tance less than δ_{ep} from the point P, then X and P lie together in a connected sub-set of M every point of which is at a distance of less than e from the point P. The set M is said to be *uniformly* connected im kleinen if for every positive number e there exists a positive number δ_e such that if P_1 and P_2 are two points of M at a distance apart less than δ_e then they lie together in a connected sub-set of M every point of which is at a distance of less than e from P_1. Cf. Hahn, H., *Jahresber. D. Math. Ver., Leipzig*, **23**, 1914, (318–322).

[6] Hausdorff, F., *Grundzüge der Mengenlehre*, Veit & Co., Leipzig, 1914.

[7] Cf. my paper, A theorem concerning continuous curves, *Bull. Amer. Math. Soc.*, **23**, 1917, (233–236).

[8] Cf. Theorem 43 of my paper, On the foundations of plane analysis situs, *Trans. Amer. Math. Soc., New York*, **17**, 1916, (131–164). I take this opportunity to correct an error in the statement of Theorem 44 of this paper. In this statement the upper 'interior' and the two upper 'without's are to be omitted.

A BIOMETRIC STUDY OF HUMAN BASAL METABOLISM

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Investigators are now generally agreed that the metabolism, expressed in terms of calories per unit of time, of the normal subject shall be taken as a basis of comparison in the investigation of all the special problems of human nutrition, for example, that of the requirements for muscular activity, that of the influence of specific diseases or of the level of nutrition upon metabolism, that of the change of metabolic activity with age, and so forth. Critical investigations in both European and American laboratories have shown that the gaseous metabolism is so affected by various factors that determinations which are to serve as a standard must be made under very exactly controlled conditions. It is not merely necessary to devise apparatus in which the physical difficulties of direct calorimetry (or of the exact measurement of gaseous exchange from which heat production may be computed) are overcome. Certain biological factors must be ruled out. Those of greatest importance as sources of experimental error are muscular activity and the stimulatory action of recently ingested food. The heat production of the individual in a state of complete muscular repose 12–14 hours after the last meal, i.e., in the postabsorptive condition, has been called the basal metabolism.

For a decade the Nutrition Laboratory has been engaged in carrying out a series of determinations of basal metabolism in normal human individuals of both sexes and of widely different ages. These have been made with all the modern refinements of method and manipulation. The subjects were in presumably good health. All those with febrile temperature were discarded. All were in the postabsorptive condition. Perfect muscular repose during the short periods required for indirect calorimetry was assured by an automatic record of all movements, even those imperceptible to a trained observer.

Measurements on 136 men, 103 women and 94 new-born infants have been analyzed biometrically with the purpose of determining the statistical constants (means, standard deviations, coefficients of variation, coefficients of correlation, and regression equations) which may serve as standard constants in work on human metabolism until those based on more extensive series of data are available. In carrying out this analysis we have proceeded on the conviction that the widest possible usefulness of laboratory investigations of human metabolism will result from basing measurements upon individuals who are in presumably good health, but who are otherwise typical of the population at large. It is only when the subjects used for experimentation are representative of the general population in type, variability and correlation that results of laboratory research upon limited series of individuals may be safely generalized for rationing or for other practical social applications. Statistical tests of the suitability of the series used in the present investigation have been applied.

The relationship between certain of the physical and physiological measurements of the individual and between the various physiological measurements has been determined. Our series of data show practically no relationship between basal or minimum pulse rate and stature or body weight in adults. There is a low but significant positive correlation between minimum or basal pulse rate and gaseous exchange and heat production. The Nutrition Laboratory has long emphasized the correlation between pulse rate and metabolism in the same individual, that is, the intra-individual correlation between the rate of the heart beat and the amount of the katabolism. Here, however, we are dealing with the problem of the relationship between the minimum or basal pulse rate of a series of individuals and their basal metabolism—that is, with inter-individual correlation.

There is a substantial correlation between stature and heat production. The correlation between body weight and heat production is higher being of the order $r = 0.75$ to $r = 0.80$ in the new-born infants, of the order $r = 0.80$ in men and $r = 0.60$ in women. Analysis by means of partial correlation coefficients indicates that both stature and body weight have independent significance as bases for the prediction of the basal metabolism.

The change in basal metabolism with age during the period of adult life has been shown to be well represented by the linear equations,

For men ($N = 136$)

$$h = 1823.80 - 7.15, a, \ h_k = 28.703 - 0.112\, a, \ h_d = 1022.17 - 3.60\, a.$$

For women ($N = 103$)

$$h = 1420.47 - 2.29\, a, \ h_k = 28.308 - 0.124\, a, \ h_d = 942.25 - 2.96\, a.$$

where h = total heat production in calories per 24 hours, h_k = calories per kilogram of body weight, h_d = calories per square meter of body surface as estimated by the Du Bois height-weight chart. Thus in men the daily heat production decreases about 7.15 while in women it decreases about 2.29 calories per year. Women are smaller than men and have a lower heat production. When the decrease in metabolism with age is expressed in calories per kilogram of body weight or in calories per square meter of body surface, the results for the two sexes are much more nearly identical.

The problem of the difference in the metabolism of men and women, dealt with in the past by a number of writers, has been reconsidered on the basis of the larger series of data now available. The average daily (24 hours) basal heat production of men is 1632 calories whereas that of women is 1349 calories. Thus women have an average daily heat production about 300 calories less than that of men. But women are smaller than men. If correction for body size be made by expressing heat production in calories per kilogram of body weight, it is 25.7 calories in the 136 men as compared with 24.5 calories, or 1.2 calories per kilogram less, in the 103 women. On the basis of heat production per square meter of body surface as estimated by the Du Bois height-weight chart the men show an average daily heat production of 925 calories as compared with 850 calories, or 75 calories less, in the 103 women. The most critical test of the difference of men and women in the level of metabolism is that furnished by a modification and extension of the selected group method of Benedict and Emmes. In the new method the control values for the several groups of women are not the empirical constants for men of as nearly as possible like stature and body weight but are determined from equations taking into account stature, weight and age in all the available data for men. Analysis shows that, however expressed, the metabolism of American women is lower than that of the men. Our results show that the differentiation of the sexes is not evident in infancy. They do not confirm the conclusion of Sondén and Tigerstedt that the difference between men and women tends to disappear with age. Instead we find the difference in the metabolism of men and women well-marked throughout the period of adult life.

The validity of the so-called body surface law, according to which metabolism is proportional to the superficial area of the individual, i.e.,

$$h = a\bar{h}_a$$

where a = superficial area and $\bar{h}_a$ = mean heat production per unit of time per square meter of body surface in a standard series, has been critically tested. It has been shown that the supposed proofs of its validity hitherto adduced are erroneous. Heat production is not 'proportional to body surface but not to body weight' as has been asserted to be the case, but is highly and about equally correlated with both body weight and body surface. It has been shown that as a basis for predicting the heat production of a subject the above relationship is less satisfactory than multiple regression equations involving stature, weight and age. Thus the 'body surface law' is deprived of its unique significance as a basis for the prediction of the metabolism of an unknown subject. An analysis of the data of actual experimentation on subjects at changing levels of nutrition shows that the changes in metabolism are not proportional to those in body surface. Surface area may not be looked upon as a determining factor in basal metabolism.

The closest prediction of the daily heat production of a subject can be made by the use of the multiple regression equations,

For men, $h = 66.4730 + 13.7516\,w + 5.0033\,s - 6.7550\,a$

For women, $h = 655.0955 + 9.5634\,w + 1.8496\,s - 4.6756\,a$

where h = total heat production per 24 hours, w = weight in kilograms, s = stature in centimeters, and a = age in years. These equations have been tabulated for values of weight from 25.0 to 124.9 kgm., for stature from 151 to 200 cm., and for age from 21 to 70 years, so that the most probable basal metabolism of an unknown subject may be easily determined.

Such tables should render service in clinical and other fields of applied calorimetry. Their usefulness has been demonstrated in testing the typical or atypical nature of series of metabolism measurements, in investigating the differentiation of the sexes with respect to metabolic activity, of the metabolism of athletes as compared with non-athletic individuals, and of individuals suffering from disease.

The detailed measurements and statistical constants, with full discussions of pertinent literature, are about to appear in Publication No. 279 of the Carnegie Institution of Washington.

SEX AND SEX INTERGRADES IN CLADOCERA

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There is probably no one factor in the biological world of greater interest and importance than sex.

Most plants are dioecious, producing the reproductive cells of both sexes within the same individual organism. Several lower animals are normally hermaphroditic but by far the larger part of the forms in the animal world are unisexual.

So general is unisexuality in animals and so little thought do we in general give to the comparatively few normally hermaphroditic forms that we are accustomed to think of maleness and femaleness as opposed and mutually exclusive states which cannot coexist in the same organism. We are accustomed to think of maleness as indicating the possession not only of a sperm-producing gland and accessory reproductive structures but also the possession of the peculiar secondary sex character—structural, physiological, and even psychological and behavior characteristics. The term female implies, pro-