphur Excretion as Function of Body Weight.— While we have not done experimental work on this problem, it seemed interesting to examine in this connection and from this point of view the available data in the literature. The results of this examination are presented in Fig. 4 based on the compilation of data in table 4. The data points seem to be widely, even erratically, scattered in Fig. 4; but the slope (exponent in the equation) of the general curve is seen to be, within the limits of experimental errors, of the same order of magnitude as the slopes of the basal metabolism and endogenous nitrogen curves shown in Figs. 1 and 2.

Perhaps a word is needed for explaining the erratic distributions of the neutral-sulphur data in Fig. 4. As is well-known, Folin discovered the fact that the neutral sulphur excretion tends to be independent of the protein intake. No dietary precautions would therefore seem to be needed for securing reproducible data on neutral sulphur. As a matter of fact a large literature has recently grown up indicating that Folin's conclusion with regards to the constancy of neutral sulphur is relatively, but not absolutely, true. Since no special dietary precautions were taken in securing the neutral sulphur data, plotted in Fig. 4, and since the diet is an influencing factor after all, the distribution of the data in Fig. 4 is irregular.

The most recent, and perhaps the most extensive, discussion of the variability of neutral sulphur excretion, and its relation to the variations in energy, nitrogen and creatinine, is due to Amann.
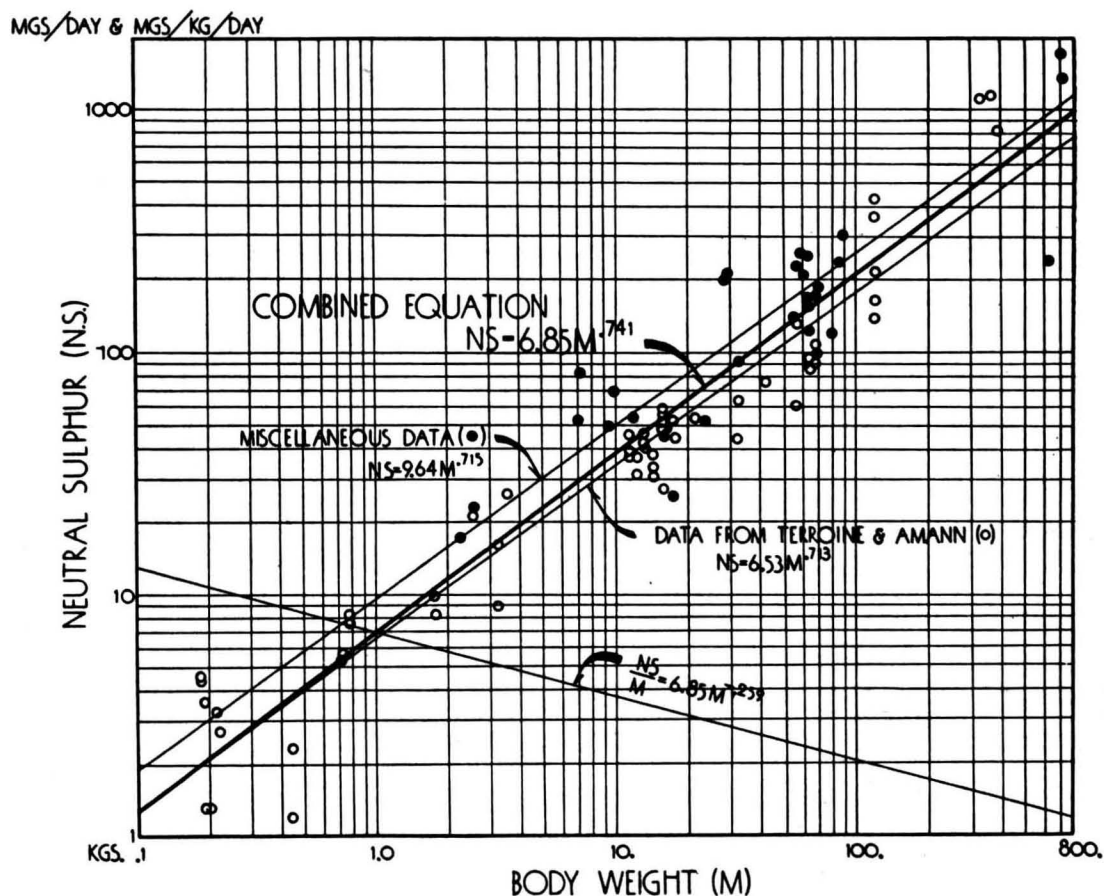
Fig. 4.—Neutral sulphur excretion plotted against body weight. The numerical data are given in Table 4 of the appendix. The lower black circle at the extreme right of the chart was not included in fitting the equation.

from Terroine's laboratory [Amann, Arch. Internat. Physiol., **37**, 121 (1933) and **37**, 139 (1933); Amann & Mourot, ibid., **37**, 150 (1933); Amann, ibid., **37**, 168 (1933)]. According to Amann and Mourot the neutral sulphur excretion is the same on low as on "normal" protein diets, but it is increased on high-protein diets. When the dietary protein is increased 15 times, the neutral sulphur excretion is tripled. In other words, the amount of neutral sulphur is not strictly endogenous (originating from destruction of tissue proteins only); it is not altogether independent of the diet, although, of course, it is relatively constant, that is in comparison with total sulphur excretion. According to Amann, the factors affecting the metabolism of energy also affect the excretion of neutral sulphur, but the neutral sulphur excretion is not definitely proportional to calorie production as is the case with endogenous nitrogen.

III. PREDICTION TABLES

Fig. 5 and Table A present, corresponding to given live weights, the numerical values for basal metabolism; endogenous urinary nitrogen excretion and its protein equivalents, that is, Nx6.25; creatinine nitrogen; neutral sulphur; and finally the ratios between the several variables. All these are based on the average, or general, equations in Figs. 1 to 4. The systematic deviations in the ratios of endogenous urinary nitrogen to basal metabolism are, as pointed out, due to the fact that while in the case of basal metabolism, the exponent relating it to body weight was found to be (by the method of least squares) 0.73, that for the urinary nitrogen, the exponent was only 0.72. Inasmuch as a difference of one unit in the second decimal place in the exponent is within the limits of experimental errors, the apparently systematic deviations of the ratio Mg. N/Cal. shown in Table A are without real physiological significance. The same is true as regards the Mg. Neutral S./Calories ratios. But in the case of the ratio of Mg. creatinine N,/Calories there is undoubtedly a systematic increase with increasing body weight. Likewise, consequently, the percentage of creatinine nitrogen with respect to total urinary nitrogen increases with increasing size of the animal. While the percentage of nitrogen in the form of creatinine nitrogen increases with increasing body weight, yet the nitrogen coefficient (Mg. creatinine N/kg. body wt.) decreases with increasing body weight. This is due to the fact that the exponent in the general equation relating creatinine to body weight is not quite unity. However, as pointed out, while this may be true of the general equation including all species of animals, this does not appear to be true as regards members of the same species, as indicated by the equations in the lower right-hand corner of Fig. 3.

The protein equivalent values of endogenous nitrogen presented in table A and Fig. 5 refer to endogenous urinary nitrogen, and in the case of Terroine's data also for total (including fecal) nitrogen. The average fecal nitrogen in the case of Terroine's data is seen to be about 41% of the urinary nitrogen. We cannot however infer from this that the endogenous fecal N is always 40% of the endogenous urinary nitrogen, inasmuch as Terroine's data included only small animals with simple digestive tracts (mice, rats, pigeons, chickens). The endogenous fecal ni-

TABLE A.—PREDICTION TABLE FOR BASAL METABOLISM, ENDOGENOUS URINARY NITROGEN, CREATININE N., NEUTRAL SULPHUR AND FOR RATIOS OF THE VARIOUS FACTORS.

Body Wt. Kgs.	Basal Metabolism Cals/Day Per Animal 1	Per Kg.	Endogenous Urin. Nitrogen Mgs/Day Per Animal 2	Per Kg.	Protein Equivalent Gms/Day Per Animal 3	Per Kg.	Creatinine-N Mgs/Day Per Animal 4	Per Kg.	Neutral Sulphur Mgs/Day Per Animal 5	Per Kg.	Ratios Urinary N Excretion to Basal Metabolism Mgs/Cals Urin. N.	Protein Equivalent	Creatinine N.	Neutral Sulphur	Creat. N. Urin. N. %	Neutral Sulphur Urin. N. Ratio	Cals. in Form Ur. N. Protein Per Day 6	% of Basal Metabolism
.01	2.40	240	5.30	530	.033	3.30	.205	20.5	.227	22.7	2.21	13.7	.085	.095	3.87	.0428	.132	5.50
.02	3.99	200	8.73	437	.055	2.75	.381	19.0	.379	18.9	2.19	13.7	.095	.095	4.36	.0434	.220	5.51
.03	5.37	179	11.7	390	.073	2.43	.549	18.3	.501	16.7	2.18	13.6	.102	.095	4.69	.0428	.292	5.44
.04	6.64	166	14.4	360	.090	2.25	.710	17.8	.633	15.8	2.17	13.5	.107	.095	4.93	.0439	.360	5.42
.05	7.82	156	16.9	338	.106	2.12	.867	17.3	.746	14.9	2.16	13.5	.111	.095	5.13	.0441	.424	5.42
.06	8.94	149	19.3	327	.121	2.02	1.02	17.0	.854	14.2	2.16	13.5	.114	.095	5.28	.0442	.484	5.41
.07	10.0	143	21.5	307	.134	1.91	1.17	16.7	.957	13.7	2.15	13.4	.117	.096	5.44	.0445	.539	5.39
.08	11.0	138	23.7	296	.148	1.85	1.32	16.5	1.06	13.3	2.15	13.4	.120	.096	5.57	.0447	.592	5.38
.09	12.0	133	25.8	287	.161	1.79	1.47	16.3	1.15	12.8	2.15	13.4	.123	.096	5.70	.0446	.644	5.37
.10	13.0	130	27.8	278	.174	1.74	1.61	16.1	1.25	12.5	2.14	13.4	.124	.096	5.79	.0450	.696	5.35
.20	21.6	108	45.8	229	.286	1.43	3.00	15.0	2.08	10.4	2.12	13.2	.139	.096	6.55	.0454	1.14	5.28
.30	29.1	97.0	61.4	205	.384	1.28	4.32	14.4	2.81	9.37	2.11	13.2	.148	.096	7.03	.0458	1.54	5.27
.40	36.0	90.0	75.5	189	.472	1.18	5.59	14.0	3.48	8.70	2.10	13.1	.155	.097	7.40	.0461	1.89	5.25
.50	42.4	84.8	88.6	177	.554	1.11	6.82	13.6	4.10	8.20	2.09	13.1	.161	.097	7.70	.0463	2.22	5.24
.60	48.5	81.0	101	168	.631	1.05	8.04	13.4	4.69	7.82	2.08	13.0	.166	.097	7.96	.0464	2.52	5.20
.70	54.3	77.6	113	161	.706	1.01	9.23	13.2	5.26	7.51	2.08	13.0	.170	.097	8.17	.0465	2.82	5.19
.80	59.9	74.9	124	155	.775	.969	10.4	13.0	5.81	7.26	2.07	12.9	.174	.097	8.39	.0468	3.10	5.17
.90	65.3	72.6	135	150	.884	.938	11.6	12.9	6.34	7.04	2.07	12.9	.179	.097	8.59	.0470	3.38	5.17
1.00	70.5	70.5	146	146	.913	.913	12.7	12.7	6.85	6.85	2.07	12.9	.180	.097	8.70	.0470	3.65	5.17
2.00	117	58.5	241	121	1.51	.755	23.6	11.8	11.4	5.70	2.06	12.9	.202	.097	9.79	.0473	6.04	5.16
3.00	158	52.7	321	107	2.01	.670	34.0	11.3	15.4	5.13	2.03	12.7	.215	.097	10.6	.0480	8.04	5.09
4.00	195	48.8	396	99.0	2.47	.618	44.0	11.0	19.1	4.78	2.03	12.7	.226	.098	11.1	.0482	9.88	5.07
5.00	230	46.0	465	93.0	2.91	.582	53.7	10.7	22.5	4.50	2.02	12.7	.233	.098	11.5	.0484	11.6	5.04
6.00	263	43.8	530	88.3	3.31	.551	63.2	10.5	25.8	4.30	2.01	12.6	.240	.098	11.9	.0487	13.2	5.03
7.00	294	42.0	593	84.7	3.71	.530	72.6	10.4	28.9	4.13	2.01	12.6	.247	.098	12.3	.0487	14.8	5.03
8.00	324	40.5	652	81.5	4.07	.509	81.8	10.2	31.9	3.99	2.01	12.6	.252	.098	12.5	.0489	16.3	5.03
9.00	354	39.3	710	78.9	44.4	.493	90.9	10.1	34.8	3.87	2.00	12.5	.257	.098	12.8	.0490	17.8	5.03
10.0	382	38.2	766	76.6	4.79	.479	100	10.0	37.6	3.76	2.00	12.5	.262	.099	13.1	.0491	19.2	5.02
20.0	636	31.8	1260	63.0	7.87	.393	186	9.30	62.9	3.15	1.98	12.4	.292	.099	14.8	.0499	31.5	4.95
30.0	856	28.5	1690	56.3	10.6	.353	267	8.90	84.9	2.83	1.97	12.4	.312	.099	15.8	.0502	42.4	4.95
40.0	1060	26.5	2080	52.0	13.0	.325	346	8.65	105	2.63	1.96	12.3	.326	.099	16.6	.0505	52.0	4.91
50.0	1250	25.0	2440	48.8	15.3	.306	423	8.46	124	2.48	1.96	12.2	.338	.099	17.3	.0508	61.2	4.90
60.0	1420	23.7	2780	46.3	17.4	.290	498	8.30	142	2.37	1.95	12.2	.351	.099	17.9	.0511	69.6	4.90
70.0	1590	22.7	3110	44.4	19.4	.277	571	8.16	159	2.27	1.95	12.2	.359	.099	18.4	.0511	77.6	4.88
80.0	1760	22.0	3420	42.7	21.4	.267	644	8.05	175	2.19	1.94	12.2	.366	.099	18.8	.0512	85.6	4.86
90.0	1920	21.3	3730	41.4	23.3	.259	716	7.96	191	2.12	1.94	12.1	.373	.099	19.2	.0512	93.2	4.85
100	2070	20.7	4020	40.2	25.1	.251	787	7.87	207	2.07	1.94	12.1	.380	.100	19.6	.0515	100	4.83
200	3450	17.3	6620	33.1	41.4	.207	1460	7.30	345	1.72	1.92	12.0	.423	.100	22.1	.0521	166	4.81
300	4640	15.5	8870	29.6	55.4	.185	2105	7.02	466	1.55	1.91	11.9	.454	.100	23.7	.0525	222	4.78
400	5730	14.3	10910	27.3	68.2	.171	2725	6.81	577	1.44	1.90	11.9	.475	.101	25.0	.0529	273	4.76
500	6750	13.5	12810	25.6	80.1	.160	3330	6.66	681	1.36	1.90	11.9	.493	.101	25.9	.0532	320	4.74
600	7715	12.9	14610	24.3	91.3	.152	3920	6.53	789	1.31	1.89	11.8	.508	.101	26.8	.0534	365	4.73
700	8640	12.3	16320	23.3	102	.146	4500	6.43	873	1.25	1.89	11.8	.521	.101	27.6	.0535	408	4.72
800	9530	11.9	17970	22.5	112	.140	5070	6.34	964	1.21	1.89	11.8	.532	.101	28.2	.0536	448	4.70
900	10390	11.5	19560	21.7	122	.135	5630	6.26	1050	1.17	1.88	11.7	.542	.101	28.8	.0537	488	4.70
1000	11220	11.2	21100	21.1	132	.132	6190	6.19	1140	1.14	1.88	11.7	.552	.102	29.3	.0540	528	4.70

1. Computed from equation $Q = 70.5M^{0.734}$ (see Fig. 1).
2. Computed from equation $Ur.N = 146M^{0.72}$ (based on data and equation given in Fig. 2).
3. Protein equivalent = endog. urin. nitrogen times 6.25.
4. Computed from equation $C.N. = 12.7M^{0.896}$ (based on data and equation given in Fig. 3)
5. Computed from equation $N.S. = 6.85M^{0.74}$ (based on data and equation given in Fig. 4)
6. Calorific equivalent = gm. protein $\times$ 4.

Fig. 5.—Prediction chart giving the various metabolic activities as functions of body weight. Numerical prediction values are given in Table A.

trogen apppears to vary, as pointed out by Smuts, not only with size of the animal but also with the kind and amount of nitrogen-free diet consumed, as well as with the species. The endogenous fecal nitrogen excreted by cattle, sheep, and other herbivora, particularly ruminants, is undoubtedly greater in comparison to the urinary nitrogen than in the case of rats, chickens, dogs, humans, and other carnivorous or omnivorous species with simple digestive tubes. This uncertainty concerning the fecal nitrogen excretion makes it difficult to estimate the total (including

fecal) endogenous nitrogen losses. If one assumes that in carnivors and in omnivors the endogenous fecal nitrogen is 40% of the urinary nitrogen; in non-ruminating herbivors it is 60%; in ruminating herbivors it is 80%; and if one further assumes that the biological value of protein is 100%, then the minimum need of digestible protein for maintenance would be respectively 1.4, 1.6 and 1.8 times that given in table A. If the biological value of the protein is 50%, then the minimum need would be respectively 2.8, 3.2 and 3.6 times that given in table A. These estimates are, of course, offered merely as illustrations of the manner in which table A and Fig. 5 might be used as guides in practical nutritional problems. One must also remember when using table A that, as pointed out in the introduction, the endogenous level of urinary excretion is greatly influenced by (1) the nature of the diet preceding the non-protein feeding period; (2) the time the animal is kept on the N-free diet. The endogenous nitrogen level is therefore an empirically, or conventionally, determined and not a rigorously defined biological entity; therefore the prediction values in table A. derived from the conventionally determined endogenous level, must likewise be considered at present as conventional estimates needing experimental substantiation.

As regards food energy requirements for maintenance, in case of cattle feeds, the net energy is about 50% of the gross energy; therefore the food (gross) energy required for maintaining quietly resting cattle is about double the values given in Table A. In the case of humans, the average net-energy value of human food is probably of the order of 75% of the gross energy; therefore, the food energy required for maintaining quietly resting humans is about 1.3 times the expenditure values given in Table 1. Of course, additional energy must be supplied for muscular activity. Thus walking at moderate speed increases the energy expenditure about 100% above standing; hence the net energy in the food must be twice as great when supplying energy for walking than for standing.

It seems instructive to illustrate the above theoretical discussion by a practical issue. This may be done by formulating tentative maintenance feeding standards which follow the same course with increasing body weight as do the basal metabolism and endogenous nitrogen curves in Figs. 1 and 2. The fecal-nitrogen uncertainty may be avoided by presenting the standards in terms of conventional *digestible* nutrients. In the proposed standard one gram "digestible nutrients" is

taken to be equivalent to four Calories (or one pound digestible nutrients equivalent to 1812 Cal.) This is a conventional equivalent used, for example, in Sherman's text book. The protein needs are presented in terms of conventional "digestible crude protein" ("digestible nitrogen" x 6.25). The proposed tentative feeding standards are presented in Table B. To assist the eye, and for comparative purposes, the situation is exhibited graphically in Figs. 6 and 7. In these charts the heavy curves, designated by (A), represent basal metabolism, or endogenous urinary nitrogen. The lighter curves designated
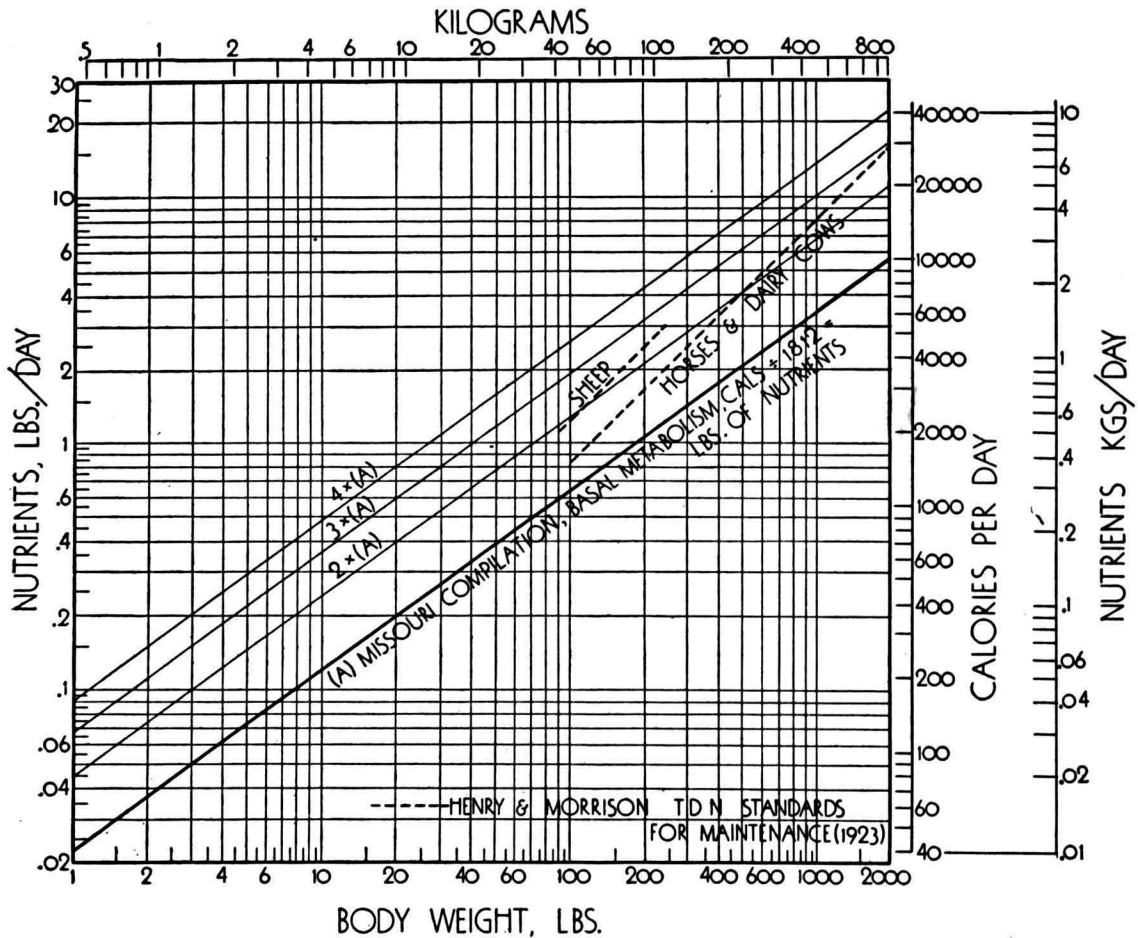
Fig. 6.—(A) designates the weight curve of basal metabolism; 2A, 3A & 4A designate respectively 2, 3, & 4 times basal energy levels. The proposed T D N standard represents curve 2A. (1 gm. T D N is considered equivalent to 4 Cal. or 1 pound to 1812 Cal.). The broken curves represent Henry & Morrison's maintenance standards (1923). The values of B in equation $T D N = BM^{0x73}$ may be helpful (B is the value of T D N when body weight, M, = 1).

Body weight units	T D N units	Multiples of basal metabolism, A	Values of B
pounds	pounds	1 A	.0218
pounds	pounds	2 A	.0436
kg.	kg.	2 A	.0352
kg.	Cal.	2 A	141.0
pounds	Cal.	2 A	79.2

by (2A), (3A), (4A), represent 2, 3, 4 times the basal levels. The broken curves represent Henry & Morrison's feeding standards (1923) for maintenance, which increase *directly* with body weight (curves A, 2A, etc. increase with the 0.73 power of body weight).

The total digestible nutrient (or Cal.) values in table B represent curve (2A) in Fig. 6, (i. e., assuming the maintenance requirement for energy is double the basal.metabolism); the digestible crude protein values in table B represent curve (4A) in Fig. 7 (i. e., assuming the maintenance requirement for digestible crude protein is four times the
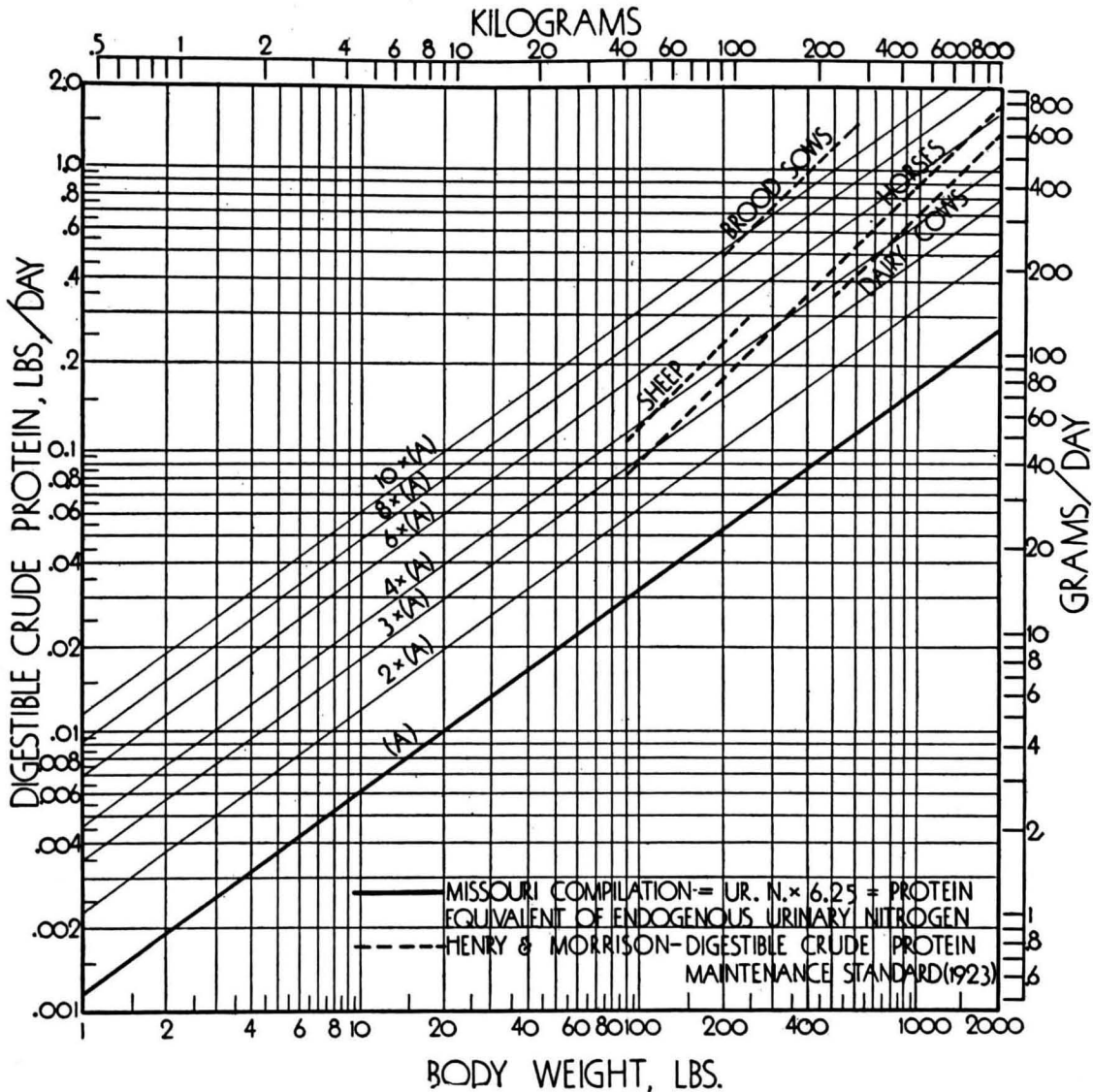
Fig. 7.—(A) designates the weight curve of the D C P (digestible crude protein) equivalent of urinary endogenous nitrogen (1 unit D C P is equivalent to 6.25 units urinary endogenous nitrogen). 2a, 3A etc. designate respectively, 2, 3 .... times the urinary endogenous level curve. 4A (i. e., 4 times endogenous level) represents the proposed D C P standard for maintenance. The broken curves represent Henry & Morrison's maintenance standards (1923). The following values of B in equation $D C P = B M^{0.72}$ may be helpful (B is the value of D C P when body weight, M, = 1).

Body weight units	D C P units	Multiples of endogenous urinary nitrogen level, A	Value of B
pounds	pounds	A	.00113
pounds	pounds	4 A	.00452
kg.	kg.	4 A	3.65
pounds	gm.	4 A	2.05

protein equivalent of the endogenous urinary nitrogen excretion). These standards are in agreement with the 3000 Cal. and 70 to 80 gm. protein maintenance allowance for a 70 Kg. man, or with Henry &

Morrison's maintenance requirement standards for about 500-pound farm animals (Henry & Morrison's standards are seen in Figs. 6 and 7 to be higher for heavier animals and lower for lighter animals than the tenttive standards here proposed). The new contribution of the "standards" here proposed are: (1) they are probably equally applicable to all species of warm blooded animals from mice to elephants; (2) they show that the maintenance requirements per unit weight decline with increasing weight not only as regards energy (or T D N) but also as regards nitrogen (or D C P) with some indication that a similar decline will be found to hold true with respect to most other nutrients. The maintenance requirements are shown in table B to vary not directly with body weight (as indicated by all current feeding standards), nor with the 2/3 power of body weight (as might be inferred from "Rubners' law") but with the 0.73 power ob body weight.

No finality would be claimed for the *absolute* values for energy and protein indicated in table B, even if conoditions of activity and environmental temperature could be held constant. It is however, believed that future investigations are not likely to change appreciably the *relative* maintenance requirements between animals of different weights (i.e., they are not likely to change the slope of the curves in Figs. 6 and 7).

SUMMARY AND CONCLUSIONS

Basal metabolism, endogenous nitrogen excretion and possibly neutral sulphur excretion follow the same course with increasing body weight in mature animals of different species; they all increase with, roughly, the 0.73 (0.72 to 0.74) power of body weight. Creatinine, on the other hand tends to increase with the 0.90 power of body weight for mature animals of different species, and directly with body weight in animals of the same species. It follows that, within the limits of experimental errors, the ratios of endogenous nitrogen to basal metabolism and to a less extent the ratios of neutral sulphur to basal metabolism tend to remain constant for all body weights; while the ratios of creatinine to basal metabolism, and also creatinine nitrogen to endogenous urinary nitrogen, increase with body weight. Since the exponent relating creatinine with body weight of animals of different species is less than unity, therefore the ratio of creatinine to body weight (creatinine coefficient) tends to decrease with increasing live weight. Extensive prediction tables are presented based on these findings.

The direct proportionality between creatinine and body weight is in conformity with all the evidence that creatinine represents the muscular mass, and therefore the principal active mass, of the body. The

correlation between basal metabolism and endogenous nitrogen in all mature warm-blooded animals indicates a general similarity in the chemistry of animals; a constant balance level in all animals between breakdown and resynthesis. Such a balance, and correlation between energy and nitrogen metabolism, might be expected from Borsook & Keighley's theory of protein metabolism since: (a) deamination is an oxidative process; (b) urea synthesis requires the combustion of some metabolite, whether oxygen is used or not; (c) resynthesis of ammonia and amino acids to protein requires energy. This much can not be said as regards neutral sulphur, since (a) it is not a well defined entity; (b) it is not altogether independent of protein intake.

TABLE B—FEEDING STANDARDS FOR MAINTENANCE.*

	Pound System							Gram System					
	T. D. N., lbs.		D. C. P., lbs.		T. D. N., Cals.			T. D. N., gms.		D. C. P., gms.		T. D. N., Cals.	
Body wt. lbs.	per animal	per 1000 lbs.	per animal	per 1000 lbs.	per animal	per lb.	Body wt. kgs.	kgs. per animal	gms. per kg.	per animal	per kg.	per animal	per kg.
2000	11.20	5.60	1.16	.580	20300	10.2	1000	5.45	5.45	564	.564	21800	21.8
1900	10.79	5.68	1.12	.589	19500	10.3	900	5.05	5.61	524	.582	20200	22.4
1800	10.37	5.76	1.07	.595	18800	10.4	850	4.85	5.71	504	.593	19400	22.8
1700	9.95	5.85	1.03	.606	18000	10.6	800	4.63	5.79	480	.600	18500	23
1600	9.52	5.95	.988	.617	17300	10.8	750	4.43	5.91	460	.613	17700	23.6
1500	9.08	6.05	.941	.627	16500	11.0	700	4.23	6.04	436	.623	16900	24.1
1400	8.63	6.16	.894	.639	15600	11.1	650	3.97	6.11	412	.634	15900	24.5
1300	8.18	6.29	.848	.652	14800	11.4	600	3.77	6.28	390	.650	15100	25.2
1200	7.71	6.43	.801	.667	14000	11.7	550	3.53	6.42	366	.665	14100	25.6
1100	7.24	6.58	.750	.682	13100	11.9	500	3.27	6.54	341	.682	13100	26.2
1000	6.75	6.75	.699	.699	12200	12.2	450	3.05	6.78	316	.702	12200	27.1
900	6.25	6.94	.648	.720	11300	12.5	400	2.80	7.00	290	.725	11200	28.0
800	5.74	7.17	.594	.743	10400	13.0	350	2.53	7.23	263	.751	10100	28.9
700	5.21	7.44	.539	.770	9440	13.5	300	2.26	7.53	235	.783	9050	30.2
600	4.65	7.75	.480	.80	8430	14.1	250	1.99	7.96	206	.824	7950	31.8
500	4.07	8.14	.422	.844	7375	14.7	200	1.69	8.45	175	.875	6750	33.7
400	3.46	8.65	.359	.897	6270	15.7	150	1.36	9.07	142	:947	5450	36.3
350	3.14	8.97	.325	.929	5690	16.3	125	1.20	9.60	128	1.02	4790	38.3
300	2.80	9.33	.291	.970	5070	16.9	100	1.02	10.2	105	1.05	4070	40.7
250	2.45	9.80	.254	1.02	4440	17.8	90	0.943	10.5	97.6	1.08	3770	41.9
200	2.09	10.45	.216	1.08	3790	18.9	80	0.863	10.8	89.6	1.12	3450	43.1
150	1.69	11.27	.175	1.17	3060	20.4	70	0.783	11.2	81.2	1.16	3130	44.7
125	1.48	11.84	.153	1.22	2680	21.4	60	0.700	11.7	72.4	1.21	2800	46.7
100	1.26	12.60	.130	1.30	2283	22.8	50	0.613	12.3	63.6	1.27	2450	49.0
75	1.02	13.60	.106	1.41	1850	24.1	40	0.523	13.1	54.0	1.35	2090	52.3
50	.758	15.16	.0785	1.57	1370	27.4	30	0.423	14.1	43.6	1.45	1690	56.3
25	.457	18.28	.0473	1.89	828	33.1	20	0.313	15.7	32.5	1.63	1250	62.5
10	.234	23.40	.0243	2.43	424	42.4	10	0.189	18.9	19.6	1.96	755	75.5
9	.217	24.11	.0225	2.50	393	43.7	9	0.175	19.4	18.2	2.02	700	77.8
8	.199	24.87	.0206	2.57	361	45.1	8	0.161	20.1	16.7	2.09	645	80.6
7	.181	25.86	.0191	2.73	328	46.9	7	0.146	20.9	15.1	2.16	585	83.6
6	.161	26.83	.0167	2.78	292	48.7	6	0.130	21.7	13.5	2.25	520	86.7
5	.141	28.20	.0146	2.92	255	51.0	5	0.114	22.8	11.8	2.36	457	91.4
4	.120	30.00	.0124	3.10	217	54.3	4	.0970	24.3	10.0	2.50	388	97.0
3	.0972	32.40	.0101	3.37	176	58.7	3	.0787	26.2	8.16	2.72	315	105
2	.0723	36.15	.00750	3.75	131	65.5	2	.0585	29.3	6.04	3.02	234	117
1	.0436	43.60	.00453	4.53	79.0	79.0	1	.0353	35.3	3.65	3.65	141	141
.9	.0404	44.89	.00418	4.64	73.2	81.3	.9	.0327	36.3	3.38	3.75	131	145
.8	.0371	46.38	.00384	4.80	67.2	84.0	.8	.0300	37.5	3.10	3.87	120	150
.7	.0336	48.00	.00348	4.97	60.9	87.0	.7	.0273	39.0	2.82	4.03	109	156
.6	.0300	50.00	.00311	5.18	54.4	90.7	.6	.0243	40.5	2.52	4.20	97.0	162
.5	.0263	52.60	.00273	5.46	47.6	95.2	.5	.0213	42.6	2.20	4.40	85.0	170
.4	.0223	55.75	.00232	5.80	40.4	100.1	.4	.0181	45.3	1.87	4.67	72.5	181
.3	.0181	60.33	.00187	6.23	32.8	109.3	.3	.0146	48.7	1.52	5.07	58.5	195
.2	.0135	67.50	.00139	6.95	24.5	122.5	.2	.0109	54.5	1.13	5.65	43.5	217
.1	.0081	81.00	.00084	8.40	14.7	147.0	.1	.0065	65.0	.068	6.80	26.0	260

*Computed from equation $Y = AM^{0.73}$ in which Y represents TDN (total digestible nutrients per day = digestible crude protein + digestible carbohydrates + digestible fat $\times 2.25$). or DCP (digestible crude protein per day = N $\times 6.25$) for body weight M, and from the assumptions that TDN energy (4 Cal. per gram or 1812 Cal. per pound) is twice basal-metabolism energy. and DCP is four times the DCP equivalent of endogenous urinary nitrogen. (The nutritive ratios are thus always 1:8.7 or what is the same, 10.34% of the total calories, or of the TDN, is in the form of protein.)

V. APPENDIX

The Probable Errors of The Exponents of the Equations in this Bulletin.—In order to determine whether or not the differences in the exponents of the several equations are significant, the probable and standard errors were computed. The standard error indicates that the chances are 2 to 1 that the true value of the exponent is within the range of plus or minus the standard error, whereas the probable error indicates that the chances are even that the true value of the exponent is within the range of plus or minus the probable error. The probable error is the standard

error times 0.6745.   The standard error$= \left\{ \frac{[\Sigma \log^2 Y/N - (M_{\log X})^2][1-\rho^2]}{[\Sigma \log^2 X/N - (M_{\log Y})^2][N-1]} \right\}^{\frac{1}{2}}$

Where Y=dependent variable, i. e. nitrogen, metabolism etc.

X=independent variable, body weight

$M_{\log X}$ or $M_{\log Y}$ =Mean of log X or log Y

N=number of observations

ρ =index of correlation

The following table summarizes the equations and the standard and probable errors of their exponents.

Figure	Equation	Errors of Exponent			
		Standard error,σ_n		Probable error, P.E.σ_n	
		$n \pm \sigma_n$	Range	$n \pm$P.E.σ_n	Range
1	$Q = 70.5M^{0.734}$	$.734 \pm .005$	.729-.739	$.734 \pm .003$	.731-.737
2	$N = 146M^{0.718}$	$.718 \pm .007$	.711-.725	$.718 \pm .005$	.713-.723
2a	$T.N. = 283M^{0.735}$	$.735 \pm .013$	.722-.748	$.735 \pm .009$	.726-.744
3	$NS = 6.85M^{0.741}$	$.741 \pm .025$	.716-.766	$.741 \pm .017$	.724-.758
4	$C.N = 12.7M^{0.896}$	$.896 \pm .007$	.889-.903	$.896 \pm .005$	.889-.903

Notes On Fecal Nitrogen.—As indicated in the text, the most serious obstacle to estimating the endogenous nitrogen expenses is the variability in the fecal nitrogen excretion. For one thing, the amount of the N-free diet consumption influences the fecal

nitrogen.   Schneider [Bioc. J. **28**, 360 (1934)] found that the fecal
N excretion in the rat is increased by 1 mg. if the dietary dry mat-
ter intake is increased by 1.26 gm.   An analysis we made of
Mitchell's data [J. Biol. Chem. **105**, 537 (1934)] indicates that if
the weight of the rat is held constant, the fecal N is increased by
1 mg., if the high carbohydrate diet is increased by 1.31 of if the
high fat diet is increased by 1.43 gm.   An analysis we made of
data on rats by Fixsen & Jackson [Bioc. J. **26**, 1919 (1932)] indi-
cates that, when body weight is held constant, the fecal N is in-
creased by 1 mg. if the dietary dry matter is increased by only
0.52 gm.   The following table gives the equations and statistical
constants.

Mitchells high carbo-hydrate diet rats $X_1=13.933+.1276X$ $+1.3135X_3$ $R_{1.23}=.938$			Mitchells high fat diet rats $X_1=12.435+0.1010X$ $+1.4250X_3$ $R_{1.23}=.786$			Fixsen & Jackson's rats $X_1=6.00+.02125X$ $+.5247X_3$ $R_{1.23}=.619$		
Variables	β	%	Variables	β	%	Variables	β	%
12.3	.166	16.4	12.3	.460	38.8	12.3	.392	46.7
13.2	.846	83.6	13.2	.726	61.2	13.2	.447	53.3

Where
    X_1 = Fecal nitrogen, mgs. per day
    X_2 = Body weight, gms.
    X_3 = Dry matter of food, gms. per day
    $R_{12.3}$ = Total or multiple correlation
    β = Beta coefficient and represents the comparative importance of the
        various dependent variables
    12.3 = Study between fecal-N and body weight with food intake held constant
    13.2 = Study between fecal-N and feed intake with body weight held constant.
    % = Indicates the per cent of comparative importance of the dependent
        variables.

According to the aforecited papers by Mitchell and by
Schneider, the metabolic nitrogen of feces is made up of two dis-
tinct fractions; (1) a very small fraction, represented by the fecal
nitrogen during fasting, considered as truly excretory; (2) a frac-
tion which varies directly with the intake of dry matter, considered
as a digestive waste.   The equations in the preceding paragraph
are of course based on the assumptions by Mitchell and Schneider.
Mitchell further believes that the ratio of metabolic fecal nitrogen
to dry matter consumed varies directly with the intake of indi-
gestible nitrogenous matter.

From the time curves of nitrogen excretion on N-free diets we have taken the lowest values for nitrogen excretion for our 3 groups of rats (Missouri data), and determined the percentage ratio fecal/Urinary N with the following results: (1) For 21 immature rats (average initial body weight 51 grams), the fecal nitrogen was 27.29±0.63% of the urinary nitrogen.   (2) For 64 relatively mature animals (average initial body weight 363 grams) the fecal nitrogen was 26.84±0.54% of the urinary nitrogen.   (3) For a third group of 20 rats ranging in weight from 31 to 382 grams the average fecal to urinary nitrogen percentage was 26.40 ±0.68.   [The probable error= $\dfrac{.6745\sigma}{N-1}$; where σ is the standard deviation=the square root of $\Sigma X^2/N-(Mx)^2$.

N is the number of determinations
X is the percentage ratio
Mx is the mean of X.]

A similar examination of data on rats on N-free diets by Fixsen & Jackson [Bioc. J. **26**, 1919 (1932)] indicates that fecal N/urinary N=20.4%.   An examination of the endogenous nitrogen data on rats by Terroine and Reichert [Arch. Internat. Physiol., **32**, 337 (1930)] indicates that fecal N/urinary N=60%.   The average of the data on the dog by Underhill and Goldschmidt [J. Biol. Chem. **15**, 341 (1913)] gives fecal N/urinary N=25%.   Siven's [Skand. Arch. Physiol., **10**, 91 (1900)] data on humans indicate that the percentage ratio of fecal N/urinary N varies for his several experiments from 27 through 35 to 38%.   Voltz' [Bioc. Z., **102**, 151 (1920)] data on sheep indicate the fecal N/urinary N=71%; while Klein and Steuber's data on sheep [Bioc. Z **133**, 137 (1922)] indicate a ratio of 87%.   Data on cattle by Hart, Humphrey and Morrison [J. Biol. Chem. **13**, 133 (1912)] indicate a fecal N/urinary N percentages of about 125% (one group gave an average of 138% on a very low N diet).   When we averaged the results of several fasting experiments on steers by Benedict and Ritzman [Publication 377 Carnegie Institution of Washington (1927)] we found a fecal N/urinary N ratio of 28%.   It is thus clear that feed ingestion has a profound influence on the fecal N excretion in ruminants.   This is further substantiated by Titus' [J. Agric. Res. **34**, 49 (1927)] experiments on steers.   As the alfalfa in the ration was replaced by equivalent weights of cellulose the urinary nitrogen

was of course decreased, but the fecal N/urinary N percentage was increased on account of the relative constancy of the fecal N excretion, as indicated by the following table. The steers were receiving 12 lbs. of feed divided between alfalfa and cellulose.

Alfalfa in diet %	Protein in diet %	Fecal N. gm.	Urinary N. gm.	Fecal N. Urinary N. %
100	13.6	388	992	39
100	12.7	377	954	40
85	10.6	350	735	48
85	10.3	347	703	49
70	8.38	316	517	61
70	8.35	333	507	66
55	6.80	340	284	120
55	7.20	341	318	107
40	5.06	313	161	183

Beginning with the 85% alfalfa ration, the absolute fecal N excretion is seen to remain nearly constant. In other words, when the feed intake is held constant, the fecal N appears to be relatively independent of the N intake between the given limits of the N intake. Titus suggested that the metabolic nitrogen in the feces is dependent not only on the dry matter consumed (or dry matter digested) but also on the water content of the feces. He accordingly proposed the following equations on the basis of the above steer feeding experiments:

$$M = 0.002813a - 0.001704b$$
$$M_1 = 0.002428a_1 - 0.001562b_1$$

in which M is weight of metabolic nitrogen in the feces, a is weight of dry matter digested, a_1 is weight of dry matter consumed, b is weight of water in the feces—all on the basis of 10-day feeding periods results. Analyzing these results Titus found that the metabolic nitrogen (for 10 days) is 219.14 gm. if the steers ingested 12 lbs. of alfalfa per day, and 184.95 gm. if they ingested 12 lbs. of paper pulp only; hence the amount of nitrogen in the feces of a steer consuming a nitrogen-free ration may not safely be taken as a measure of the amount of metabolic nitrogen resulting from the ingestion of an equal weight of alfalfa or other feeding stuff.

TABLE 1.—DATA ON BASAL METABOLISM PLOTTED IN FIGURE 1.

Animal and Sex	Chart No.	No. of Trials or Animals	Body Weight		Basal Metabolism Cal/Day	Sources of Data
			Kgms.	Lbs.		
Elephant, 1 male & 1 female_____	1	3	3833	8450	20924**	Missouri (unpublished)
Elephant, male_____	2	1	1360	2998	16020**	Missouri (unpublished)
Beef Steer, Hereford, 815_ _____	3	10	922	2033	9996	Missouri (unpublished)
Beef Steers, Hereford_____	4	E	700	1543	8910	Missouri Res. Bulls. 166 & 176 (1932)
Horses, Percheron females___ _____	5	E	675	1488	9743	Missouri Res. Bulls. 166 & 176 (1932)
Horses, Percheron geldings_____	6	E	650	1433	8188	Missouri Res. Bulls. 166 & 176 (1932)
Beef Steers, grade shorthorn_____	7	2	615	1356	8554*	Mitchell et al, J. Agric. Res. 45, 163 (1932)
Beef Steers (C. & D.)___ _____	8	16	601	1325	7420*	Benedict & Ritzman, Public. 377, Carnegie Inst. Wash. (1927)
Dairy Cow, Holstein, 604_____	9	4	508	1120	7958	Missouri (unpublished)
Dairy Cows, Holstein___ _____	10	E	500	1102	7210	Missouri Res. Bulls. 166 & 176 (1932)
Beef Cows, Hereford__ _____	11	E	500	1102	6600	Missouri Res. Bulls. 166 & 176 (1932)
Dairy Bulls, Jersey_____	12	E	500	1102	7307	Missouri Res. Bulls. 166 & 176 (1932)
Dairy Cows, Jersey_____	13	E	420	926	5865	Missouri Res. Bulls. 166 & 176 (1932)
Horse_____	14	3	392	864	6923*	Zuntz & Hagemann, Landw. Jahrb. 27 Ergeb.-Bd. III (1898)
Beef Steers, Shorthorn_____	15	5	336	741	5781*	Forbes, Kriss et al. J. Agric. Res. 48, 1003 (1931)
Horses, Shetland Ponies, 1 gelding___ 1 female___	16	44	281	619	4683*	Missouri (unpublished)
Beef Steers (E. & F.)_____	17	2	244	538	4725*	Benedict & Ritzman (see above)
Swine, Duroc Jersey males_____	18	E	200	441	3660	Missouri Res. Bulls. 166 & 176, (1932)
Swine, Duroc Jersey females_____	19	E	200	441	2780	Missouri Res. Bulls. 166 & 176, (1932)
Pigs, 1 Middle White & 1 Berkshire__	20	E	200	441	2760	Deighton, J. Agric. Res. 19, 140 (1929)
Pigs, males & females_____	21	5	72	159	1342	Smuts, Ill. Ph. Dissertation (1933), Urbana, Illinois
Horses, Shetland pony gelding_____	22	3	88	194	2028*	Missouri (unpublished)
Human, Am. white males_____	23	E	70	154	1700	Benedict et al; & Boothby & Sandiford
						See Mo. Res. Bull. 166
Human, Am. white females_____	24	E	60	132	1370	Benedict et al; & Boothby & Sandiford
Sheep, ewes_____	25	3	42.7	94	1105	Benedict & Ritzman, Wiss. Arch. Landw. Abt. B., 1, 1 (1931); N. H. Agric. Expt. Sta. Tech. Bulls. 43 & 45 (1930)
Sheep, rams_____	26	3	49.5	109	1306	Benedict & Ritzman (see above)
Sheep, Dorset wethers_____	27	E	70	154	1440	Missouri Res. Bull. 166-176 (1932)
Sheep, Dorset ewes_____	28	E	60	132	1135	Missouri Res. Bull. 166-176 (1932)
Sheep, Australian Merino ewes_____	29	16	46.5	103	1168*	Lines & Peirce, Bull. 55 Council for Sc. & Ind. Res. Comm. Australia, Melbourne
Dogs, male and female_____	30	E	30.66	66.1	807	Various (p. 84 Mo. Res. Bull. 166)
Dogs, male and female_____	31	E	5.0	11.0	266	Various (p. 85 Mo. Res. Bull. 166)
Dogs, male_____	32	5	20.4	45.0	618	Steinhaus
Dogs, male and female_____	33	13	13.1	28.9	319	Boothby See Kunde Am. J. Physiol. 78, 127
Dogs, female_____	34	14	11.7	25.8	446	Lusk (1926) & 80, 681 (1927)
Dogs, male and female_____	35	7	11.5	25.3	446	Kunde
Rabbits, male and female_____	36	E	3.5	7.72	189	Various (p. 85 Mo. Res. Bull. 166)
Domestic fowls, male & female_____	37	E	3.5	7.72	187	Mitchell, Card, Haines, J. Agric. Res. 34, 349 (1927)

Goose, female	38	5	3.31	7.30	204	Hari, Biochem. Z. *78*, 313 (1917)
Domestic fowls, R. I. R. (day expts)	39	8	2.57	5.66	157	Benedict, Landauer & Fox, Storrs Agr. Exp. Sta. Bull. 177 (1932)
Fowls, R. I. R. Hens (day expts)	40	3	2.00	4.41	112	Benedict, Landauer & Fox (see above)
Fowls, R. I. R. Cocks (night expts)	41	7	2.89	6.37	131	Benedict, Landauer & Fox (see above)
Fowls, R. I. R. Hens (night expts)	42	10	1.99	4.39	112	Benedict, Landauer & Fox (see above)
Cat	43	1	2.50	5.51	196	Haldane J. Physiol. *13*, 419 (1892)
Rabbits, male and female	44	10	2.20	4.85	123	Smuts (see above)
Ducks, females	45	5	0.925	2.04	83.3	Hari & Keiwuscha[1] Biochem. Z. 88, 345 (1918)
Guinea Pigs	46	E	0.70	1.54	63.7	Various (p. 85 Mo. Res. Bull. 166)
Guinea Pigs, male and female	47	9	0.43	0.95	39.0	Smuts (see above)
Pigeon, males	48	E	0.34	0.75	27.2	Riddle (p. 86 Mo. Res. Bull. 166)
Doves, males	49	E	0.15	0.33	16.1	Riddle (p. 59 Mo. Res. Bull.)
Rat, male	50	1	0.797	1.757	47.0	Benedict, Horst, & Mendel, J. Nutrition, *5*, 581 (1932)
Rat, male	51	1	0.706	1.556	51.9	Benedict, Horst, & Mendel, J. Nutrition, *5*, 581 (1932)
Rat, male	52	1	0.723	1.593	45.5	Benedict, Horst, & Mendel, J. Nutrition, *5*, 581 (1932)
Rats, males	53	12	0.484	1.067	37.3	Benedict, Horst, & Mendel, J. Nutrition, *5*, 581 (1932)
Rats, males	54	12	0.351	.676	32.3	Benedict, Horst, & Hendel, J. Nutrition, *5*, 581 (1932)
Rats, high-protein males	55	E	0.29	0.64	28.9	Missouri (Res. Bull. 166 & 176)
Rats	56	E	0.29	0.64	28.1	Benedict & McLeod (p. 73 Mo. Res. Bulls. 166 & 176)
Rats, male and female	57	E	0.29	0.64	24.7	Mitchell & Carman (p. 73 Mo. Res. Bulls. 166 & 176)
Rats, male and female	58	23	0.226	0.50	23.6	Smuts (see above)
Rats, females, milk diet, summer 1934	59	28	0.183	0.40	21.1	Missouri (unpublished)
Rats, normal females	60	143	0.141	0.31	15.6	Hemmingsen Skand. Arch. Physiol.
Rats, Ovariectomized	61	151	0.160	0.35	18.4	Hemmingsen Vols. 67 & 68 (1933-4)
Mice, quiet male & female	62	224	0.0276	0.061	5.0	Davis & Van Dyke J. Biol. Chem. *100*
Mice, sleeping male & female	63	11	0.0276	.061	3.67	455 (1933)
Mice, male & female	64	9	0.025	.055	7.84	Smuts (see above)
Mice, male & female	65	32	0.025	.055	4.74	Benedict & Fox Pflugers Arch. *231*, 30, (1933) see also Davis & Van Dyke
Mice, male & female	66	3	0.021	.046	4.81	Giaja and Males, Ann. Physiol. *4*, 875 (1928)
Mice, male & female	67	4	0.016	.035	3.95	Aszodi, Biochem. Z. *113*, 79 (1921)
Sparrow, male & female	68	10	0.022	.049	5.2	Benedict & Fox Pflugers Arch. *322*, 357 (1933)
Canary, male and female	69	43	0.0163	.036	5.2	Benedict & Fox Pflugers Arch. *322*, 357 (1933)

* = 10% deducted from original values in order to change standing to lying values.
** = 30% deducted from the original value (10% for standing & 20% for heat increment of feeding).
E = Data taken from equation relating basal metabolism to body weight for the particular species as given in Mo. Res. Bull. 166.

MISSOURI AGRICULTURAL EXPERIMENT STATION

Table 2.—Data on Endogenous Urinary Nitrogen, Plotted in Figure 2.

Animals	Body Wt. kgs.	Urin. N. Mgs. per Day	Reference No.	Animals	Body Wt. kgs.	Urin. N. Mgs. per Day	Reference No.	Animals	Body Wt. kgs.	Urin. N. Mgs. per Day	Reference No.	Animals	Body Wt. kgs.	Urin. N. Mgs. per Day	Reference No.
Rats (2nd series)	.025	8.50	1	Rats	.233	43.8	3	Swine	109	4005	11	Rats	.416	88.9	17
	.027	8.64	1		.235	54.8	3		132	4360	11		.425	78.0	17
	.032	9.60	1		.238	59.5	3	Rats	.155	39.1	12		.433	111.1	17
	.039	10.3	1		.240	51.3	3		.165	44.5	12		.435	91.1	17
	.039	10.7	1		.246	48.6	3		.220	61.5	12		.444	105.4	17
	.044	12.3	1		.254	55.8	3		.225	51.5	12		.454	116.8	17
	.044	12.4	1		.255	55.8	3	Rabbits	1.80	319	12		.481	75.5	17
	.045	11.3	1		.257	53.8	3		2.30	523	12		.488	81.8	17
	.048	12.5	1		.263	53.9	3		2.45	676	12		.516	82.9	17
	.050	12.5	1		.290	63.9	3	Dogs	7.0	685	12		.529	130.6	17
	.050	14.3	1		.324	68.1	3	Swine	11.2	1188	13		.532	108.2	17
	.059	16.8	1	Guinea Pigs	.326	62.0	3		11.5	1230	13		.537	111.9	17
	.078	18.7	1		.378	66.5	3		12.5	1122	13		.050	10.9	18
	.086	21.1	1		.410	66.0	3		14.0	1302	13		.070	16.5	18
	.220	29.0	1		.425	71.0	3		14.0	1381	13		.090	20.4	18
	.263	33.9	1		.430	83.1	3		15.5	1415	13		.110	21.3	18
	.284	34.7	1		.435	78.2	3	Rabbits	1.48	314	14		.130	21.6	18
	.315	45.7	1		.481	88.7	3		2.40	454	14		.150	29.3	18
	.340	40.8	1		.482	83.3	3		2.45	426	14		.170	33.8	18
	.357	41.1	1		.500	80.0	3		3.00	468	14		.190	33.1	18
Rats (3rd series)	.042	12.0	2	Rabbits	1.61	180	3		3.60	274	14		.210	34.7	18
	.044	12.0	2		1.68	231	3		4.39	659	14		.230	25.3	18
	.051	13.5	2		1.90	241.4	3	Swine	11.5	1449	14	Rabbits*	1.21	130	19
	.053	18.0	2		2.17	250	3		12.0	1361	14		1.49	164	20
	.053	14.5	2		2.22	251.5	3		14.0	1415	14		1.76	249	21
	.054	15.0	2		2.30	212.6	3		14.5	1280	14	Dogs*	12.2	1610	22
	.065	21.0	2		2.40	274.6	3		17.0	2680	14		12.7	2200	22
	.073	19.1	2		2.49	340.2	3		17.5	2430	14		13.1	1600	22
	.082	22.5	2		2.51	340.0	3		12.0	1367	15		13.5	1830	22
	.088	23.0	2		2.78	360.2	3		12.0	1498	15		18.5	1700	22
	.092	24.0	2	Swine	67.2	2763	3		12.5	1563	15	Swine*	10.9	540	23
	.099	22.0	2		68.0	3080	3		13.0	1915	15		14.3	960	24
	.107	23.0	2		70.8	2464	3		14.0	1609	15		16.8	900	23
	.109	19.5	2		75.0	2864	3		14.0	1769	15		17.7	1090	24
	.115	23.0	2		79.2	3421	3		15.0	1839	15		19.5	1090	23
	.120	32.0	2		11.5	1031	4		15.0	2112	15		22.2	1600	24
	.140	28.0	2		12.5	726	4		15.0	2413	15		25.0	1320	25
	.160	31.0	2		12.5	762	4		16.0	2271	15		26.3	1190	25
	.177	38.0	2		13.5	1172	4		13.0	1646	16		37.2	1610	23
	.203	45.0	2		16.0	1318	4		13.5	1325	16		38.1	1880	26
	.220	44.0	2		21.5	1838	4		14.0	2146	16		38.1	2000	26
	.240	62.0	2	Rats	.130	44.8	5		21.0	2219	16		38.5	1830	23
	.250	42.0	2		.134	39.2	5		23.0	2513	16		40.0	1950	26
	.319	52.0	2		.141	54.9	5		24.5	2573	16		41.0	1540	27
Rats (4th series)	.048	17.5	2		.150	42.5	5	Rats	.243	66	17		46.3	2230	24
	.051	25.5	2		.151	56.0	5		.271	93	17		68.1	2650	23
	.061	23.0	2		.153	47.5	5		.286	90	17		74.9	2610	23
	.062	24.8	2		.157	61.3	5		.291	79.3	17	Sheep*	31.9	990	28
	.064	33.0	2		.162	58.8	5		.294	81.9	17		33.1	1030	29
	.069	29.8	2		.166	56.4	5		.310	84.3	17		35.0	2370	30
	.076	32.3	2		.170	59.7	5		.310	96.3	17		35.0	1810	30
	.082	18.5	2		.173	50.9	5		.321	68.3	17		38.0	2590	31
	.084	33.0	2		.179	42.2	5		.322	71.7	17		40.0	1910	30
	.089	24.4	2		.183	63.8	5		.329	92.9	17		40.0	1710	30

Sp.			Ref	Sp.			Ref	Sp.			Ref	Sp.			Ref
"	.104	31.5	2	"	.186	69.8	5	"	.334	83.9	17	"	42.0	1840	31
"	.108	34.4	2	"	.192	55.5	5	"	.339	97.7	17	"	43.5	2390	31
"	.120	28.5	2	"	.192	39.9	5	"	.339	107.8	17	"	43.5	1160	29
"	.125	52.0	2	"	.196	40.6	5	"	.340	108.3	17	"	44.1	1050	29
"	.125	37.0	2	"	.211	86.7	5	"	.347	77.2	17	"	45.0	2630	30
"	.126	31.5	2	"	.216	59.7	5	"	.349	93.6	17	"	45.0	2410	30
"	.142	29.0	2	"	.225	83.0	5	"	.353	89.8	17	"	47.0	3390	31
"	.172	40.0	2	"	.227	72.9	5	"	.355	94.8	17	"	54.0	2020	31
"	.203	62.0	2	"	.226	81.2	5	"	.356	75.4	17	Humans* "	55.7	2700	32
"	.230	56.5	2	"	.278	69.0	5	"	.357	86.9	17	"	57.5	2420	33
"	.234	61.5	2	Swine "	15.5	1474	6	"	.358	90.7	17	"	57.8	1990	34
"	.240	54.5	2	"	15.5	1526	6	"	.358	100.8	17	"	58.0	1840	35
"	.250	42.0	2	"	17.0	1635	6	"	.368	77.1	17	"	60.5	2130	34
"	.320	52.0	2	"	24.5	2402	6	"	.369	82.6	17	"	61.4	2250	36
Mice	.020	12.9	3	"	8.5	997	7	"	.374	88.3	17	"	62.4	3040	37
"	.022	15.4	3	"	9.0	725	7	"	.374	63.5	17	"	63.5	3120	38
"	.022	13.7	3	"	9.5	911	7	"	.375	98.4	17	"	64.0	2600	32
"	.024	16.0	3	"	9.5	960	7	"	.376	98.0	17	"	64.0	3800	32
"	.026	15.2	3	"	11.5	1131	7	"	.381	79.7	17	"	65.0	2510	38
"	.027	16.2	3	"	13.2	1336	8	"	.383	80.9	17	"	65.3	1580	39
"	.028	15.7	3	"	14.7	1490	8	"	.385	106.9	17	"	69.7	3760	37
"	.029	16.7	3	"	15.2	1414	8	"	.386	99.3	17	"	70.5	3500	32
"	.030	17.0	3	"	15.5	1527	8	"	.388	82.1	17	"	71.0	2890	40
Rats	.172	40.0	3	"	18.5	1431	8	"	.388	91.9	17	"	71.3	3340	38
"	.178	44.0	3	"	26.5	1162	8	"	.392	98.2	17	"	72.5	1750	41
"	.179	44.8	3	"	99	4907	9	"	.394	103.9	17	"	76.2	2980	42
"	.184	39.2	3	"	200	8498	9	"	.396	81.6	17	"	79.2	2930	40
"	.186	36.9	3	"	14.5	1587	10	"	.396	104.4	17	"	88.0	2010	43
"	.191	44.8	3	"	132	4724	10	"	.396	80.8	17	Cattle* "	145	6480	44
"	.198	38.3	3	"	13.25	1333	11	"	.398	70.9	17	"	168	5030	45
"	.206	48.8	3	"	18.25	1706	11	"	.401	78.3	17	"	177	6330	45
"	.209	39.6	3	"	40.5	1559	11	"	.403	99.5	17	"	385	16320	46
"	.213	45.7	3	"	66.0	2328	11	"	.406	79.9	17	"	440	16400	46
"	.225	42.6	3	"	76.2	2157	11	"	.409	86.4	17	"	443	15000	47
"	.230	38.0	3	"	88.5	4124	11	"	.409	84.2	17	"	485	14000	47

1. Missouri Res. Bull. 190 ('33)
2. Missouri data (unpublished)
3. Smuts, Ph.D. Dissertation, Univ. Ill., Urbana ('32).
4. Terroine, Bonnet, Chotin & Mourot, Arch. Internat. Physiol., 33, 60 ('30)
5. Terroine & Reichert, ibid., 34, 337 ('30)
6. Giaja A., Internat. Physiol., 34, 222 ('31)
7. Terroine, Bonnet, Danmanville & Mourot, Bull. Soc. Chim. Biol., 14, 12 ('32)
8. Terroine, Bonnet, Danmanville & Mourot, ibid., 14, 47 ('32)
9. Terroine, Giaja & Boy, ibid., 14, 901 ('32)
10. Terroine & Champagne, Bull. Soc. Chim. Biol., 15, 23 ('31)
11. Terroine, Boy, Champagne, Bull. Soc. Chim. Biol. 15, 23 ('31)
12. Terroine, Champagne & Mourot, ibid., 15, 203 ('33)
13. Terroine & Champagne, ibid., p. 235
14. Degan, Ann., Physiologie, 9, 451 ('33)
15. Degan, ibid., 9, 469 ('33)
16. Degan, ibid., p. 495 ('33)
17. Fixsen & Jackson, 26, 1919 ('32)
18. Mitchell & Hamilton, Bioc. of Amino Acids, 490 ('29)
19. Meyers & Fine, J. Biol. Chem., 15, 305 ('13)
20. Serio, Biochem. Z., 142, 440 ('23)
21. Mendel & Rose, J. Biol. Chem., 10, 226 ('11)
22. Underhill & Goldschmidt, J. Biol. Chem. 15, 341 ('13)
23. McCollum & Steenbock, Wisc. Agr. Exp. Sta. Res. Bull. 21 ('12)
24. McCollum & Hoagland, J. Biol. Chem., 16, 305 ('13)
25. Pfeiffer, J., Landw., 33, 149 ('85)

26. Mitchell & Kick, J. Agr. Res., 35, 857 ('27)
27. Morgen et al., Landw. Vers-Sta. 85, 1 ('14)
28. Voltz, Bioc. Z., 102, 151 ('20)
29. Scheunert et al, Bioc. Z., 133, 137 ('22)
30. Morgen et al, Landw. Vers-Sta., 75, 265 ('11)
31. Morgen, ibid., 85, 1 ('14)
32. Folin, Amer. J. Physiol., 13, 117 ('05)
33. Roehl, Deutsche Arch. Klin. Med., 83, 523 ('05)
34. Robison, Bi'oc. J., 16, 131, 407 ('22)
35. Siven, Skand. Arch. Physiol., 10, 91 ('00)
36. Graham & Poulton, Quart. J. Med., 6, 82 (12)
37. Landergren, Skand. Arch. Physiol. 14, 112 ('03)
38. Klemperer, Z. Klin. Med., 16, 550 ('89)
39. Smith, J. Biol. Chem. 68, 15 ('25)
40. Kocher, Deutsche, Arch. Klin. Med. 115, 82 (14)
41. Deuel et al, J. Biol. Chem. 76, 391 ('28)
42. Thomas, Arch. Anat. Physiol., Physiol. Abt. 219 ('09)
43. Klercher, Bioc. Z., 3, 45 ('07)
44. Steenbock, Nelson & Hart, Wisc. Agr. Exp. Sta. Res. Bull., 36 (15)
45. Hart, Humphrey & Morrison, J. Biol. Chem. 13, 133 (12)
46. Honcamp, Koudela & Muller, Bioc. Z., 143, 111 ('23)
47. Copenhagen Investigators, Landw. Vers.-Sta. 101, 16 ('07)
*The starred data were taken from Mitchells compilation given in Bull. 67 National Research Council ('29).

TABLE 2A.—DATA ON TOTAL (INCLUDING FECAL) NITROGEN, PLOTTED IN FIGURE 2A.

Animals	Body wt. kgs.	Total N. mgs. per day	Reference No.	Animals	Body wt. kgs.	Total N. mgs. per day	Reference No.
Mouse	.0150	12.85	1	Rabbit	2.60	562	1
Mouse	.0165	13.74	1	Rats	.050	31.6	2
Mouse	.0167	13.75	1	Rats	.100	55.2	2
Rat	.100	56.4	1	Rats	.200	75.8	2
Rat	.123	51.2	1	Chickens	.720	237	2
Rat	.162	65.7	1	Chickens	.740	240	2
Rat	.168	78.8	1	Chickens	.760	250	2
Rat	.175	84.6	1	Chickens	.800	253	2
Rat	.202	75.6	1	Chickens	.800	230	2
Pigeon	.260	121	1	Chickens	1.60	434	2
Pigeon	.300	133	1	Chickens	1.80	454	2
Pigeon	.340	151	1	Chickens	2.00	291	3
Chicken	.910	218	1	Chickens	1.92	281	4
Rabbit	1.88	405	1	Chickens	2.25	475	4
Rabbit	2.15	463	1	Chickens	2.28	324	4

1. Terroine & Sorg-Matter, Arch. Internat. Physiol. *29*, 121 ('27).
2. Terroine & Sorg-Matter, ibid., *30*, 126 ('28).
3. Mitchell & Hamilton, The Biochemistry of Amino Acids, p. 539 New York ('29).
4. Ackerson et al, Poultry Science, *5*, 153 ('25).

TABLE 3.—DATA ON CREATININE NITROGEN, PLOTTED IN FIGURE 3.

Animals	No. of Trials or Animals	Body Wt. kgs.	Creatinine N Mgs. per Day	Reference No.
Cattle	1	75	750	1
Holstein	1	125	1500	1
fem.	1	175	1460	1
fem.	4	225	2193	1
fem.	2	275	2860	1
fem.	4	325	3388	1
fem.	3	375	4200	1
fem.	3	425	4450	1
fem.	3	475	4857	1
Cattle	3	75	550	1
Jersey	5	125	1004	1
fem.	5	175	1594	1
fem.	8	225	2190	1
fem.	10	275	2635	1
fem.	8	325	2898	1
fem.	6	375	3450	1
Rats	6	0.037	0.67	2
Mixed	8	0.063	1.00	2
(low prot.)	8	0.087	1.31	2
(low prot.)	4	0.113	2.12	2
(low prot.)	8	0.137	2.25	2
(low prot.)	12	0.163	2.37	2
(low prot.)	13	0.187	2.98	2
(low prot.)	14	0.213	3.57	2
(low prot.)	11	0.237	3.74	2
(low prot.)	18	0.263	4.03	2
(low prot.)	10	0.287	4.35	2
(low prot.)	12	0.313	4.79	2
(low prot.)	14	0.337	5.25	2
Rats	3	0.038	0.58	2
Mixed	8	0.062	0.81	2
(high prot.)	7	0.088	1.25	2
(high prot.)	4	0.112	1.63	2
(high prot.)	5	0.138	2.15	2
(high prot.)	13	0.162	2.33	2
(high prot.)	9	0.188	2.80	2
(high prot.)	15	0.212	3.08	2
(high prot.)	12	0.238	3.42	2
(high prot.)	24	0.262	3.75	2
(high prot.)	18	0.288	4.08	2
(high prot.)	9	0.312	4.75	2
(high prot.)	5	0.338	5.05	2
(high prot.)	5	0.362	5.15	2
Rats Mixed	2	0.071	1.10	3
Rats Mixed	2	0.093	1.62	3

Animals	No. of Trials or Animals	Body wt. kgs.	Creatinine N Mgs. per Day	Reference No.
Pigs	6	15.5	199	7
Pigs	6	18.5	134	7
Pigs	6	26.5	245	7
Pigs	7	8.0	85.6	8
Pigs	6	10.0	55.8	8
Pigs	7	10.7	106	8
Pigs	7	11.0	118	8
Pigs	9	11.5	110	8
Pigs	6	11.7	97.1	8
Pigs	4	11.7	98.6	8
Pigs	9	12.0	128	8
Pigs	8	12.0	119	8
Pigs	14	12.0	99	8
Pigs	5	13.0	56.2	8
Pigs	9	13.0	111	8
Pigs	12	13.0	120	8
Pigs	9	14.0	125	8
Pigs	5	14.2	124	8
Pigs	13	14.5	98	9
Pigs	10	132.0	1208	9
Pigs	6	13.2	110	10
Pigs	7	18.3	131	10
Pigs	4	40.5	379	10
Pigs	6	66.0	466	10
Pigs	7	76.3	685	10
Pigs	6	88.5	632	10
Pigs	2	109.3	1175	10
Pigs	7	132.0	880	10
Pigs	8	11.2	93	11
Pigs	6	11.5	91	11
Pigs	8	12.5	102	11
Pigs	4	14.0	113	11
Pigs	6	14.2	142	11
Pigs	6	15.5	162	11
Pigs	6	11.5	80.7	12
Pigs	5	12.2	115	12
Pigs	5	12.5	116	12
Pigs	6	13.5	107	12
Pigs	8	16.0	144	12
Pigs	5	21.5	193	12
Pigs	6	15.2	122	13
Pigs	6	15.4	127	13
Pigs	9	17.0	124	13
Pigs	6	24.5	127	13
Pigs	8	13.5	120	14

Animals	No. of Trials or Animals	Body wt. kgs.	Creatinine N Mgs. per Day	Reference No.
Humans	18	57.0	594	27
Humans	13	58.7	497	29
Humans fem.	26	58.7	340	30
Humans fem.	14	59.5	506	31
Humans	19	59.6	587	27
Humans	8	59.9	439	32
Humans fem.	6	60.3	289	33
Humans	9	60.9	515	29
Humans	25	61.6	586	27
Humans	6	62.1	303	34
Humans	7	63.3	579	29
Humans	57	63.9	573	27
Humans	17	64.0	420	29
Humans	14	64.4	553	29
Humans	9	65.4	431	35
Humans	47	66.2	603	27
Humans	16	68.3	579	29
Humans male	6	68.4	638	33
Humans	56	68.5	671	27
Humans	10	68.9	624	36
Humans male	12	69.2	521	29
Humans male	12	69.2	526	29
Humans	13	70.3	503	29
Humans	37	70.8	680	27
Humans	8	71.5	627	35
Humans	30	73.1	653	27
Humans	24	75.4	596	27
Humans	22	77.7	600	27
Humans	14	80.0	593	27
Humans	13	82.3	727	27
Humans	12	84.6	733	27
Humans	12	86.5	573	29
Humans	16	89.0	666	29
Humans	5	89.2	750	27
Humans fem	23	91.0	454	28
Humans	2	91.5	900	27
Humans	1	96.1	850	27
Humans	1	100.7	950	27
Rats	14	0.666	1.39	37
Rats	15	0.067	1.40	37
Rats	10	0.075	1.66	38
Rats	10	0.107	2.73	38
Rats	7	0.197	2.90	39
Rats	6	0.290	4.50	39
Rats	17	0.297	1.60	40

TABLE 3.—DATA ON CREATININE NITROGEN, PLOTTED IN FIGURE 3.

Animals	No. of Trials or Animals	Body Wt. kgs.	Creatinine N Mgs. per Day	Reference No.	Animals	No. of Trials or Animals	Body wt. kgs.	Creatinine N Mgs. per Day	Reterence No.	Animals	No. of Trials or Animals	Body wt. kgs.	Creatinine N Mgs. per Day	Reference No.
Rats Mixed	2	0.114	1.84	3	Pigs	8	13.5	128	14	Rabbits	6	0.764	5.92	41
Rats Mixed	2	0.138	2.17	3	Pigs	8	15.0	118	14	Rabbits	9	1.35	18.3	42
Rats Mixed	2	0.159	2.71	3	Pigs	8	15.0	124	14	Rabbits	18	1.85	25.7	42
Rats Mixed	2	0.172	3.19	3	Pigs	6	15.5	145	14	Rabbits	11	1.85	26.2	43
Rats Mixed	2	0.180	3.56	3	Pigs	5	15.5	162	14	Rabbits	12	2.08	32.0	44
Rats Mixed	2	0.189	3.57	3	Pigs	6	16.0	153	14	Rabbits	16	2.23	34.9	45
Mice	4	0.022	0.71	4	Pigs	3	16.0	169	14	Rabbits	11	2.77	42.2	46
Mice	5	0.028	0.82	4	Humans	5	3.28	9.5	15	Rabbits	12	2.82	16.1	46
Rats	23	0.266	3.43	4	Humans	12	3.40	16.9	16	Rabbits	11	2.95	20.9	40
Guinea pigs	9	0.430	5.48	4	Humans	3	8.80	8.7	17	Guinea pigs	5	2.20	46.8	47
Rabbits	10	2.20	37.8	4	Humans	12	3.83	10.3	18	Fox	1	4.78	45.0	48
Pigs	5	72.0	5.25	4	Humans	6	6.68	28.3	19	Coyotes	6	7.10	100	49
Rats	1	0.155	4.42	5	Humans	3	6.73	26.5	19	Coyotes	1	15.0	140	48
Rats	1	0.165	4.16	5	Humans	4	6.80	27.2	19	Dogs	149	3.17	28.2	50
Rats	1	0.220	5.67	5	Humans	7	7.79	34.9	16	Dogs	14	7.07	57.5	51
Rats	1	0.225	5.82	5	Humans	11	9.60	78.5	20	Dogs	2	7.44	76.4	52
Rabbits	1	1.80	17.0	5	Humans male	3	14.0	82.2	21	Dogs	13	9.48	97.7	50
Rabbits	1	2.30	23.0	5	Humans	4	14.4	64.5	22	Dogs	4	9.59	43.1	40
Rabbits	1	2.45	30.0	5	Humans	1	16.0	81.5	23	Dogs	4	11.1	101	53
Dogs	1	7.00	58.0	5	Humans	6	17.1	72.9	20	Dogs	3	11.7	121	54
qRats	2	0.11	0.99	6	H9mans	4	17.9	96.9	22	Dogs	4	14.5	152	55
Rats	4	0.13	1.44	6	Humans	8	18.5	133	24	Dogs	3	18.0	93.6	40
Rats	3	0.30	3.17	6	Humans	10	19.0	89	25	Dogs	1	26.4	410	56
Pigs	4	8.00	58.4	6	Humans	10	22.3	173	24	Pigs	3	18.1	156	57
Pigs	7	8.50	58.8	6	Humans	16	25.2	181	24	Pigs	2	24.5	148	58
Pigs	5	9.00	66.2	6	Humans male	1	28.4	150	26	Pigs	6	31.5	337	59
Pigs	4	9.50	69.6	6	Humans	4	28.7	176	22	Pigs	1	46.3	488	57
Pigs	4	9.50	78.9	6	Humans male	1	30.0	90	26	Sheep	5	57.4	324	60
Pigs	8	11.2	111	6	Humans	1	33.5	301	23	Sheep	2	64.6	361	61
Rabbits	4	2.7	36	7	Humans	1	38.0	239	23	Sheep	5	82.0	651	60
Rabbits	4	3.3	47.2	7	Humans	2	45.5	650	27	Camel	1	515	3430	62
Pigs	6	13.5	161	7	Humans	2	52.4	500	27	Steers	5	724	5160	63
Pigs	10	15.0	146	7	Humans fem.	24	53.6	428	28	Steers	4	707	5955	63
Pigs	10	15.0	159	7	Humans	9	54.7	639	27	Steers	20	636	5107	63
					Humans	13	55.7	418	29					

1. Missouri, Res. Bull. 191, ('33)
2. Missouri, Res. Bull. 189 & 190, ('33)
3. Rose & Cook, J. Biol. Chem. *64*, 325 ('25)
4. Smuts, Univ. Illinois, Ph. Dissertation, Urbana ('33)
5. Terroine, Champagne & Mourot, Bull. Soc. Chim. Biol. *15*, 203, ('33)
6. Terroine, Bonnet, Danmanville & Mourot, Bull. Soc. Chim. Biol., *14*, 12, ('34)
7. Terroine, ibid., p. 47
8. Terroine & Danmanville, ibid., p. 68
9. Terroine & Champagne, ibid., *15*, 23, ('33)
10. Terroine, Boy, Champagne & Mourot, ibid., *15*, 42, (33)
11. Terroine, Bonnet & Champagne, ibid., p. 235
12. Terroine, Bonnet & Chotin, Arch. Internat. Physiol. *33*, 60, ('30)
13. Giaja, ibid., *34*, 222, ('31)
14. Garot, ibid., p. 55, ('27)
15. Amberg & Morrill, J. Biol. Chem., *3*, 311 ('07)
16. Roughichitch, Am. J. Dis. Child., *31*, 504 ('26)
17. Ellinghaus, Muller & Standel, Z. Physiol. Chem. *150*, 133 ('25)
18. Amberg & Rowntree, John Hopk. Hosp. Bull. *21*, 40 ('10)
19. Gamble & Goldschmidt, J. Biol. Chem. *40*, 199 ('19)
20. Denis & Kramer, J. Biol. Chem. *30*, 189 ('17)
21. Powis & Raper, Biochem. J. *10*, 363 ('16)
22. Harding & Gaebler, J. Biol. Chem. *54*, 579 ('22)
23. Folin & Denis, J. Biol. Chem. *11*, 253 ('12)
24. Wang, Frank, Kern, & Hays, Am. J. Dis. Child. *32*, 360 ('26)
25. Sawyer et al, Am. J. Dis. Child. *15*, 1, ('18)
26. Krause, Quart. J. Exper. Physiol. *7*, 87 ('13-'14)
27. Beard, Human Biol. *4*, 351, ('32)
28. Denis & Minor, J. Biol. Chem. *31*, 561 ('17)
29. Folin, Am. J. Physiol. *13*, 45, 66 & 117 ('05)
30. Tracy & Clark, J. Biol. Chem. *19*, 115 ('14)
31. Hodgson & Lewis, Am. J. Physiol. *87*, 288 ('28)
32. McLaughlin & Blunt, J. Biol. Chem. *58*, 285 ('14)
33. Hull, J. Am. Chem. Soc. *36*, 2146 ('14)
34. Krause, Quart. J. Physiol. *4*, 293 ('11)
35. Palmer, Means & Gamble, J. Biol. Chem. *19*, 239 ('14)
36. Youngburg & Finch, J. Biol. Chem. *60*, 335 ('26)
37. Mitchell, Beadles & Keith, J. Biol. Chem. *71*, 15 ('26)
38. Mitchell & Carman, J. Biol. Chem. *68*, 183 ('26)
39. Folin & Morris, J. Biol. Chem. *14*, 509 ('13)
40. Chanutin & Kinard, J. Biol. Chem. *99*, 125 ('32)
41. Krause, Quart. J. Exper. Physiol. *1*, 87, ('13, 14)
42. Myers & Fine, J. Biol. Chem. *15*, 283, '13)
43. Myers & Fine, ibid., *14*, 9, ('13)
44. Shapiro & Zwarenstein, Bioc. J. *26*, 1880 ('32)
45. Mandel & Rose, J. Biol. Chem. *10*, 213 ('11, 12)
46. Schenk, Archiv. Exper. Pathol. & Pharm. *95*, 45 ('22)
47. Palladin & Kratinowa, Bioc. Z., *159*, ('25)
48. Hawk, J. Biol. Chem. *8*, 465, ('10)
49. Hunter & Givens, J. Biol. Chem. *8*, 449 ('10)
50. Harding & Gaebler J. Biol. Chem. *57*, 25 ('23)
51. Osterburg & Wolf, Bioc. Z. *5*, 304 ('07)
52. Benedict & Osterberg, J. Biol. Chem. *18*, 195 ('14)
53. Bollman, J. Biol. Chem. *85*, 169, (1929)
54. Benedict & Osterberg, ibid., *56*, 229 ('23)
55. Underhill & Goldschmidt, J. Biol. Chem. *15*, 341 ('13)
56. Howe, Mattill & Hawk, J. Biol. Chem. *11*, 103 ('12)
57. McCollum & Hoagland, J. Biol. Chem. *16*, 299 ('13)
58. Gross & Steinbach, J. Biol. Chem. *47*, 33 ('21)
59. McCollum & Steinbock, J. Biol. Chem. *13*, 209 ('12)
60. Palladin, Arch. Ges. Physiol. *203*, 73, ('24)
61. Hunter, Quart. J. Exper. Physiol. *8*, 13 ('14, 15)
62. Read, J. Biol. Chem. *64*, 615 ('25)
63. Carpenter, Am. J. Physiol., *81*, 518 ('27)

TABLE 4.—DATA ON NEUTRAL SULPHUR, PLOTTED IN FIGURE 4.

Animals	No. of Trials or Animals	Body wt. kgs.	Neutral Sulphur Mgs/day	Reference No.	Animals	No. of Trials or Animals	Body wt. kgs.	Neutral Sulphur Mgs/day	Reference No.	Animals	No. of Trials or Animals	Body wt. kgs.	Neutral Sulphur Mgs/day	Reference No.
Rabbits	9	2.52	20.8	1	Pigs	11	120	210	2	Pigs		21.5	52.8	4
Rabbits	8	3.25	16.0	1	Pigs	8	120	367	2	Humans	13	55.7	139.0	5
Rabbits	5	3.58	25.6	1	Pigs	10	120	427	2	Humans	10	57.5	223	5
Pigs	17	13.3	41.8	1	Rats	6	0.185	4.4	3	Humans	13	58.7	257	5
Pigs	6	14.5	37.8	1	Rats	6	0.185	4.5	3	Humans	9	60.9	207	5
Pigs	4	17.5	51.4	1	Rats	3	0.191	3.6	3	Humans	7	63.3	167	5
Pigs	9	18.0	44.0	1	Rats	6	0.192	1.3	3	Humans	17	64.0	246	5
Humans	6	57.5	130.8	1	Rats	4	0.195	1.3	3	Humans	14	64.4	154	5
Humans	6	57.5	131.0	1	Guinea Pigs	3	0.445	2.3	3	Humans	16	68.3	166	5
Humans	5	57.0	60.3	1	" "	2	0.445	1.2	3	Humans	13	70.3	185.	5
Humans	4	65.0	94.3	1	Guinea Pigs	6	0.712	5.3	3	Humans	12	86.5	234	5
Humans	4	65.0	86.8	1	" "	6	0.725	5.7	3	Humans	16	89.0	302	5
Humans	5	65.0	84.8	1	Rabbits	5	0.780	8.3	3	Rabbits	3	2.27	17.0	6
Humans	2	68.0	108.0	1	Rabbits	5	0.785	7.6	3	Rabbits	7	2.59	22.6	7
Humans	5	69.0	90.6	1	Rabbits	2	1.782	9.7	3	Dogs	14	7.07	52.2	8
Rats	5	0.212	3.3	2	Rabbits	2	1.782	8.3	3	Dogs	11	7.23	80.6	9
Rats	5	0.220	2.7	2	Dogs	13	13.4	45.2	3	Dogs		9.6	50.0	10
Pigs	6	11.5	37.0	2	Dogs	12	14.6	33.4	3	Dogs		12.0	53.0	10
Pigs	6	11.5	38.0	2	Humans	3	3.25	8.9	3	Dogs	6	10.0	68.3	11
Pigs	6	11.5	45.0	2	Humans	8	14.5	27.1	3	Dogs	11	16.0	44.3	12
Pigs	9	16.0	51.0	2	Humans	8	19.5	30.4	3	Pigs	1	17.7	25.0	13
Pigs	8	16.0	58.0	2	Humans	6	42.2	74.5	3	Pigs	6	24.0	51.5	14
Pigs	8	16.0	27.0	2	Horses	6	330	1118	3	Pigs		28.7	199	15
Pigs	9	16.0	45.0	2	Horses	5	360	1130	3	Pigs		29.7	209	15
Pigs	7	16.0	48.0	2	Horses	4	384	834	3	Humans		69.5	98	16
Pigs		16.0	55.0	2	Pigs		11.5	38.0	4	Humans		80.0	121	16
Pigs	4	32.5	62.0	2	Pigs		12.5	31.0	4	Humans	8	64.0	120	17
Pigs	8	32.5	91.0	2	Pigs		12.5	36.0	4	Steers	19	636	236	18
Pigs	5	32.5	43.0	2	Pigs		13.5	40.0	4	Steers	4	707	1723	18
Pigs	8	120.0	137.0	2	Pigs		16.5	48.5	4	Steers	5	724	1339	18
Pigs	5	120.0	162.0	2										

1. Amann, Arch. Internat. Physiol., 37, 121 ('33)
2. Aman & Mourot, ibid., 37, 150 ('33)
3. Amann, ibid., 37, 168 ('33)
4. Terroine, Bonnet, Chotin & Mourot, ibid., 33, 60 ('30)
5. Folin, Am. J. Physiol., 13, 45, 66 & 177 ('05)
6. Lewis, Updegraff & MacGuinty, J. Bio .lChem., 59, 59 ('24)
7. O'Shima, H. Chosen Med. Assoc. p. 431 ('28)
8. Osterburg & Wolf, Bioc. Z. 5, 304 ('07)
9. Hele, Bioc. J., 18, 586 ('24)
10. Cerecedo, J. Biol. Chem., 88, 695 ('30)
11. Denis & Reed, J. Biol. Chem., 73, 51 ('27)
12. Morgulis, J. Biol. Chem., 77, 627 ('28).
13. McCollum & Hoagland, J. Biol. Chem., 16, 229 ('13)
14. Muldoon & Sherwin, J. Biol. Chem., 60, 59 ('29)
15. Gross & Steenbock, J. Biol. Chem., 47, 33 ('21)
16. Zeller, Arch. f. Physiol. p. 213 ('14)
17. Shaffer, Am. J. Physiol. 22, 445 ('08)
18. Carpenter, Am. J. Physiol. 81, 518 ('27)