5. The average 24-hour basal heat production of groups of girls from 12 to 17 years of age was 1250 calories per individual, irrespective of age.

6. The heat production per kilogram of body weight per 24 hours decreases regularly with increasing age from 29.9 calories at 12 years, 2 months, to 21.7 calories at 17 years. The curve indicating the general metabolic trend is throughout its entire length materially below the few scattered observations of earlier writers.

7. The heat production per square meter of body surface per 24 hours likewise decreases, but not so regularly, with increasing age, ranging from 928 calories at 14 years to 745 calories at 16 years.

8. The metabolism of groups of young girls can be predicted from the general curve indicating the heat production per kilogram of body weight referred to age to within an average error of ±3.1 per cent. The prediction for the heat production per unit of body weight is somewhat better than that per unit of surface area.

9. The curves representing the heat production per kilogram of body weight referred to weight and per square meter of body surface referred to weight for these groups of girls from 12 to 17 years of age blend with remarkable uniformity with similar curves based upon the measurement of a large number of normal girls from birth to 12 years of age.

10. No influence of puberty or the prepubescent stage is clearly proven in any of the results.

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BORNHARDT'S FORMULA.

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INTRODUCTION.

BOUCHARD said in 1897: "For a long time to come, good and serviceable medicine will be practised without geometric determinations; but there is a part of medicine in which they are indispensable. . . . . the diseases of nutrition." This field of pathology and the related study of normal weight have received a large amount of attention, as witnessed by the several standards of normal weight in the literature. Each has been used, more or less widely, according to the convenience of the form in which it was presented, the reputation of its author, or the positiveness with which it was claimed to be correct. But despite the great value of standards for determining normal weight to nearly every physician, the original claims have been tested but seldom by other than the original observers and reports of these tests showing the degree of accuracy of prediction obtained are rare. This accuracy is, however, easily quantitated, by figuring the deviation (error) of the calculated (predicted) weight from the actual (observed) weight, then converting this deviation in kilograms (or pounds) into an error expressed as a percentage of the actual weight, and finally averaging these per cent. errors for each method of prediction.

BORNHARDT'S FORMULA.

Accuracy in Relation to Formula. This has been demonstrated in previous papers by applying six of these standards (Bornhardt's, U. S. Army and Navy, Medico-Actuarial, Guthrie's, Broca's, and von Noorden's) to two groups of healthy native American men totaling 249, and to Bornhardt's original series of 56. The percentage errors indicated that the most accurate was Bornhardt's rule, for its prediction error averaged 6.0% as contrasted with 8.3% for the next best and 23% for the worst.

Accuracy of Bornhardt's Formula in Relation to Age, Height, Chest-girth and Weight. From work reported by Mayall and myself, it is apparent that the prediction error:

1. Is not affected by age within the age-groups observed, *i.e.*, roughly 20-30; but some later studies (unreported) indicate unreliability in children weighing less than 55 kg. (110 lbs.).
2. It is not affected by height.
3. Is not affected by chest-girth.
4. Is affected by weight. When the subject is unusually heavy or light, *i.e.*, in this series less than 128 pounds, or more than 171, the error in prediction was notably larger. By inference from this, either these individuals were abnormal though not so recognized, or for such extremes a different formula is necessary.

Different Conceptions of the Normal. Bornhardt, in 1886, thought different standards advisable for judging persons of builds which to the eye seemed weaker or stronger than the average, and similar views have been discussed by others since, *e.g.*, Stratz 1914, Schlesinger 1917, Wood 1920.

In this connection it is pertinent to consider that while the usual "normal" is a mean, or better a mode, the mode is only a "dominant" (Lange 1903), between a high line above and a low normal below (Pfaundler 1916), thus bounding "standard lives" (Medico-Actuarial Committee 1912) in a "normal zone" (Holt 1918). From a theoretical standpoint the intensive mathematical studies by Pfaundler's pupils, Chose and Dikanski, 1914, and by himself in 1916, on the variation distribution, have commanded great interest in Germany, while from a practical point of view, at present, more value may be attached to the judgment of the Medico-Actuarial Insurance Committee, 1912, and Holt, 1918, that the limits of healthy normal variation should be taken as 10% from the mean, or of Emerson as 7%.

Review of Literature on Bornhardt's Formula. Bornhardt's first paper in 1886 dealt with the "body weight of drafted men as a means of determining fitness for military service." He quoted, as a straw man so to speak, the view of Quetelet, 1835, and Hammond, that the body weight of the healthy grown man bears a relation to his body length.

In passing it might be added that this view has been a vain inspiration to many others. A height-weight index (H/W), or a weight-height index (centimeter-weight, W/H), or an age-height-weight law, may be seen in the work of Broca (date ?), Von Noorden (date ?), Shepherd 1899, Bouchard 1900, Medico-Actuarial Committee 1912, Gaertner 1913, von Pirquet 1913, Matusiewicz 1914, Stratz 1914, Guthrie 1916, U. S. Army 1916, Pfaundler 1916, Whyte 1918, Dufestel 1920, Bardeen 1920.

Bornhardt, however, "was led by the fact that with increase of the chest girth, also the girth of the other parts of the body increases and that the product of the two measures given (height x chest) is the approximate expression of the body surface." On comparison of this approximate body surface with the body weight of eighteen artillery recruits, he noticed a definite relation between them. In people of *average* robustness and health they were as 1 : 5. "On substitution for Russian pounds and werschok, of grams and centimeters, the figures would naturally be different, but the results analogous." However, he further concluded that "with smaller height the weight may be greater, as in robust men; that the weight does not vary proportionately to the body surface, and that with the same surface the weight may be varied. Hence followed the conservative claim that "the body weight cannot be reckoned *a priori* from height and chest girth. These measurements, however, together with the actual weight, give us valuable data, whose relationship is a clear expression of the . . . . individual's fitness for military service."

In his second paper, with the same title as Paper I, a larger field of usefulness was claimed, and justly: "This gives us the possibility . . . . of calculating the body weight. If we call the height H, the chest girth C and the weight P, then the above relation is expressed for Russian units of measurement, by the equation:

$$HC = 5P \text{ or } P = HC/5 \quad (i.e.\ P = HC \times 0.20)$$

"The carrying out of the above calculations during recruiting is too time-consuming. It is desirable to reckon in advance a table for the weights of men of varying statures and chest girths. This I have reckoned for men of *average* constitution all the way from 2 Arschin, 3 Werschok through 2 Arschin, 9 Werschok in height, and from 17 through 24 Werschok in girth at nipple level . . . . arranged *gradatim* according to rising height and chest measurements.''

In Paper III on ''The Numerical Definition of Bodily Constitution,'' he tabulated measurements and weights of 38 more recruits, and also discussed the tests of his method by Alexejewski and Abkowitsch: ''The original Russian measures of weight and distance they transformed into centimeters and grams. . . . . Dr. Alexejewski, who made 79 measurings and weighings, and Dr. Abkowitsch, who weighed and measured 667 recruits, likewise came to the conclusion that a constant relation, varying only within very narrow limits, exists between height and chest girth on one side and weight on the other.''

After these two Russians no further trials of Bornhardt's method seem to have been reported until thirty years later, when it was tested by the present writer on twenty American students and later on a larger group of 229 soldiers. True, the formula had been quoted, but without discussion, by Fröhlich 1895, Vierordt 1906, Baer 1912, Gaertner 1913, Barker 1916, and Vedder 1918. It was their translation of it which we have used throughout:

$$W \text{ (in kg.)} = H \text{ (in cm.)} \times C \text{ (in cm.)} \div 240$$

It was, however, more convenient, in order to record to the nearest integer without bothering with fractions (common or decimal), to transform kilograms into the smaller unit of pounds, thus yielding the hybrid formula:

$$W \text{ (in lbs. avoirdupois)} = H \text{ (in cm.)} \times C \text{ (in cm.)} \div 109$$

or, as multiplication is easier than division:

$$W \text{ (in lbs. avdp.)} = H \text{ (in cm.)} \times C \text{ (in cm.)} \times 917$$

When testing Bornhardt's formula against his own reported observations conversion equivalents were used as shown in Table I.

TABLE I.

Linear Constants of Measure

1 arschin = 16 werschok =	71,120 cm. =	21,0000 inches
1 werschok =	4.445 cm. =	1.7500 inches
	1.000 cm. =	0.3937 inches
	2.540 cm. =	1.0000 inch

Weight Constants of Mass

1 Russian Funt (pound) =	0.4082 k. =	0.90 lbs. avdp.
	1.0000 k. =	2.20 lbs. avdp.
	0.4536 k. =	1.00 lb. avdp.

Possibilities of Improving Bornhardt's Standard. An improvement on Bornhardt's rule presumably might be made by utilizing more measurements of each subject, but any increase of the measurements beyond two would obviously make impracticable the expression of the results in a two-entry table, and so would oblige the worker to do his own calculating, a labor that would prevent the formula from coming into general use. Modification is possible, however, without encountering the difficulty just named, by taking no more measurements, but by altering the constant or by using a root or power of the height, or a similar function of the chest-girth, or a combination of these variations. This would make the formula no more difficult to use, but might reduce the prediction error (the main desideratum), and might incidentally produce an easier factor than 240, the constant in the usual metric translation of Bornhardt's Russian unit formula.

The cube of the height was experimented with by Buffon 1828, Livi 1886 and 1889, and Von Pirquet 1913, in vain according to Meeh 1879, Oeder 1915, and Von Pirquet 1917. The square of the height also has some theoretical reasons in its favor, and was experimented with by Quetelet 1871.

This is even more true of the square of the chest girth, because this power corresponds roughly to the area of a cross section of the chest at the nipple level where the perimeter is customarily measured. This statement is based upon the fact that the area of a circle = Pi R^2, or (since the circumference of a circle = 2Pi R and therefore R = C/2Pi), the area = Pi $(C/2Pi)^2$ = Pi $C^2/4Pi^2$ = $C^2/12.57$.

Then the body volume, if considered irregularly analogous to that of a cylinder, would be H x C^2 x sp. gr. of the body ÷ 12.57. In practice the latter two numerical constants could be consolidated with any other necessary constant factor like that of Bornhardt's. One might expect accordingly that the height times the square of the chest girth (H x C^2) would express the *volume* of the body as accurately as the height times the chest girth (HC) of Bornhardt expresses the *surface* of the body. One would certainly expect that some expression of volume would give a more precise formula, because of the law of physics that weight varies as volume and not as surface, as pointed out in this connection by Moleschott 1879 and Meeh 1879. A further reason for squaring the chest circumference might be deduced (1) from the observation of Allaire in 1863, after studying 730 French recruits, that weight is modified less by stature than by the circumference of the thorax; and (2) the independent note of Dreyer in 1920 that the weights calculated from chest measurements show greater individual variations than those from trunk lengths.

The use of roots makes a formula excessively inconvenient for practical use. Squares are bad enough.

EXPERIMENTAL EFFORTS TO IMPROVE BORNHARDT'S RULE.

In the attempt to gain evidence along the lines of the above speculations we have tried a variety of formulae constructed by changing the constant and using squares.

This has been done for the most part empirically, trying various combinations that suggested themselves. In the case of the constant factor a guide has been obtained by substituting in the formula the actual weight of each case in a group, solving the formulae and averaging the factors to get the "constant." For example, using the formula: Weight (in pounds avoirdupois) equals H (in cm) x C (in cm.) x Factor, we got from the series of 229 soldiers the factor 909, and from this series combined with Bornhardt's 56, *i.e.,* a total of 305 cases, the factor 915. It also seemed interesting to see whether a different factor would be obtained by excluding those solutions of the formulae on the men who gave extremely high or low factors (owing to peculiarities of height or chest girth); on omitting therefore arbitrarily the 15 highest factors and the 15 lowest factors, a total of 30, or about 10% of the total, the remaining central and presumably more normal factors gave the average of 901 in the series of American soldiers mentioned, and 912 for the central factors derived from the consolidated group of 305 men.

The various experimental formulae were then applied to the recorded measurements and weights, and the percentage of error in predicting weight was calculated by the methods detailed in our previous papers. For the sake of simplicity only the average error without regard to sign, that is, the arithmetic mean, was considered; and no attempt was made to estimate the algebraic mean, the standard deviation, or the coefficient of variation. The resulting averages in Table II show that the least error, 5.6%, pertains to the formula:

W (in lbs.) = 91 x H (in cm.) x C (in cm.),
i.e. W (in kg.) = 414 x H (in cm.) x C (in cm.),
i.e. W (in lbs.) = 587 x H (in inches) x C (in inches)

Presumably the slight superiority over Bornhardt's of the factor here proposed is due to the larger series on which it was based.* In the same way the factor proposed can probably be excelled by anybody who will make similar calculations on a larger series.

* After determining on this factor 91, it seemed worth while to confirm the translation of Bornhardt's factor as hitherto cited in the literature and earlier in this paper, namely:
W (in kg.)=H (in cm.)×C (in cm.) divided by 240.
Starting from Bornhardt's model: W (in Russian Funt)=H (in Werschok)×C (in Werchok)/5, I got

$$W \text{ (in kg.)} = \frac{0.4082}{5} \times \frac{H \text{ (in cm.)}}{4.445} \times \frac{C \text{ (in cm.)}}{4.445} = \frac{0.4082}{5 \times 19.758} \times H\,C = \frac{0.4082}{9879} \times HC = \frac{1}{242} \text{ or } 4132 \times HC$$

instead of 1/240 or 417×H (in cm.)×C (in cm.) as hitherto translated.

$$\text{And } W \text{ (in lbs. avdp.)} = \frac{0.9}{5} \times \frac{H \text{ (in cm.)}}{4.445} \times \frac{C \text{ (in cm.)}}{4.445} = \frac{0.9}{5 \times 19.758} \times HC \text{ (in cm.)} = \frac{0.9}{9879} \times H\,C \text{ (in cm.)} = 911 \times H\,C$$

The range of his series, of mine, and of Dreyer's† may be of interest and is given in Table III.

TABLE III.

	BORNHARDT'S 56	GRAY'S 249	DREYER'S No. ? IN BOOK	DREYER'S 16 IN LANCET
Age	21–25 yrs.	18–34 yrs.		13–52 yrs.
Height	165–182 cm.	147–193 cm.		140–186 cm.
Chest-girth	85–99 cm.	70–106 cm.	55–112 cm.	67.5–96.4 cm.
Weight	115–167 lbs.	105–236 lbs.	42–292 lbs.	66–196 lbs.
	52.2–75.7 k.	47.6–107.0 k.	18.9–132.9 k.	29.8–88.8 k.

† To be discussed in a separate paper to be published shortly in this Journal. The bibliography with the forthcoming paper will include the authors here referred to.

SUMMARY.

For the estimation of the weight of a healthy person, the formulae of the U. S. Army and Navy, of the Medico-Actuarial Committee, of Guthrie, Broca, and of Von Noorden have been shown less accurate than Bornhardt's rule. The present study was begun with the hope of attaining even greater accuracy by some modification of Bornhardt's method. Experiments with various formulae are reported above, but the best of these was only slightly different from Bornhardt's, and was only slightly more precise, reducing the error from 5.64% to 5.61% when applied to the prediction of the weights of 305 men, collected in three different groups, aged 18 to 34 years.

We are greatly indebted for assistance in the large number of calculations here summarized, to Mrs. J. M. Walker of Lexington.

TABLE II.—RESULTS WITH EXPERIMENTAL FORMULAE.

	Series	FORMULA (H=height in cm.; C=chest girth in cm.)									
		HC×90	HC×91	HC×917	HC×92	HC×93	HC×94	HC³	HC³×101	H²C×526	H²C×530
I	20 Students	5.80	5.70	5.55				6.25	5.50	5.00	
II	115 U. S. Soldiers (selected by lot)							6.64	6.99	6.48	
III	114 U. S. Soldiers (the remainder)							5.99	5.95	6.46	6.42
IV	Total 229 U. S. Soldiers	5.79	6.00	6.00	6.20	6.60	7.1	6.31	6.47	6.48	
V	Total 249 Normal Americans	5.79	5.98	5.96				6.31	6.39	6.36	
VI	Bornhardt's 38	6.78	4.24	4.20				4.47			
VII	Bornhardt's 18	5.56	3.42	4.20				3.22			
VIII	Bornhardt's total 56	6.41	3.98	4.20				4.07	3.78	4.80	
X	Grand Total, 305 Normal Men	5.91	5.61	5.64				5.89	5.91	6.07	
		1	2	3	4	5	6	7	8	9	10

Book Reviews.

Clinical Ophthalmology for the General Practitioner. By A. MAITLAND RAMSAY, M.D., Glasgow: Oxford Medical Publications, 1920.

The author makes the following statement in his preface: "The book is not meant to take the place of a systematic treatise on Ophthalmology. It is purely clinical, deals with the symptomatology of Eye Diseases and is an attempt to present the subject as the general practitioner meets it in his daily practice."

This book can be recommended especially to the practitioner who, from choice or necessity, does his own eye work. It is rather more complete than the author's statement would indicate. Treatment is gone into minutely, and operative procedures, even the major ones, are described at some length. There are 500 pages of text, with 20 pages of plates, 11 of which are in color. Sixty pages are devoted to Therapeutic Formulae and Notes. Eye injuries and their treatment are given careful consideration. An admirable feature of the work is the arrangement of several of the chapters under the headings of signs and symptoms, thus: "The Clinical Significance of Oedema of the Eyelids," "The Clinical Significance of Failing Sight." With such an arrangement, the reader is at once shown the possibilities of his case and is not obliged to work backward by first making a provisional diagnosis and then reading to see if the case fits his diagnosis.

Lice and Their Menace to Man. By LIEUT. LL. LLOYD, *R.A.M.C.* (T.) With a Chapter on Trench Fever by MAJOR W. BYAM, R.A.M.C. London: Oxford University Press. 1919.

Within the last few years there has been collected a considerable amount of information concerning the lice of man. Since the war has made it necessary to discover more about its habits in order to combat its activities, scientists have worked unselfishly on this problem for the last four years. The rôle which the louse plays in spreading disease is an extensive one, and is responsible for a large proportion of human suffering. Typhus fever, relapsing fever, and recently trench fever, are attributed entirely to the activities of the louse. This volume, "Lice and Their Menace to Man," discusses the structure of the body louse, its early development, habits of living and feeding, and its dissemination. Methods of disinfection are varied; among them are hand-picking, brushing, ironing, dry storage, heat, and treatment by chemicals and greases. The habits of the head louse and of the crab louse and means of eliminating them are also considered in this book. The results obtained from experiments conducted on soldiers to determine the migration of body lice and their effects on man are illustrated by charts and tables.