Basal metabolism determinations

with original portable Benedict apparatus

By G.W. McCaskey---J.A.M.A. Apr. 9, 1921
medicine in which he chooses to work. He knows, for example, that he prefers general surgery, or internal medicine or dermatology or ophthalmology, and he is, or ought to be by that time, mature enough to know his own mind. Why, if he decides on ophthalmology, should he be required to take a course dealing with the special details of obstetrics, the measurements of the pelvis, the mechanism of occipitoposterior position, etc.? Why should he be required to master the technic of the operation for extirpation of the kidney, laceration of the perineum or amputation of the breast? Why should he be forced to learn formulas for the artificial feeding of infants of various ages or to spend days in the study of the stools in cases of ulcer of the duodenum, carcinoma of the bowel, amebic dysentery or mucous colitis? May he not more profitably be engaged for a portion of his time in studies with a direct bearing on his chosen work? He may thus shorten his time of graduate work for specialization by at least a year. Is there any vital objection to this? The same principle might be carried still farther back in our system of education, to our literary and scientific colleges, and even, as has been suggested by good educators, to our high and grade schools. Instead of putting all students of medicine through the same mill and turning them out at the age, say of 27, with the stamp of general practitioners, may we not allow or even compel our undergraduates to do as is required in many general cultural courses in our literary colleges, to major in some subject or group of subjects especially in his last two years. He would still be a qualified practitioner, but he would have more than a mere outline of each of the many subjects included in our curriculums of today. In some subject or perhaps two he would by concentration become something of an expert; he is an embryo specialist, if you please. When he goes out into general practice he will be likely to continue his studies of this topic and to become perhaps the practitioner-specialist of his neighborhood. At the rate, he is a better general physician for knowing one subject thoroughly than because he knows all subjects only fairly well. Our bright students are doing this today. They help and do extra work in the pathologic laboratories, in the department of electrocardiography, or in the surgical clinics. They are specializing. This is done in many of our technical schools. Our schools of engineering have certain common required courses in English, foreign language, mathematics, physics, etc.; and then, branching out, stress for the one student electricity, for another chemistry, architecture or naval construction, depending on what branch of engineering he intends to pursue. Of these permit him, if he chooses, to take the all round mechanical engineering course, comparable to a general practitioner course. These ideas are suggestive only. They may be illtimed, crude and half-baked. I admit contradictions and inconsistencies.

**SUMMARY**

A paper is supposed to end with conclusions. But what is one to do who has not even in his own mind reached a satisfactory solution of the problems presented, who has not reached conclusions?

Briefly summarized, the thought running through this paper is that there is an inevitable and justifiable trend toward specialization in medicine. This committee is engaged in the laudable attempt to see that only those qualified shall be regarded as specialists. The creation of a class of approved specialists will serve to draw more sharply than ever the line between specialist and practitioner between which classes relations are already somewhat strained. It is necessary to proceed cautiously to be sure we do not set our standard for the specialist so high that we defeat our own purpose by shutting out many desirable men, that we do not create a type of superspecialist that will still further arouse the antagonism of the practitioner. In all our planning we must devote more time to a consideration of what should be done for the unfortunate practitioner. If he is doomed, what is to take his place? If he can be saved, how is his salvation to be wrought?

Furthermore, there is advanced the idea that while the primary function of the undergraduate medical school is to educate a high grade general practitioner, there are many students who may in their last year or two concentrate on some one subject, in reality begin to specialize. By so doing, they save time if they are to practice a specialty. If they do not specialize, they are better practitioners for knowing one subject unusually well.

And I trust there has been manifest in this paper the thought that whatever we plan for specialist or practitioner, it must never be forgotten that the interest that is paramount is that of the patient.

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**BASAL METABOLISM DETERMINATIONS WITH THE ORIGINAL PORTABLE BENEDICT APPARATUS AND A SIMPLIFIED METHOD OF CALCULATION**

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The present widespread clinical interest in basal metabolism marks an epoch in the practical application of scientific methods to the elucidation of life phenomena in their relationship to disease. It places before the clinician, with very moderate effort, an exact measure of the "speed" with which the stream of life's chemism is being driven, and thereby reveals facts, the fascination of which is exceeded only by their clinical importance.

In the animal body, oxygen consumption is an accurate measure of the processes of combustion; and these processes fundamentally underlie all animal life phenomena. The physics of physiology can, therefore, be expressed in terms of oxidation, each liter of oxygen calculated at zero centigrade and sea level barometric pressure—760 mm. of mercury—being equivalent to a certain number of calories, which varies somewhat with the substance or substances undergoing oxidation. For example, when oxidizing glucose, its caloric value is 5; when oxidizing protein, it is 4.6, etc.

The caloric value of oxygen, the exact knowledge of which is essential in the determination of basal metabolism, can be accurately calculated at any given time from the respiratory quotient, that is, the quotient of the carbon dioxide output divided by the oxygen consumption. Benedict found this average quotient very constant at about 0.82, after fasting overnight and resting one-half hour, and this corresponds to a caloric value of 4.825 for each liter of oxygen when its volume has been corrected to the standard conditions before mentioned. He has, therefore, assumed this value as 1. Sherman, H. C.: Chemistry of Food and Nutrition, New York, the Macmillan Company. 1916.
constant under the usual conditions for determining basal metabolism, that is, fasting and resting state.

Fortunately, the mechanics of respiration, the function of which is to supply the tissues with oxygen and remove from them carbon dioxide—the principal product of body combustion—lends itself very readily to this inquiry. It is only necessary to measure the quantity of oxygen consumed in a given period of time in order to have all the data required to calculate the heat production, which equals the "metabolism" of the body. Now, simple as this may seem to be, it was not until the advent of the Benedict portable respiration apparatus that the measurement of the oxygen consumption became clinically applicable outside expensively equipped institutions. This apparatus, which has already been fully described in the literature, uses what is called the closed-circuit method, the patient breathing into and out of a closed receptacle; the oxygen consumed being determined by loss in the volume of gas, which, inasmuch as the carbon dioxide is absorbed by passing through soda lime and the oxygen unchanged, accurately represents the oxygen consumed. It is rather inconveniently portable, although it can be readily moved from one part of a hospital, or office, to another.

As the result of an experience of about two years of constant use of this apparatus in general diagnostic work, this paper is written with these objects in view:

1. To summarize again briefly my conclusions on the general diagnostic value of basal metabolism determinations.

2. To consider further certain points concerning the original Benedict portable respiration apparatus in particular, with which all my work has been done.

3. To offer a new and simplified method of calculation, which makes optional the use of logarithms.

4. To consider certain criticism recently made of this apparatus, which, if well founded, must be regarded as a serious indictment of work done with this style of apparatus.

1. GENERAL VALUE OF BASAL METABOLISM DETERMINATIONS

As stated in an earlier paper, in my opinion indispensable in the differential diagnosis of a large group of cases, such as those tabulated in the paper to which reference has just been made. These cases have some of the symptoms of thyrotoxicosis, but they may be due to entirely different causes. The entire endocrine system must, of course, be considered and weighed as far as our present imperfect knowledge will permit; but I am more and more convinced of the substantial correctness of the opinion recently expressed by Boothby that in actual practice "at least 95 per cent. of all abnormally increased metabolic rates (either that of exophthalmic goiter or of thyroid adenoma) are due to hyperthyroidism if a febrile condition is eliminated by the thermometry."

It seems to me that a word of caution is needed at this time. A new and somewhat spectacular method of diagnosis has been placed before the profession, and the temptation, subconsciously, to commercialize its impressiveness is very great. Patients may inadvertently be given an impression, and thoughtless physicians, if there are such, may even share the impression, that a "mathematical diagnosis" has been made. Of course, nothing of the sort has been done.

An important biologic phenomenon has been made available for study by the clinician, and is to be considered by him as a part of the data with which the final diagnosis, which is always a complex clinical judgment, is to be constructed. It should take its place without undue "fuss or feathers" by the side of the fever thermometer, cardiographic apparatus, etc., to assist in furnishing the clinician with a broader basis of fact upon which to rest his working clinical formula. An increase of metabolic rate up to 40 or 50 per cent. on a single observation may be nearly always regarded as an indictment of the thyroid, but whether or not the thyroid should be convicted of playing the major role in the pathology of any given case must depend on other factors. Overstimulation of the thyroid, to an extent sufficient to produce this result, at least transiently, may be caused by other primary pathologic conditions, such as focal infections, the existence of which is the duty of the clinician to determine. Their removal may "cure" a mild hyperthyroidism; but such a result would be very doubtful with extreme increases in basal metabolic rates, for example, up to from 75 to 100 per cent. In such cases, the thyroid gland may at once be regarded as playing the major role. Such cases are usually so plain without the determination of the metabolic rate that he who runs may read, and, therefore, in this type of case, metabolism determinations may be said to be of somewhat less importance, at least for actual recognition of thyroid disease, although still important as a scientifically accurate measure of its severity and progress. In the group of cases with slight or moderate metabolic perversions and in which these data are most needed, they are least decisive.

It will be strange if commercial "enterprise" does not seize on the opportunity afforded by the increasing recognition of this method of diagnosis to foist on the profession crude and inaccurate methods, which do not bear the stamp of high scientific approval. The accuracy of the Benedict apparatus is certified by men of established reputation. The oxygen consumption is measured with great accuracy after careful calibration of the spirometer bell; and certainly nothing less accurate than this should be accepted by diagnosticians having a due regard for as great a degree of scientific accuracy as is practical or necessary in a clinical method.

2. RELIABILITY OF THE BENEDICT APPARATUS

Relative to the reliability of the Benedict apparatus in giving dependable results in the determination of the metabolic rate, there is no doubt, in my opinion, that it comes safely within the negligible margin of error permissible in clinical tests. In the first place, we have the reputation of Benedict as a well known scientific investigator, thoroughly familiar with the requirements of such a test. In fact, his work makes up a large part of the history of the subject. When, therefore, he offers this method to the clinician as a practical substitute for the unpractical methods heretofore in use, it can be confidently regarded as a considerable guarantee that the results compare sufficiently closely with the more exact methods of gas analysis to bring it easily within the range of dependability in clinical diagnosis.
In fact, Benedict and Collins,² as a result of an “extensive series of well agreeing comparison tests” made by Benedict, Miles, Roth and Smith³ with a group of young men, specifically say: “Therefore, we can assume that the original portable apparatus gives results, particularly for oxygen, fully as satisfactory as any of the older and more complicated types of respiration apparatus.” This conclusion is supported by another similar series of observations on seventeen healthy medical students made by Hendy, Carpenter and Emmes.⁴ These comparisons were made between the original portable apparatus and the one later described, which has been modified to meet the requirements of greater portability; and the results show slight variations, no greater than those obtained in the same person in two observations made close together. Variations in heat production as large as this might easily occur in the interval between two tests, even when made close together, as a result of slight nervousness, variations in respiratory or circulatory mechanisms, etc. In view of these observations and conclusions of Benedict and his associates, we need have no hesitation in accepting these methods as entirely trustworthy, provided detailed

bration of the spirometer bell, which contains oxygen, makes it possible to measure the exact loss of volume during the observation, and this equals the oxygen consumption.

3. CALCULATION

The metabolic rate is determined from the measurement of the oxygen consumption over a given period of time—say, ten or fifteen minutes. The calculations are a trifle cumbersome and have been made by the use of logarithms, a “weapon” with which clinicians, as a rule, are not very familiar. In following the work of my clinical assistants in making these basal metabolism determinations in selected cases in routine diagnostic work, it seemed to me both possible and desirable to devise a method of calculation which would meet these indications:

1. To make the use of logarithms entirely optional with the clinician.

2. To make the different steps of the calculation logically clear, so that, among other reasons, a mental check might be kept on the procedure throughout.

3. To shorten the process, at least to a slight extent, by eliminating one or two intermediate calculations by a “short cut.”

The first step in the calculation is to observe the exact number of cubic centimeters of oxygen consumed in a certain number of seconds (covering the entire period of the observation), preferably in two or three shorter periods, each to be checked against the other. The range of temperature of the contents of the spirometer bell is noted by reading a thermometer, preferably centigrade, projecting from it, at the beginning and at the end of the observation. For each rise of 1 degree C., 1.8 c.c. is added to the “observed” volume (Benedict). The mean temperature is then determined, being that temperature which is midway between the two extremes. This temperature, together with the barometric pressure expressed in millimeters of mercury, are the two essential factors for carrying out the next step in the calculation, the reduction of the “observed volume” to the so-called “corrected volume,” which is the volume it would have at 760 mm. of mercury, and 0 C.

Instead of making this correction by logarithms, as heretofore advised, a table has been constructed, covering the most usual ranges of barometric pressure and temperature. Table 1 indicates that percentage of the “observed volume” which corresponds to the “corrected volume.”

The figures represent percentages of the observed volume, which correspond to the corrected volume. No other corrections are needed with the portable Benedict apparatus.

Table to be used for the correction of the volume of oxygen gas from the temperature centigrade given in left hand column and barometric pressure in millimeters of mercury given at the head of each column to 0 C. and 760 mm. of mercury.

The accurate measurement of oxygen consumption and the correct calculation of the total calories per square meter per hour, together with the comparison of the result obtained with the normal standard for the age and sex of the individual, are the main additional points involved in the question of accuracy.

<table>
<thead>
<tr>
<th>Temperature Centigrade</th>
<th>Barometric Pressure in Millimeters of Mercury</th>
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<tr>
<td>700</td>
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<td>750</td>
<td>756</td>
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<tr>
<td>760</td>
<td>769</td>
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</table>

Table 1—Percentage of Observed Volume Which Corresponds to the Corrected Volume


80.40 86.89 87.39 87.88 88.38 88.87 89.36 89.85 90.35 90.84 91.34 91.83 92.32 92.81 93.30 93.80 94.29 94.79 95.29 95.79 96.29 96.79 97.29 97.79 98.29 98.79 99.29 99.79 100.29 100.79 101.29 101.79.

90.40 96.89 97.39 97.88 98.38 98.87 99.36 99.85 100.35 100.84 101.34 101.83 102.32 102.81 103.30 103.80 104.29 104.79 105.29 105.79 106.29 106.79 107.29 107.79 108.29 108.79 109.29 109.79 110.29 110.79 111.29.

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Instead of making this correction by logarithms, as heretofore advised, a table has been constructed, covering the most usual ranges of barometric pressure and temperature. Table 1 indicates that percentage of the “observed volume” which corresponds to the “corrected volume.” It is, therefore, necessary only to multiply the “observed volume,” either with or without logarithms, by that percentage in the table (which corre
sponds to the two factors of temperature and pressure just indicated) and all necessary corrections are made.

This table has been computed from data obtained from a work on chemical calculations. The range selected is from 700 to 760 mm. of mercury, barometric pressure, and from 15 to 30 C. These percentages are obtained by means of the formula for the reduction of gas volume to 0 C. and 760 mm., using logarithms in the working out of Charles' law for this reduction. The correction for vapor tension has been ignored. It is so small that it is ridiculous in a clinical calculation with normal fluctuations as wide as those found in basal metabolism. Benedict 11 says that the air passing from the soda lime to the mouthpiece is only 5 per cent, saturated, because of the very rapid "ventilation rate," all of the contents of the spirometer bell being driven through the soda lime about three times a minute.

By common consent the metabolic rate is expressed in calories per hour per square meter of body surface. From the data already obtained, we deduce the total oxygen consumption per hour. While this can be done in several ways, perhaps as good a way as any is to divide the corrected volume of oxygen consumed by the number of seconds in the period of observation, and to multiply this by 3,600, the number of seconds in an hour, and divide by 1,000, the result being the volume of oxygen expressed in liters. Multiplying this by 4.825 gives the total calories of heat production during one hour, or the "metabolic rate." From this the "rate" per square meter is easily obtained by dividing by the body surface expressed in square meters as obtained from the "height-weight" chart of Du Bois and the percentage, if any, above or below the assumed normal standards can be quickly calculated. Permits as it may be illustrated by an actual case record:

Case 2200.—A woman, aged 46; weight, 38.4 kg.; height, 165 cm.; body surface, obtained from Du Bois' chart, 1.38 square meters, was the subject. The observed volume of oxygen consumed was 2,100 c.c. in 500 seconds. The temperature of the spirometer bell at the beginning of the observation was 20 C., at the close, 24 C. The mean temperature was 22 C.; the rise during observation, 4 C., and the corrected barometric reading, 745 mm. of mercury. For rise of temperature, according to Benedict, 7 C. c.c. was added, making the total volume 2,107 c.c. Now, we find on consulting the table that at a temperature of 22 C. and barometric pressure of 745, the corrected volume would be 90.7 per cent. of the observed volume, which equals 1,911 c.c. Dividing this amount by 500, the number of seconds, and carrying the result to two decimals, we find the oxygen consumption to be 3.82 c.c. per second. This must be multiplied by 3,600, which gives the number of cubic centimeters per hour, and the result divided by 1,000 gives the number of liters per hour, which is 1,359.75. To get the number of calories per hour, we must multiply by 4.825, the caloric value of a liter of oxygen at the accepted respiratory quotient of 0.82. This gives 66.34 calories per hour. Dividing this by the body surface, expressed in square meters, 1.38, we obtain 48.0 calories per square meter per hour. The normal for her age (Table 2) is 36; and we find that 48 calories is 33% per cent. above the normal, or +33% per cent., which is the final result.

In order to simplify still further, a constant has been determined for a hypothetical case in which exactly 1 c.c. of oxygen was consumed per second, and in which the body surface was exactly 1 square meter. Such a person would have a metabolic rate of 17.37 calories per square meter per hour. The reason for determining this constant, 17.37, was to make the calculation from a basis of unity in regard to both oxygen consumption per second and square meters of body surface. This furnishes a sort of mental check of the entire procedure, as it is only necessary to multiply this constant by the number of cubic centimeters of oxygen consumed per second and dividing this by the body surface. We may now condense the entire calculation in the case heretofore cited to this:

\[
\frac{2107 \times 0.907 \times 17.37}{500 \times 1.38} = 48,
\]

the number of calories per square meter per hour, which is found to be as heretofore indicated, 33% per cent. above normal for the individual.

As already stated, logarithms can be used with this percentage table, if so desired. The calculation by logarithms in the case just cited would be made thus:

\[
\begin{align*}
\log \text{of } 2107 & \approx 3.32366 \\
\log \text{of } 90.7 & \approx -1.95761 \\
\log \text{of } 17.37 & \approx -1.23980 \\
\text{Sum of these logs} & \approx 4.52107 \\
\log \text{of } 500 & = 2.69897 \\
\log \text{of } 1.38 & = 0.13988 \\
& = 2.83885 \\
& = 1.68222 \text{ difference, or } 48.1 \text{ calories}
\end{align*}
\]

4. CRITICISMS OF THE BENEDICT APPARATUS

In a recent brochure, Boothby and Sandiford, 4 in discussing the "closed circuit" method, of course, with the Benedict apparatus especially in mind, made the following statement: "The chief objection to the apparatus for clinical work is the fact that it cannot be cleaned, and the patient is exposed to the serious danger of infection by rebreathing contaminated air." Such a statement, coming from what is undoubtedly the largest basal metabolism clinic in the world, demands full consideration. If it is well founded, it raises a fair question as to whether or not we are justified in subjecting our patients to such risks. What are the facts?

In regard to the rebreathing of air remaining in the apparatus from previous patients, it can be said at once that such a thing can easily be made impossible. The spirometer bell has a capacity of 9,000 c.c. when emptied as completely as possible by pushing out the residue of gas remaining at the close of an observation; it can be refilled with room air by closing the valves in the breathing tubes and opening the cock through which the oxygen gas is introduced. If then, the valves are opened and the oxygen cock closed, and the bell forced down, 7,000 c.c. of air is forced through the breathing tubes, sweeping out all the air in the spirometer bell and breathing tubes. This can be done twice, although it is probably entirely unnecessary. It is, therefore, perfectly obvious that in a few minutes,

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12 Du Bois, De la Be, and Du Bois, E. F.; A Formula to Estimate the Approximate Surface Area if Height and Weight Be Known, Arch. Int. Med. 17: 863 (June) 1916.
every vestige of residual air left in the apparatus by a previous patient can be completely removed. It, therefore, cannot be rebreathed.

It is impossible for the patient to expire directly back into the tube carrying the purified air from the soda lime to the mouthpiece because of the strong ventilation current forced through by the motor. This is more than 20 liters per minute and is, therefore, many times greater than the tidal volume of respiration. This “ventilation current,” excepting that which is inspired by the patient, is returned to the spirometer bell, completing the circuit again through the soda lime. As just indicated, the volume of this current each minute is from three to four times the contents (which are 7 liters) of the spirometer bell. The patient cannot, therefore, rebreathe even his own air until it has passed through this “circuit.”

In view of these facts, it would seem that the only possible source of danger to subsequent patients would be the deposit of infectious material by an explosive expiration or cough in some part of the expiratory circuit leading to the spirometer bell. That part of the tube leading from the mouthpiece to the right angle bend just beyond the valve, and, of course, including the latter, can be quickly cleaned by suitable brushes and an antiseptic alkaline solution. The possibility of carrying particulate germ-laden material beyond this point is questionable; and its conversion, under the prevailing conditions of moisture, into “floating matter” which might be carried around the circuit through the spirometer bell and through the filtering mass of soda lime, may be fairly said to be impossible. So far as the part coming in direct contact with the patient is concerned, that is, the mouthpiece or the mask, it would seem that the mouthpiece which is used in the Benedict apparatus, although the mask can be used, can be more completely sterilized by boiling than can the mask by washing. We may, therefore, eliminate the mouthpiece itself as a possible source of danger. Finally, it seems perfectly obvious in view of these facts that with the same precautions that are obligatory under all similar technical conditions there is perfect safety from accidental infection.

Taking everything into consideration, it seems to me that the small portable closed-circuit apparatus is the only practical thing for the clinician to use, especially if basal metabolism determinations are to have the wide clinical application that their importance demands. This choice can be made without regret, in view of the fact that its accuracy, especially in determining the oxygen consumption, according to the unqualified statement of Benedict and Collins, compares favorably with that of the larger apparatus requiring gas analysis, and, in view of the further fact, that with suitable precaution it is absolutely free from the danger of communicating infection from one individual to another. In fact, for most clinicians, this type of apparatus alone is possible. No one doubts the somewhat greater accuracy of gas analysis, but after all, even the latter is not absolutely accurate. The margin of error is presumably somewhat smaller, but Boothby and Sandford ignore an error up to 0.06 per cent. for oxygen in check observations. The same comparison may be made between an ordinary fever thermometer which will register temperature within 0.1 degree F. and an electrotherm apparatus which will give readings of 0.01 degree or less. However interesting or even necessary such minute accuracy may be in certain scientific investigations, it has not sufficient value in clinical diagnosis to justify the “handicap” which such methods would impose.

Basal metabolism, like most other physiologic processes, has normal variations which concern the physiologist more than the clinician, although the latter must recognize them in order not to be misled by them. A clinical method gives results which are reliably within the range of these normal variations, it meets the requirements of clinical diagnosis.

The case is a little different with a large investigative clinic like that of the Mayos, with practically unlimited facilities. The foundation of future exact science of endocrinology, for which we are hoping, is being laid on an unprecedented scale. This is a great contribution to medical science, and Boothby and Sandford have done wisely in making the data of this enormous clinical material (at present about 10,000 observations a year) as accurate as the present state of applied science makes possible. While these minute variations must be regarded as at present clinically negligible, there are two reasons why they should be made as small as possible within the practical limits of clinical methods. The first reason is that there is a real danger as already pointed out, that in the widespread application of basal metabolism determinations enough grossly careless or incompetent work may be done to discredit this diagnostic method. The second reason is that in dealing with borderline cases, the importance of which will probably greatly increase with increasing knowledge and experience, small errors will play an apparently large and certainly confusing role.

We cannot, at present, interpret these smaller variations because of the individual variations of the “norm” of the basal metabolic rate. This is quite constant for each normal individual, changing with age, and possibly seasonal and climatic conditions. By comparison with this variation of individual “norms” of the basal metabolic rate extends 10 per cent. above and 10 per cent. below the assumed standards, which are only averages for the different decades of life.

**Summary**

The value of basal metabolism determinations in proving the pathogenic rôle of thyroid hyperactivity has been confirmed by additional experience. Probably more than 90 per cent. of all cases showing marked increase in metabolic rate are due to hyperthyroidism. Other endocrine glands play a small, subordinate rôle.

There is necessity for a warning against “subconsciously commercializing” the impressiveness of the method and the foisting on the profession of crude and inaccurate methods, by commercial “enterprise,” which would inevitably bring discredit on this means of diagnosis.

The accuracy of the Benedict apparatus has been proved, by ample tests, to be substantially the same as the more complicated apparatus requiring gas analysis.

A new and simplified method of calculation is offered involving the use of a percentage table with which logarithms can be used to the desired degree of accuracy.

Certain criticisms relative to the dangers of infection in the use of such an apparatus are considered. It is shown, that by taking certain precautions which are obvious and obligatory in all medical and surgical work involving such questions there is no danger whatever from this source.

13. Footnotes 7 and 9.