The

BASAL METABOLISM

of

Young Men

at

Hyderabad (Deccan)

with

a Study of Their Physical Characters.

by

S. A. Rahman.

INTRODUCTION

Ever since the remarkable piece of work by A. Ozorio de Almeida (1921) in Brazil, the interest of the workers in metabolism has been aroused as to the influence of the racial and the climatic factors in modifying basal metabolism. De Almeida, who studied the basal metabolism of 10 white men and 10 negro labourers using a Tissot gasometer, discovered that the metabolism of the whites was considerably lower than the generally accepted standards for the United States and that the metabolism of the negroes, though higher than that of the whites, was still much below the figures obtained in the temperate zones.

These findings of de Almeida have not been substantiated by many other workers. Prior to de Almeida's work, Eijkmann (1896, 1921), using a Zuntz-Geppert apparatus studied 12 Malays and 11 Europeans living in Batavia and found no difference in the metabolism of the Malays, Europeans in Batavia and Europeans studied in Germany by Geppert, Loewy and Magnus Levy. Takahira (1925) studied the basal meta-

metabolism of 120 Japanese men and women and came to the conclusion that there was no significant difference in metabolism between the Japanese and the Europeans.

On the other hand Montoro (1921, 1922) in Havana obtained results similar to those of de Almeida. The results obtained by Knipping (1923) and confirmed by Fleming (1925) show that prolonged residence in the tropics tends to lower the basal metabolism.

Though the evidence is in favour of the inference that residence in the tropics tends to cause lowering of the basal metabolism, recent investigations suggest that there is also a racial factor involved. McLeod, Crofts and Benedict (1925) studied 7 Chinese and 2 Japanese women who had been students in American colleges for at least fifteen months under the same climatic, dietetic and other conditions as western women. Their metabolism averaged 10.4 per cent below the Harris-Benedict standards for women and 10.2 per cent below the Aub-DuBois standards. The Authors have found both these standards about 5 per cent too high for American College women. But even then this leaves the oriental women about 5 per cent below the American standards. This is in spite of the fact that for over a year the environmental conditions were exactly the same in both the cases. Williams & Benedict (1928) and Shattuck & Benedict (1931) carried out a series of studies on the Maya Indians in Yucatan in connection with the comprehensive program of the Carnegie Institution of Washington for investigating racial metabolism. They used a field respiration apparatus. These investigations brought out the extra-ordinary fact that the average meta-bolism of the Mayas was somewhat above the basal metabolism of the North American whites. This is the first report in which a tropical or subtropical race has shown metabolism higher than that of the American or the European standards.

Again in the third expedition to Yucatan, Steggerda and Benedict (1932) reinvestigated the metabolism in the Maya Indians. They confirmed the results obtained previously that the male Mayas have a high basal metabolism and a low pulse rate. A group of 30 male Mayas were found to have heat production on the average 8 per cent above the prediction standards for the whites. They definitely concluded that this high metabolism was largely due to the racial factor involved. This will be discussed later along with the other factors which have been supposed to influence metabolism.

<u>Basal metabolism observations in India:-</u> In India very few observations have so far been made. Mukherjee (1926) reported the results of observations on 15 male Bengalis between the ages of 22-27 years. The measures were carried out with the Douglas bag and the Haldane's gas analysis apparatus when the subject had been without food for 16-18 hours at a room temperature averaging 27°C. The metabolism on the average was 9 per cent

below the Sanborn standards. In a second paper Mukherjee and Gupta (1931) reported a new series of healthy Bengali men from 20-29 years whose metabolism averaged 13.3 per cent below the Du-Bois standards with individual variations of from -0.3 to - 31.2 per cent. Sokhey (1927), using a Collin's chain-compensated gasometer (a modification of Tissot's gasometer) with the Haldane's air analysis apparatus (Henderson's modification), measured the basal metabolism in 21 male medical students in Bombay between 19-30 years of age. He found that 15 of his subjects showed a basal metabolism 10-23 per cent lower than the Du-Bois standards. The details of the experiments are not given.

Recently Mason (1931) has investigated the basal metabolism of 54 women (Tamils, Malayalis, Telugus, Coorgs and Kanarese) in South India of ages ranging from 17 to 31 years by means of Benedict's portable apparatus. She obtained results 16.9 per cent lower than the Harris-Benedict standards and 17.2 per cent lower than the Aub-DuBois standards and concludes that ~~the~~ there is a definite racial factor.

All these investigations were carried out at seaside places. So far as I am aware, with the exceptions of the tests done at Lucknow which are discussed elsewhere, basal metabolism investigations have not been reported from the interior of India. The present investigations were undertaken with a view to study the physical characters of young men in Hyderabad which is situated at a higher level (nearly 1,700 ft above sea level) and has a drier climate than those places in India whence the basal metabolism results have so far been received.

Technique.

The apparatus used was the Sanborn Motor - Grafic Metabolism Tester, manufactured by the Sanborn Company, Cambridge, Mass. It is a spirometer type of respiration apparatus based on the same principle as the Benedict-Roth apparatus. It consists of an inverted bell supported by a counterweight and floating on water. The bell is filled with medicinally pure oxygen from a small cylinder which is conveniently fixed to the trolley carrying the apparatus. The subject breaths into and out of the bell through a rubber mouth piece, the nose having been closed by means of a nose clip. The rubber mouth piece is connected to an oxygen control valve. When this valve is open, the subject breaths the outside air; when it is closed, the subject is connected to the breathing circuit of the apparatus. The expired air is led through a vessel containing sansoline (supplied by the Sanborn Company) which absorbs the carbon dioxide and the water vapour and the subject breaths in almost pure oxygen. The movements of the bell which correspond to the respiratory movements of the subject are registered on a chart applied to a revolving cylinder which moves by means of clock work.

The apparatus indicates only the oxygen consumption of the subject and in this respect the results are not so accurate as those obtained by the Douglas bag or the Tissot methods, which measure both the oxygen consumption and the carbon dioxide production of the body from which the actual respiratory quotient may be calculated. On the other hand a great advantage of the apparatus is that the results are graphic and permanent (Beaumont & Dodds 1931). The rate of the absorption of oxygen is indicated by the rate of decline in the level of the writing ink-pen which is attached to the spirometer. This method offers a means of checking up leaks that may develop in the apparatus during the test; a very rapid fall in the level of the pen being caused by a leak. Another great advantage of this method is that it registers the mode of breathing. It is reported by Earle and Goodall, and Hannon and Lyman (quoted by King 1924) that only subjects in whom breathing is regular give satisfactory results by the closed system, and other results are readily weeded out by the record of respirations upon a Kymograph. This is certainly true to some extent. I have found that the most constant and accurate results are obtained when the breathing is uniform and regular. If the breathing is irregular, the results obtained are almost invariably too high.

Another advantage of the apparatus is the convenience in calculation; the oxygen consumption per minute is directly read off from the chart, thus eliminating the personal factor in the measurements of the gases.

The apparatus can be used with the motor blower or without it. In the latter case rubber valves are substituted for the motor blower. The motor blower was used, however, only in a few cases. It was found that, with the motor blower in use, the respirations did not remain normal but were much accelerated, while some subjects actually had a feeling of opression as if the air was being pumped into their lungs. (Chart 1.) For this reason the motor blower was dispensed with and the tests were performed with the valves in position.

During most of the experiments, a weight of about 1 lb was placed on the oxygen bell and kept there for two minutes in order to test for outward leaks. This was done as a further precaution, though really it was not necessary as the instrument was tested for leaks before starting the experiment. In order to be sure that the sansoline was working satisfactorily, the gas left over in the bell after an experiment was frequently tested for the presence of carbon dioxide.

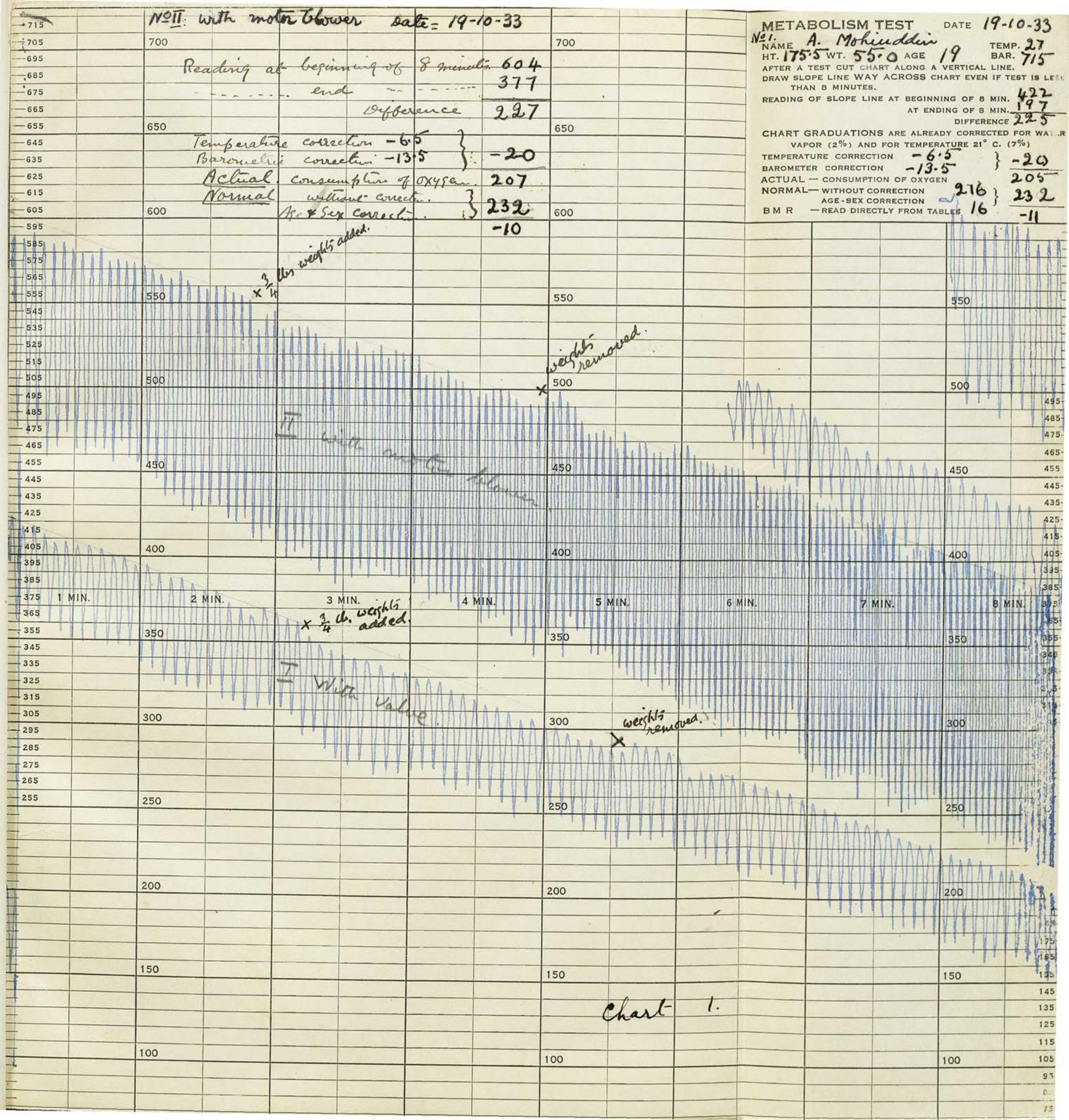
No II with motor blower date = 19-10-33
Reading at beginning of 8 minutes 604
end 377
Difference 227
Temperature correction -6.5
Barometric correction -13.5
-20
Actual consumption of oxygen 207
Normal without correction
Age & Sex correction
232
-10
METABOLISM TEST DATE 19-10-33
No 1. NAME A. Mohiuddin
HT. 175.5 WT. 55.0 AGE 19 TEMP. 27 BAR. 715
AFTER A TEST CUT CHART ALONG A VERTICAL LINE.
DRAW SLOPE LINE WAY ACROSS CHART EVEN IF TEST IS LESS THAN 8 MINUTES.
READING OF SLOPE LINE AT BEGINNING OF 8 MIN. 422
AT ENDING OF 8 MIN. 197
DIFFERENCE 225
CHART GRADUATIONS ARE ALREADY CORRECTED FOR WATER VAPOR (2%) AND FOR TEMPERATURE 21° C. (7%)
TEMPERATURE CORRECTION -6.5
BAROMETER CORRECTION -13.5
-20
ACTUAL — CONSUMPTION OF OXYGEN 205
NORMAL — WITHOUT CORRECTION 216
AGE-SEX CORRECTION 16
232
BMR — READ DIRECTLY FROM TABLES -11
x 3/4 lbs weights added.
x weights removed.
II with motor blower.
1 MIN.
2 MIN.
3 MIN.
4 MIN.
5 MIN.
6 MIN.
7 MIN.
8 MIN.
x 3/4 lb. weights added.
I With valve
x weights removed.

Chart 1.

After a basal metabolism test was made, the chart was slid off the cylinder and cut along one of the vertical lines at the beginning of a good portion of the test. Using a celluloid ruler, a straight line was drawn along the tops of the chart records across the entire breadth of the sheet. This line represented a fair average - a few peaks above and a few peaks below so that the sum total of the distances above the straight line would equal the sum total of those below. The slope line, thus obtained, represented the ave -rage rate of consumption of oxygen during the test. The oxygen consumption per minute was read off directly from the chart. This reading included correction for water vapour (2 per cent) and for temperature of 21°C (7 per cent). Corrections for other temperatures and for the barometric pressures were made by the use of the tables given in the instruction booklet supplied with the apparatus.

A thermometer was supplied with the instrument attached in such a way as to show the temperature of the gas inside the bell. This was hardly ever found to be different from the room temperature. The baro -metric readings were taken by means of Fortin's barometer The wet - and dry - bulb thermometer readings were also recorded.

The majority of the subjects selec -ted were medical students and it was easy to have cooperation from them. Most of the vegetarians, however, were non-students. These volunteered willingly enough for the first day's tests but were not willing for another day's tests. In almost all the cases the subjects slept in the precincts of the Physiology Department (where all the tests were made) having taken their meals between 6 and 7 p.m. The basal metabolism tests were performed the next morning between 8 & 10 A.M. This was the best method to ensure that the subjects did not have anything to eat in the interval and had sufficient rest.

Before the test was made in the morning, the subject was made to lie quiet on the metabolism cot for at least three-quarter of an hour. In the meanwhile his temperature was taken and the pulse and respiration counted. The thermometer was kept in the mouth for at least two minutes and often longer, and care was taken to see that the subject closed his mouth properly. The pulse and respiration counts were taken for one complete minute each. The pulse count was taken repeatedly at short intervals till the pulse rate became constant.

In order not to arouse any undue curiosity on the part of the subject and thereby raise his metabolism, the whole technique of the experiment was explained to him before-hand. So that after he was made to lie on the metabolism cot, he was asked to remain at perfect mental rest and to relax his body as completely as he could.

The rubber mouth piece which was already sterilised by boiling was attached to the Metabolism Tester and applied to the subject's mouth. The bell was then filled with oxygen, the nose clip applied and the test started.

Each test lasted for ten to twelve minutes. The last eight minutes only were taken into account; the first two to four minutes being discarded as often the breathing was irregular in the beginning due to a little excitement. If the breathing showed great irregularity (which it did in a few cases) the test was discarded and another taken. During each test the pulse rate was taken at least once. Usually two and sometimes three, consecutive tests were taken on a subject on the same day.

Selection and Study of the Subjects.

The selection of the subject was made after a careful physical examination. The previous history was thoroughly gone into. Any abnormality found, such as increased tendon jerks or undue nervousness, disqualified a person for the test. One person was disqualified because of congenital nystagmus. The urine was tested as a routine for the presence of albumin, sugar or any abnormal deposits. In short care was taken to ensure that the subject selected was in good health.

<u>Age:-</u> The ages ranged from 19 to 32 years. Only 3 of the subjects were 19 years of age and only 2 were over 30 years. The majority were 20 years of age or a little over, the average for all the 32 subjects working out as 22 years. (Table I.)

<u>Weight :-</u> The weights were taken on empty stomach just after the metabolism tests were done. The subjects were usually thin; the body weight as a whole being rather lower compared to the western standards. In Table II, the actual weights obtained are compared with those published by the Association of Life Insurance Directors and Actuarial Society of America (1912) and adapted by Joslin (1923). The actual weights are converted into pounds (1 kilo = 2.2 lbs.) in order to compare with the standard weights which are given in pounds. It is seen that with the exception of subjects numbers 20, 24, 26, 30, 31, 32, all the subjects are below the standards given for Westerners. According to the standards for the Westerners, the average weight corresponding to the heights and ages of the 32 of my subjects works out as 134.3 lbs, whereas the actual average obtained is 119.3 lbs i.e. 15 lbs (6.8 kilos) less than what it should have been according to the western standards. This does not

Table I.

Subject Number.	N a m e.	Age. Yrs.	Body-weight (without clothes) kgm.	Height cm.	Sitting height cm.	Pelidisi
1.	A.Ahmed	24	51.7	174.7	90.6	89
2.	A.Manan	20	58.5	171.2	87.3	96
3.	S.A.Khan	23	50.8	170.7	88.9	90
4.	L.A.Khan	23	56.2	170.7	88.9	93
5.	S.A.Husain	23	47.2	167.9	88.1	88
6.	M.Y.Zubairi	22	55.8	171.5	90.2	91
7.	M.Imamuddin	21	45.4	166.8	87.6	88
8.	T.N.Reddi	20	55.8	174	89.4	92
9.	S.M.Ali	22	55.5	162	...	...
10.	S.A.Husain	27	59	166.4	84.6	99
11.	A.Mohiuddin	19	55	175.5	89.7	91
12.	R.R.Saksena	22	48.5	168.6	85.8	92
13.	H.A.Ansari	21	46.5	168.3	86.9	91
14.	M.Sharfuddin	19	43.2	166	87.6	86
15.	M.Musiquddin	20	45.4	168.6	87.9	87
16.	Jagmohan	20	52	166.6	85.8	94
17.	Bhushnam	21	49	160.2	86.4	91
18.	I.Rahman	20	56.5	178.6	91.4	90
19.	Q.S.A.Rashid	22	52.5	170.7	90.9	89
20.	K.S.Manvikar	22	71.3	177.7	93.9	95
21.	R.Karan	22	53	177	...	...
22.	Q.Ali	20	55.5	174	90	91
23.	M.R.Beg	20	63	174.5	94.2	98
24.	I.Ahmed	21	57	164	86.6	96
25.	R.N.Abhyankar	32	54	165.1	87.9	93
26.	P.Shankarya	22	57.2	162.2	83.8	99
27.	X.Ramiah	20	46.5	164.5	86.4	90
28.	S.Ramiah	19	41.5	168	86.4	86
29.	R.B.Phatkay	20	56.2	172	90.3	91
30.	I.G.Gadray	28	60.2	159.5	85.3	99
31.	Ranade	31	68.2	162.5	87.6	100
32.	V.G.Gadray	23	68.2	167	89.1	99
	Average	22	54.2	169.3	88.3	92 ±

necessarily indicate a state of undernutrition. The smaller weight of my subjects is certainly due in part to the lower stem height (sitting height). Mason (1931) has also found that the average weight of her women subjects in Madras was slightly less (about 3.6 kilos) when compared to the American standards. This, I would add, was in spite of the fact that the Indian women have a greater tendency to accumilate the adipose tissue.

With the exceptions of the subjects Nos. 14 and 28 who were very thin and had a low pelidisi (Table I) and therefore might have been undernourished, the rest of the subjects were not under nourished. They were certainly getting a good diet and were apparently quite active and healthy. It would therefore seem that the smaller weight in the case of the young Indians is a racial character partly depending on the fact that the stem height is low.

Sitting height:- The sitting height was actually measured in every case with all the precautions emphasised by Dreyer (1921). As mentioned by Pirquet (1922), the sitting height thus measured equals, in Westerners at least, one half of the total height plus 5 cm. Table II shows the actual sitting heights obtained in the case of my subjects as compared with the sitting heights calculated according to the formula, h/2 plus 5 cm, where h stands for the total height. It is seen that the actual sitting height in most of the cases is less than the calculated sitting height. The average sitting height

TABLE II.

Subject No:	Height Cm.	Sitting height cm.			Body weight (without clothes) Lbs.			Deviation from Normal.		
		Actual	Calculated.	Difference.	Actual	American standards.	Difference.	Harris-Benedict per cent	Aub-Du Bois per cent	Sanborn per cent.
1	174.7	90.6	92.3	− 1.7	114	146	− 32	− 14.5	− 17.1	− 14.7
2	171.2	87.3	90.6	− 3.3	129	136	− 7	− 6.7	− 7.9	− 7.75
3	170.7	88.9	90.3	− 1.4	112	137	− 25	+ 2.7	0	+ 0.6
4	170.7	88.9	90.3	− 1.4	124	138	− 14	− 5	− 6.8	− 5
5	167.9	88.1	88.9	− 0.8	104	134	− 30	− 1	− 1.2	− 1
6	172.7	90.2	91.3	− 1.1	123	140	− 17	+ 2.7	+ 0.4	+ 3.2
7	166.8	87.6	88.2	− 0.6	100	129.5	− 29.5	− 17.4	− 19	− 18
8	174.0	89.4	92.0	− 2.6	123	140.0	− 17.0	− 10	− 11	− 12
9	162.0	87	86.0	+ 1.0	122	125	− 3.0	− 9	− 10	− 8.7
10	166.4	84.6	88.2	− 3.6	130	134.5	− 4.5	− 14	− 16	− 14
11	175.5	89.7	92.7	− 3.0	119	140	− 21.0	− 0.8	− 4.3	− 5.8
12	168.6	85.8	89.3	− 3.5	107	134	− 27.0	− 6	− 7.8	− 7.3
13	168.3	86.9	89.1	− 2.2	102	131	− 29.0	− 16	− 17.7	− 17
14	166.0	87.6	88.0	− 0.4	95.5	136	− 40.5	+ 8	+ 2.3	+ 8
15	168.6	87.9	89.3	− 1.4	100.0	132	− 32.0	− 1	− 4.5	− 3

T A B L E II (CONTINUED).

Subject No.	Height Cm.	Sitting height cm. Actual	Sitting height cm. Calculated.	Sitting height cm. Difference	Body weight (without clothes) Lbs. Actual	Body weight (without clothes) Lbs. American standards.	Body weight (without clothes) Lbs. Difference.	Deviation from Normal. Harris-Benedict per cent.	Deviation from Normal. Aub-Du Bois per cent.	Deviation from Normal. Sanborn per cent.
16	166.6	85.8	88.3	− 2.5	114	128	− 14.0	+ 3	+ 2.2	+ 1.3
17	160.2	86.4	85.1	+ 1.3	108	119.5	− 11.5	− 11	− 12.5	− 11
18	178.6	91.4	94.3	− 2.9	124	148.5	− 24.5	− 8	− 8.8	− 11
19	170.7	90.9	90.3	+ 0.6	115.5	136	− 20.5	− 1	− 4.15	− 2.8
20	177.7	93.9	93.8	+ 0.1	157	148	+ 9.0	− 10.5	− 10.5	− 10.3
21	177.0	87	93.5	− 6.5	117	144	− 27.0	− 11.5	− 14.65	− 12.75
22	174.0	90	92.0	− 2.0	122.5	140	− 17.5	− 9	− 10	− 10
23	174.5	94.2	92.2	+ 2.0	139	142	− 3.0	− 8	− 7.6	− 8.3
24	164.0	86.6	87.0	− 0.4	125	125	± 0	− 17	− 17.2	− 16.5
25	165.1	87.9	87.5	+ 0.4	119	135	− 16.0	− 10	− 16.4	− 10.2
26	162.2	83.8	86.1	− 2.3	125.4	125	+ 0.4	− 4.25	− 5.15	− 3.75
27	164.5	86.4	87.2	− 0.8	102	126	− 20.0	+ 0.6	− 1.5	+ 0.5
28	168.0	86.4	89.0	− 2.6	91	130	− 39.0	− 11	− 14.6	− 7
29	172.0	90.3	91.0	− 0.7	123	137	− 14.0	− 12	− 13.4	− 11.5
30	159.5	85.3	84.7	+ 0.6	132	125	+ 7.0	− 9.2	− 11.9	− 10
31	162.5	87.6	86.2	+ 1.4	150	130	+ 20.0	− 6.5	− 7.8	− 6.5
32	167.0	89.1	88.5	+ 0.6	150	133	+ 17.0	− 6	− 4.9	− 4
Average	-	-	-	− 1.2	119.3	134.3	− 15.0	− 6.8	− 8.7	− 7.4

works out as 1.2 cm less than the calculated average. From this it is seen that the average young Indian has a stem height about 1.2 cm less, and therefore correspondingly longer legs, than the average Westerner. Even greater difference in sitting heights was found my Mason (1931) in the case of her women subjects. She foundthat with the Tamils one half of the average total height was 77 cm and the actually measured sitting height was, on the average, only a little over 1 cm greater than this. Much the same picture was shown by her other groups.

Pelidisi. The usual clinical classification of well nourished, moderately well nourished, poorly nourished etc. is not precise and therefore not satisfactory as an indication of the state of nutrition of an individual. As the basal metabolism is affected by the nutritional state of the individual, it is essential for the study of the normal subject to have a precise knowledge of his state of nutrition. The Nutrition Laboratory of the Carnegie Institution of Washington has found the pelidisi of Pirquet of great ad--vantage over the ordinary, rather gross, clinical indications (Shattuck & Benedict 1931).

Pelidisi is the relationship between the weight of the individual and his sitting height. This method of fixing the state of nutrition of an individual was first originated by the late Professor Clemens Pirquet (1922) of Vienna and is known as the Pirquet index.

It is expressed by the formula

$$\sqrt[3]{\frac{10 \text{ X weight in gm}}{\text{sitting height in cm}}}$$

and the result is multiplied by 100.

In the original preparation of the material, Pirquet assumed that for small children a pelidisi of 100 represented the ideal. It has since been found that for adults a value somewhat less than this probably nearer 97 or 98 represents the normal state of nutrition. It has been found that with Westerners a pilidisi around 90 represents a distinctlylow state of nutrition and that a pelidisi over 100 represents a fat person.

Table I. shows the pelidisi in the case of my subjects as it has been calculated from the sitting height actually obtained. The majority of the results are over 90, the minimum being 86 in the subjects Nos. 14 & 28, the maximum being 100 in the sub-ject No. 31. The average for 30, out of the 32 subjects, works out as 92 ± 4.

It is therefore clear that the pelidisi as obtained in these subjects is less than that **which is** accepted as representing the normal state of nutrition in the Westerner. Does this denote that these subjects were under-nourished? I do not think so. Exceptions might be made in the case of subjects Nos. 14 & 28 who were unusually thin. The rest were certainly in good health and were getting good food. It would probably be more correct to infer from the results that a pelidisi of about 92 indicates the normal state of nutrition in young Indians. That the pelidisi showing the normal state of nutrition may differ in different races is suggested by the measurements in the Chinese. Stevenson (1928), after examining over three thousands ~~of the~~ Chinese, came to the conclusion that the Chinese approaches the pelidisi of 90 as the basic standard. Benedict and Meyer (1933) found that the average pelidisi of their 18 American born Chinese girls (12 - 22 years of age) was 92.

<u>Blood pressure:</u> The blood pressure was taken after the basal metabolism tests were over and before the subject had partaken of any food. The instrument employed was of Riva Rocci type fitted with mercury monometer the zero point of which was carefully adjusted. The elastic cuff was about 12 cm broad. This is assumed to give an error of from plus 7 to plus 9 per cent compared with the pressures obtained directly from the artery (Norris, Bazett & McMillan 1928). The auscultatory method was employed. The subject was made to sit on a stool with the left hand, which was used for examination, resting relaxed on a table in front, palm upwards. In this posture the brachial artery was level with the heart. Readings were taken during release of pressure. Reading of the systo -lic pressure was taken at the point at which the first

clear thump was heard below the cuff (first phase) the stethoscope being snugly applied to the artery. The dia-stolic pressure was read at the so called fourth phase i.e at the point where the second clear thump becomes suddenly muffled. Several consecutive readings were taken to ensure correctness of results, the pressure between the readings being allowed to fall to zero and sufficient time permitted to elapse for the venous pressure to fall to normal level. The psychical element of interference in the case of these subjects was negligible and did not interfere in obtaining correct results.

The blood pressure estimates show that the readings are invariably lower than what has been taken as normal for Westerners. The average systolic pressure obtained was 100.4 ±11 mm of mercury, the maximum being 125 mm in subject No. 4 and the minimum being 75 mm in subject No. 22 (Table III). The normal systolic pressure in Westerners as studied by Melvin and Murrey (1914) was 112 mm for young men between the ages of 20-29 years. Fisher (quoted by Norris et al 1928) found that, in 64, 574 cases studied by him, the average auscultatory systolic pressure was 123.2 mm ranging from 116 mm at 16 years to 136 mm at 65 years. More important are the results obtained by Alvarez (1920, 1923) who, unlike Fisher, did not base his results on insurance statistics but studied students in a State controlled University. He found that 45 per cent of the male students had pressure exceeding

T a b l e III.

Subject Number.	Date.	Mouth temperature. °F	Blood pressure. Systolic	Average systolic	Diastolic	Average diastolic	Average Pulse pressure	Pulse rate. Before start of experiment.	Pulse rate. During experiment.	Respiration rate. Before experiment	Respiration rate. During experiment.
1	8.9.1933	98.2	92	94.5	64	68	26.5	48	54	21	18
1	14.10.1933	98.1	97		72			55	53	15	14
2	8.9.1933	98.5	100	95.5	68	65.5	30.0	56	49	15	28
2	8.4.1934	98.5	91		63			67	73	22	21
3	8.9.1933	99.0	122		80			86	82	19	12
3	18.10.1933	98.8	112	113	80	77.3	35.7	78	77	15	15
3	22.8.1934	98.4	105		70			67	60	18	15
4	27.9.1933	98.2	125	125.0	85	85.0	40.0	66	70	--	--
5	27.9.1933	98.0	110	110	65	65	45	73	68	--	--
6	27.9.1933	98.4	123		75			66	66	16	12
6	28.9.1933	98.0	108	114.2	75	78.5	35.7	63	61	16	12
6	8.10.1933	98.0	110		82			61	61	11	12
6	18.10.1933	97.9	116		82			61	61	13	10
7	28.9.1933	98.0	108	108	75	75	33	63	61	16	14
8	28.9.1933	97.6	115	115	75	75	40	62	62	19	14
9	27.9.1934	97.7	95	95	70	70	25	53	53	22	31
11	8.10.1933	98.4	120		100			--	--	13	16
11	19.10.1933	97.5	108	111	85	87	24	72	75	14	12
11	8.4.1934	98.2	105		76			78	77	17	15
12	9.10.1933	98.5	103	98	69	71	27	76	70	16	11
12	21.10.1933	97.5	93		73			62	59	18	12
13	12.10.1933	97.8	102	102	72	72	30	66	60	20	17
14	12.10.1933	99.4	98	98	68	68	30	93	93	22	21
15	14.10.1933	98.7	110	110	72	72	38	78	82	19	17
16	15.10.33	98.5	111		70			54	54	15	15
16	31.7.1934	98.0	95	103	65	67.5	35.5	54	53	18	15
16	1.8.1934	98.0	--		--			53	51	20	16
17	21.10.1933	98.0	95	95	65	65	30	58	58	20	14
18	18.10.1933	98.4	85	85	64	64	21	60	62	20	21

T a b l e III (Continued)

	Date.	Mouth tempera-ture. °F	Blood pressure. Systolic.	Average systolic.	Diastolic	Average diastolic.	Average Pulse pressure.	Pulse rate. Before start of experiment.	Pulse rate. During experiment.	Respiration rat[e] Before experiment.	Respiration rat[e] During experiment.
19	24.3.1934	98.4	97	97	73	73	24	61	60	17	11
20	25.3.1934	98.0	98	98	67	67	31	57	57	17	14
21	31.7.1934	98.4)	100)	100	75)	75	25	60	61	18	15
21	1.8.1934	98.2)	--)		--)			61	60	18	17
22	27.9.1934	98.2	75	75	60	60	15	51	53	21	21
23	28.8.1934	98.2	105	105	75	75	30	67	65	15	12
24	28.8.1934	98.4	97	97	78	78	19	65	60	20	19
26	22.8.1934	98.0)	85)	85	65)	65	20	52	51	19	14
26	23.8.1934	97.6)	--)		--)			47	44	17	16
27	9.10.1934	99.0	84	84	64	64	20	79	71	20	17
28	9.10.1934	99.0	89	89	70	70	19	75	74	20	18
29	12.10.1934	98.4	98	98	73	73	25	71	67	21	20
30	12.10.1934	98.2	112	112	78	78	34	85	81	22	13
31	27.10.1934	97.6	95	95	75	75	20	56	57	15	9
32	27.10.1934	98.4	105	105	75	75	30	65	68	23	18
	Average.	98.3		100.4 ±11		71.8 ±5	28.6 ±7.2	65	64	18.7	16.4

130 mm which he considered to be abnormal. According to Alvarez, the normal upper limit of the systolic blood pressure for healthy young men is 130 mm.

The lower limit of the normal systolic blood pressure, according to Norris, Bazett and McMillon (1928), is usually 110 mm, and when this pressure goes below 105 few can be on their feet regularly. It is evident that these figures cannot be applied to Indians.

Diastolic pressure: The average diastolic pressure of 71.8 ±5 in my subjects (Table III) is in keeping with the estimate of Woley (1910) who felt that it should be 70 per cent of the systolic pressure. Fisher, in the cases above referred to, found that the diastolic pressure had averaged 80 mm.

Pulse pressure: Fisher, basing his results on the insurance statistics above referred to, found that the average pulse pressure for all ages was 43.2 mm. This figure tallies closely with that of Symond (1923) who found the average pulse pressure for all builds and all ages to be 44.1 mm. Norris, Bazett and McMillan (1928) place the limits of normal pulse pressure between 30 & 50 mm and regard a pulse pressure persistantly as low as 20 or as high as 60 mm as pathological.

The average pulse pressure in my subjects is 28.6 ±7.2 mm which is lower than what Narris et al regard as minimum in the normal range. The minimum pulse pressure obtained is 19 mm in the case of subjects Nos.24 and 28, the maximum is the maximum is 35.7 mm in the subjects Nos. 3 and 6. These pulse pressures, though very low compared to the Western standards, are, however, quite in proportion to the systolic and the diastolic pressures obtained in the subjects.

Previous observers in the tropi -cal and sub-tropical countries have also noted lower blood pressure in the inhabitants. McCay (1907) investigated the blood pressure in a large number of the Bengali students. The readings for the systolic blood pressure were taken at the dis-appearance of the pulse at the wrist. The pressure varied between 83 mm and 118 mm the average being slightly over 100 mm (sitting position, arm level with heart). The observations on the Philippinos by Musgrave and Sisson (1910) also indicate a lower systo -lic level. Cadbury (1922) studied the Chinese students and found their systolic blood pressure from 20-30 mm and diastolic pressure from 10-20 mm lower than the normal one finds in the inhabitants of North America and Europe.

Recent investigations in India give further evidence of low blood pressure in the Indians. Mukherjee and Gupta (1931) recorded the blood pressure of 12 Bengali students and found the average systolic to be 108, average diastolic 78 and the pulse pressure 30 mm. The Indian Medical Record (1931) gives the average systolic pressure of healthy Punjabees, between the ages of 21 and 25, as 114 mm and the diastolic pressure as 74. Stock and Karns (1924) examined 14

Indian students resident in London along with 103 British male students. They found a systolic average of 118.7 and a diastolic of 80.3, while the corresponding figures for the British group were 130.3 and 84.8 respectively. More recently Subba Reddy (1933) has investi-gated the blood pressure in 112 male students of Vizaga-patam Medical College between the ages of 18 and 27 years. His results show that 41.07 per cent of his subjects have the systolic pressure between 111 and 120 mm, and 23.21 per cent between 121 and 130 mm. The average systolic pressure was 116.8, the average diastolic 76.9, and the average pulse pressure 39.9 mm. These results are higher than those obtained by Cadbury in the Chinese students and higher than the results obtained in the case of my subjects. The high results obtained on Vizagapatam students may partly be due to the fact that the investigations were made in the afternoon presumably after the mid-day meal when the blood pressure may be expected to be somewhat higher. Even then the results obtained at Vizagapatam are lower than those given for Westerners by Fisher and Alverez.

It is possible that the warmer climate of the tropical and sub-tropical countries lowers the blood pressure by causing the dilatation of the skin capillaries. That environmental conditions are an important factor in determining blood pressure is brought out by the studies of Tung (1928) on the Chinese. Blood pressure was examined in the case of 30 Chinese during their stay in America and also after their return to Peking. The average systolic pressure in America was found to be 113 mm. and in China 102 . The average diastolic pressure in America was 72, and it was 64 in Peking. Tung also reports that there is a distinct tendency for the blood pressure of Westerners resident in China to approach that of the Chinese. It therefore seems, as Tung suggests, that environmental and not racial differences are the main determining factors of blood pressure.

Mouth temperature: This ranged from 97.5° to 99.0° F, the average working out as 98.3° F (Table III). The mouth temperature was taken before the basal metabolism test was started, the subject lying on the metabolism cot. The thermometer was kept in the mouth for at least two minutes.

Pulse rate: Column 9 of Table III gives the pulse rate taken just before starting the basal metabolism tests. This is compared with the rate of the pulse taken while the tests were in progress. It is seen that the latter is slightly lower than the former.

The pulse rate, taken before starting the metabolism tests, ranged from 53 in the case of subjects Nos. 9 & 16 to 86 in the case of subject No. 3. The average for 30 subjects works out as 65.

The data on the basal pulse rate are numerous in the case of western subjects. Körösy

(1910) counted the pulse rate of 255 soldiers, between the ages of 20 and 24 years, early in the morning before they had arisen from the beds and partaken of any food. He found the average rate of 64.2 with the maximum of 108 and the minimum of 42. Sutliff and Holt (1925) established for 146 adult men an average pulse rate of 62. Harris and Benedict (1919, quoted by Boas and Goldschmidt 1932) found the average basal pulse rate in the case of 121 adult males as 61.26 ± 6.73. Boas and Goldschmidt (1932) found in 51 males of the average age of 28.1 years, the basal pulse rate of 61.4 ± 8.22. They state that the basal pulse rate is lower and less variable than the pulse rate measured under less standardised conditions, because many extracardiac factors that affect the heart rate are eliminated in the post absorptive resting state.

It is seen that the pulse rate in the case of my subjects corresponds closely with the results obtained in the Westerners.

Mason (Mason & Benedict 1931) also found that the average pulse rate in the case of the South Indian women corresponded closely with the average pulse rate in 90 American women studied by Harris and Benedict (1919).

That the pulse rate may differ with certain races is suggested by the observations of Steggarda and Benedict (1932) on the Mayas. They found in 30 male Mayas an average pulse rate of 52, with the minimum rate of 34 - figures considerably lower than the average established in other peoples.

Respiration rate: The respiration rate was counted before commencing the metabolism tests, the subject lying on the metabolism cot. Precautions were taken not to attract the subject's attention to his respirations. The respirations were counted for fully one minute. The lowest rate was in the subject No. 6, being 11, 13, 16 and 16 on the four different dates. The highest rate was 23 in the subject No. 32. The average for all the subjects works out as 18.7 per minute. There seems to be little difference between the respiration rates as obtained in these subjects and those described for Westerners. M'Kendrick (1889) mentions that in health there are usually 15 respirations per minute in the adult. Quételet (quoted by M'Kendrick 1889) gives a table indicating the maximum respiration rate between the ages of 20-25 years, as 24 per minute, the minimum 14 per minute and the average 18 per minute. According to Burton - Opitz (1921), the average rate of respiration between these ages is 18.7, exactly the same as has been obtained in the case of my subjects. Halliburton and McDowall (1930) give the rate of respiration in a healthy adult person as ranging from 14-18 per minute. Thus it would seem that, considering the warmer climate and the lower barometric pressure (about 720 mm Hg.) the respiration rate in these subjects is not any higher than what has been recorded for Westerners.

Table III gives also the respiration rates during the periods in which the metabolism tests were carried out i.e. the periods in which the subjects were connected with the metabolism apparatus. It is seen that in such a state the respiration rate is almost invariably lower, the average working out as 16.4. This accords with the experience of the Nutrition Laboratory of the Carnegie Institution of Washington that, not invariably but in general, there is a tendency for the respiration rate to become somewhat slower when any breathing appliance is attached (Shattuck and Benedict 1931; Mason and Benedict 1931).

The respiration rates so obtained are not far from those found in the case of the Mayas by Shattuck and Benedict (1931) under similar conditions and which were not considered by them as far from the normal.

Surface area: The necessity to obtain the surface area of the body has arisen in order to find the basal metabolism. A commonly accept-ed standard of the basal metabolism is the amount of heat produced per square metre of the body surface per hour. The surface area, however, was not actually measured but was obtained by the help of the excellent chart prepared by DuBois (1916, DuBois 1927) and based on his height - weight formula.

In the case of the Chinese adults, it has been shown by Waddell, Han and Ch'en (1928 that the DuBois height-weight formula for the estimation of surface area is applicable with as much accuracy as in the case of the American subjects. Whether it can be applied with as much accuracy in the case of the Indians with smaller stem height is problematic.

Oxygen consumption: This was measured with all possible care. All possible attention was given to guard against leakage. The mouth piece gave no trouble, but the nose clip required perticular and, in some cases, constant attention. It had to be applied tight enough to prevent any leakage through the nose and at the same time not so tight as to be uncomfortable to the subject. The leak-tester was frequently used both before starting the chart to run to see if the nose clip was properly applied or not, and also during the time when the chart was running and the respiration recorded. Occas-sionally it was found that the nose clip seemed to have had been applied properly before starting a test, the leak-tester indicating no leakage; however, when the actu-al test was going on slight leakage was discovered during some period of the test. Such tests were obviously incorrect and were discarded. The leak-tester consisted of a brightly polished white metal piece. This was cooled by keeping it in cold water and, before use, was wiped clean with a piece of white muslin. During the monsoon season it was found that the use of ice cold water to cool the leak-tester was not proper. This made the leak-tester too cold, so that when it was removed from the ice cold water and wiped clean for use, it was found that a thin film of moisture from the atmosphere, which was nearly saturated, was deposited on the surface and made the leak-tester unsuitable for work. Water a few degrees colder than the tap water was best for the purpose.

Usually two tests were made on a subject on any perticular day. The oxygen consump -tion per minute was read off from the chart. This is shown in detail in column 6 of Table IV. It is seen that the results obtained of the two consecutive tests are usually within 5 per cent of each other. Column 7 of the same Table gives the average of two or more tests done on the same day. Occassionally a test had to be discarded when a leak was discovered or when the breath -ing was very irregular. Often tests on a subject were made on two or more different days. This was deemed specially necessary when high readings were obtained, to make sure that the high results were not due to any error in technique.

The average exygen consumption for all the 32 subjects works out as 200.4 c.c. per minute.

Heat production per hour:

Column 8 of Table IV gives the total heat production of the body per hour from which the heat production per square metre of the body surface was calculated. This is given in column 9. The heat production was computed from the oxygen consumption. It was assumed that the

TABLE IV.

Subject No:	Date.	Weight (without clothes) Kgm.	Height Cm.	Surface area Sq. m.	Oxygen consumption per minute C. C.	Average oxygen consumption per minute C. C.	Heat production per hour Cal: Total	Heat production per hour Cal: per Sq. m.	Deviation from normal: Harris-Benedict	Deviation from normal: Aub-Du-Bois	Deviation from normal: Sanbor
1	8th Sep: 1933	51.7	174.7	1.63	194	194	56.2	34.5	– 9	– 13	– 11
1	14th Oct: 1933	52.0	174.7	1.63	180, 177	178.5	51.65	31.3	– 20	– 21.2	– 18.
2	8th Sep: 1933	58.5	171.2	1.69	207	207	59.9	35.5	– 9	– 10	– 10
2	8th April 1934	55.4	171.2	1.65	206.5, 217.5	212	61.4	37.2	– 4.5	– 5.8	– 5.5
3	8th Sep: 1933	51.0	170.7	1.59	226	226	65.4	41.2	+ 7	+ 4.3	+ 5.0
3	18th Oct: 1933	51.0	170.7	1.59	205.0, 210.5	207.7	60.1	37.8	– 1	– 4.3	– 3.5
3	22nd Aug: 1934	49.5	173.0	1.58	215.0, 216.0	215.5	62.35	39.5	+ 2	± 0	+ 0.2
4	27th Sep: 1933	56.2	170.7	1.66	211	211.0	61.1	36.8	– 5	– 6.8	– 5
5	27th Sep: 1933	47.2	167.9	1.52	205	205.0	59.3	39.5	– 1	– 1.2	– 1
6	27th Sep: 1933	56.0	172.5	1.67	245	245.0	70.9	42.5	+ 10	+ 7.6	+ 10
6	8th Oct: 1933	55.8	171.5	1.66	212	212.0	61.4	36.98	– 4	– 6.4	– 4
6	18th Oct: 1933	55.8	171.5	1.66	233.0, 220.0	226.5	65.52	39.5	+ 2	± 0	+ 3.5
7	28th Sep: 1933	45.4	166.8	1.48	163.5	163.5	47.35	31.99	– 17.4	– 19	– 18
8	28th Sep: 1933	55.8	174.0	1.67	203.0	203.0	58.8	35.2	– 10	– 11	– 12

T A B L E IV. (CONTINUED).

Subject No:	Date.		Weight (without clothes) Kgm.	Height Cm.	Surface area Sq. m.	Oxygen consumption per minute C. C.	Average oxygen consumption per minute C. C.	Heat production per hour Cal: Total	per Sq. m.	Deviation from normal. Harris-Benedict	Aub-Du-Bois	Sanborn
9	27th Sep:	1934	55.5	162.0	1.59	197.5, 193.0	195.2	56.5	35.5	− 9	− 10	− 8.7
10	17th Aug:	1933	59.0	166.4	1.67	190.0	190.0	55.0	32.93	− 14	− 16	− 14
11	19th Oct:	1933	55.0	175.0	1.67	205.0, 207.0 214.0	208.7	60.4	36.2	− 8	− 11.7	− 9.3
11	8th Oct:	1933	54.0	175.5	1.66	224.5, 231.5	228.0	66.0	39.8	+ 2	− 3.0	− 1.5
11	8th April	1934	56.0	175.5	1.69	236.5, 230.0	233.2	67.5	41.7	+ 3.5	+ 1.7	− 1.1
12	9th Oct:	1933	48.5	168.6	1.54	209.6	209.6	60.68	39.4	+ 1.5	± 0	± 0
12	21st Oct:	1933	48.5	168.6	1.54	173.5, 181.5	177.5	51.35	33.3	− 13.5	− 15.7	− 14.5
13	12th Oct:	1933	46.5	168.3	1.51	169.5	169.5	49.05	32.5	− 16.0	− 17.7	− 17.0
14	12th Oct:	1933	43.2	166.0	1.45	210.0	210.0	60.8	41.9	+ 8.0	+ 2.3	+ 8.0
15	14th Oct:	1933	45.5	168.6	1.49	199.0	199.0	57.6	37.9	− 1.0	− 4.5	− 3.0
16	15th Oct:	1933	52.0	166.6	1.57	209.5, 211.0	210.2	60.8	38.7	− 1.0	− 2.0	− 1.7
16	31st July	1934	53.3	167.1	1.59	234.0, 231.0	232.5	67.35	42.35	+ 8.0	+ 7.2	+ 7.0
16	1st Aug:	1934	53.3	167.1	1.59	221.0, 219.0	220.0	63.7	40.0	+ 2.0	+ 1.5	+ 1.5
17	21st Oct:	1933	49.0	160.2	1.49	181.0, 175.0	178.0	51.5	34.6	− 11.0	− 12.5	− 11.0

TABLE IV. (CONTINUED).

Subject No:	Date.	Weight (without clothes) Kgm.	Height Cm.	Surface area Sq. m.	Oxygen consumption per minute C. C.	Average oxygen consumption per minute C. C.	Heat production per hour Cal: Total	Heat production per hour Cal: per Sq. m.	Deviation from normal. Harris-Benedict	Deviation from normal. Aub-Du-Bois	Deviation from normal. Sanborn
18	18th Oct: 1933	56.5	178.6	1.70	207.5, 215.5	211.5	61.25	36.0	– 8.0	– 8.8	– 11.0
19	24th March 1934	52.5	170.0	1.60	207.0, 211.5	209.2	60.5	37.8	– 1.0	– 4.3	– 3.5
19	25th March 1934	52.5	170.0	1.60	216.0, 203.0	209.5	60.65	37.9	– 1.0	– 4.0	– 3.5
20	24th March 1934	71.3	177.5	1.88	232.0, 230.0	231.0	66.9	35.6	– 10.0	– 10.0	– 9.5
20	25th March 1934	71.3	177.5	1.88	228.0, 228.0	228.0	66.0	35.1	– 11.1	– 11.0	– 11.0
21	31st July 1934	53.0	177.0	1.65	199.0, 199.0	199.0	57.6	34.9	– 9.0	– 11.6	– 11.0
21	1st Aug: 1934	53.0	177.0	1.65	196.0, 186.0	191.0	55.3	33.5	– 14.0	– 17.7	– 14.5
22	27th Sep: 1934	55.5	174.50	1.67	207.5, 203.0	205.2	59.3	35.5	– 9.0	– 10.0	– 10.0
23	28th Aug: 1934	63.0	174.5	1.76	224.5, 217.5	221.0	64.0	36.4	– 8.0	– 7.6	– 8.3
24	24th Aug: 1934	57.0	164.0	1.62	184.0, 182.0	183.0	53.0	32.7	– 17.0	– 17.2	– 16.5
25	14th Aug: 1933	54.0	175.5	1.66	187.0, 191.0	189.0	54.7	33.0	– 10.0	– 16.4	– 10.2
26	22nd Aug: 1934	57.2	162.0	1.61	214.0, 211.0	212.5	61.55	38.2	– 2.5	– 3.3	– 2.0
26	23rd Aug: 1934	57.2	162.2	1.61	208.0, 202.0	205.0	59.3	36.8	– 6.0	– 7.0	– 5.5
27	9th Oct: 1934	46.5	164.5	1.50	209.0, 194.0	201.5	58.35	38.9	+ 0.6	– 1.5	+ 0.5

T A B L E IV. (CONTINUED).

Sub-ject No.	D a t e.	Weight (with-out clothes) Kgm.	Height Cm.	Surface area Sq. m.	Oxygen consumption per minute C. C.	Average oxygen consum-ption per min-ute C. C.	Heat production per hour Cal: Total	Heat production per hour Cal: per Sq. m.	Deviation from normal. Harris-Benedict	Deviation from normal. Aub-Du-Bois	Deviation from normal. Sanbor
28	9th Oct: 1934	41.5	168.0	1.43	178.5, 168.0	173.2	50.1	35.0	− 11.0	− 14.6	− 7.0
29	12th Oct: 1934	56.2	172.0	1.66	197.5, 195.0	196.2	56.7	34.2	− 12.0	− 13.4	− 11.5
30	12th Oct: 1934	60.2	159.5	1.63	196.5	196.5	56.8	34.8	− 9.2	− 11.9	− 10.0
31	27th Oct: 1934	68.2	162.5	1.73	217.0, 218.5	217.7	63.0	36.4	− 6.5	− 7.8	− 6.5
32	27th Oct: 1934	68.2	167.0	1.76	228.5	228.5	66.15	37.6	− 6.0	− 4.9	− 4.0

average respiratory quotient was 0.82 in which case it has been calculated that each litre of oxygen gives rise to the production of 4.825 calories. For the purpose of expressing the amount of oxygen in terms of calories per hour, use was made of the excellent table contained in the Sanborn Company's hand-book (1933). The average heat production per square metre of the body surface per hour for all the 32 subjects works out as 36.16 calories.

Basal Metabolism: The basal metabolism is expressed here as the per centage deviation from two commonly accepted standards viz Aub-DuBois and Harris-Benedict. Comparison with the so called Sanborn Normals has also been made.

The Aub-DuBois standards (1917) are based on 8 cases tested by DuBois and his colleagues, and on reports of 46 tests made by other investi-gators, 21 of these being tests reported by Benedict (Sanborn 1933). The Aub-DuBois standards are based on surface area, the result being expressed as the number of calories produced per square metre of the body surface. According to this standard a normal male between the ages of 18-20 years produces 41.0 calories per hour per square metre of the body surface, and one between the ages of 20-40 years produces 39.5 calories.

The Harris - Benedict standards (1919) are based on about 300 tests on adults and nearly 100 tests on infants. Harris and Benedict have come to the conclusion that the best formula for the prediction of the basal metabolism for men is the following:

$$h = + 66.4730 + 13.7516_w + 5.0033^s - 6.7550 a$$

where

h = heat production per 24 hours.
w = weight in kgm.
s = height in cm.
a = age in years.

The Sanborn Values are intermediate between the Benedict and the DuBois standards "never varying more than 5 per cent from either table."

In order to compare the results obtained in the case of my subjects with the Harris -Benedict standards, I have made use of the tables published by the Carnegie Institution of Washington and abridged and rearranged by F.B. Sanborn (1933).

The results are shown in Table IV. Here each day's result is given separately. In Table II is given the average result for each subject of the different days that the tests were taken. From this it is seen that only five of the 32 subjects give positive results. All the rest give negative results. The lowest results obtained are in the subjects Nos. 1, 7, 13 & 24. The average for all the 32 subjects works out as 6.8 per cent lower than the Harris-Benedict standards and 8.7 per cent lower than the Aub-DuBois standards. The Aub-DuBois standards are, therefore, only 1.9 per cent higher than the Harris-Benedict standards as far as their application to these subjects is concerned.

It has been brought forward by recent investigations that, for ages of 20 years and thereabout, the Aub-DuBois Values are nearly the same as those of Harris-Benedict. The results obtained in my subjects tend to support this statement.

In the case of subjects Nos. 19,20, 21 & 26, tests were made on two consecutive days. It is seen that, except in the case of subject No. 19, the second day results are lower than the first day results. This I do not beleive to be due to a greater mental or muscular repose obtained on the second day, as these subjects were apparantly quite at ease on the first day also. The lower results obtained on the second day are probably due to a feeling of fatigue as a result of experiment on two successive days. In the subjects Nos. 1, 2, 3, 6, 11, & 16, tests were made on two or more widely different days. It is seen that the results of the second or subsequent tests are not necessarily lower than the first tests and also that the difference in the results is sometimes considerable. This is certainly not due to any error in technique but rather to the fact that the metabolism in an individual changes from day to day (DuBois 1927). This might be due to the psychical state of the subject as has been recently brought out by Benedict (1935). His own metabolism was measured on eighteen consecutive days in May 1932 and on thirtythree consecutive days in May and June 1933. The results were extraordinarily uniform from day to day. Only on five out of these fifty-one days there were marked variations which were attributed by the author to have been caused by emotional disturbances.

Comparison with the basal metabolism results obtained in India by other investigators: It has already been stated that Mukherjee (1926) found, in 15 Bengalis, the basal metabolism 9 per cent lower than the Sanborn Normals. And again Mukherjee and Gupta (1931), studying 18 normal Bengali young men, obtained results 13.3 per cent below Aub-DuBois standards. Sokhey (1927) in Bombay obtained results 10-23 per cent below the Aub-DuBois standards, but as the details are not given, it is not possible to compare the present results with those obtained by Sokhey. Mason's (1931) results are the lowest of all, her 54 women subjects giving an average value of 16.9 per cent below Harris-Benedict standards and 17.2 per cent below those of Aub-DuBois. Banerji (1931) studied 145 prisoners of the district jail, Lucknow, and found the average basal metabolism to be 6.9 per cent below the "European standards". Banerji finds that during the monsoon season, when the atmosphere is very humid, the basal metabolism values are lower than those obtained during the drier seasons. He, however, does not mention which standards he had actually compared his results with. In any case it would be doubtful if the results obtained on prisoners in an Indian prison can be compared with the results obtained usually on students.

It is thus seen that the results obtained in my subjects are higher than those obtained in Bombay, Madras and Calcutta. They are about 5 per cent higher than the results obtained by Mukherjee and Gupta at Calcutta and about 9 per cent higher than the results obtained by Mason in the South Indian women. It may here be pointed out however that, so far, enough work has not been done in India to establish the sex difference in metabolism. It is quite possible, as DuBois (1927) suggests, that the sex difference is greater in the Oriental. This view is supported by the studies of Takahira who found the basal metabolism of the Japanese women 9.3 per cent less than that of the Japanese men: whereas the sex difference for the Americans has been worked out as about 7 per cent (Gephart and DuBois 1916, Harris and Benedict 1919). Krishnan and Vareed (1932) studied 76 medical students in Madras of whom 15 were women. Their ages varied from 18-25 years. They found that the average basal metabolism of their male subjects was 12 per cent and of their female subjects 16 per cent below the DuBois standards. This gives a sex difference of 11 per cent.

It is thus seen that the results obtained by me at Hyderabad are higher than those obtained elsewhere in India with the exception of Lucknow. Nevertheless, these results are lower than the standards accepted for Westerners. The cause of this low metabolism in the Indians has been attributed to various factors viz, climatic, dietetic, occupational and racial.

<u>Climatic factor:</u> Is climate a factor in determining the basal metabolism? This has already been discussed to some extent, but the evidence on this point is conflicting. There is evidence, however, to believe that a prolonged residence in a warm climate tends to lower the basal metabolism. Earle (1928) reported the results of the studies made by him and his colleagues on 166 Chinese and also on 41 Westerners in Hong Kong and Peking. The basal metabolism of the Chinese subjects was found to be 8 per cent below the DuBois standards and that of Westerners in Hongkong and Peking 7 per cent below the DuBois standards. On the other hand 5 Orientals examined by Earle in London were found to have basal metabolism 6.5 - 8.5 per cent below DuBois, Harris Benedict and Dreyer standards. These results therefore "appear to afford evidence of a climatic factor as the controlling influence in basal metabolism".

In a recent publication Mason (1934) reports that the average decrease in metabolism in a group of nine European women moving to the tropics was 5.1 per cent and that three Indian women measured in two climates showed an increase in metabolism of 4.8 per cent in cold climates.

The influence of warm moist climate in lowering metabolism is suggested by Banerji (1931). If this is accepted, then it would also explain why the basal metabolism results are higher in Hyderabad than at the damp seaside places like Bombay, Calcutta and Madras.

Table V gives the basal metabolism results with reference to the humidity of the air. It is seen that the average basal metabolism for those days in which the difference between the wet and the dry bulb readings was 4°C or more works out as 4.4 per cent below the Harris-Benedict standards; whereas the average for those days in which this difference was less than 4°C is 7.1 per cent below the Harris-Benedict standards. These experiments, however, are not of much value being few in number and not undertaken specially to show the effect of humidity on the basal metabolism. They, neverthless, point to the possibility of humidity being a factor in modifying the basal metabolism. Further work is needed to elucidate this point.

Dietetic factor: Evidence has accumilated that protein rich diet is a potent factor in raising the basal metabolism. This was brought forward by Krogh and Lindhard (1920). Heinbecker (1928) found the metabolism of Eskimos, who are heavy protein consumers, to average 33 per cent above the normal standards. Benedict and Roth (1915), however, examined 11 male and 11 female vegetarians and found that the metabolism did not differ significantly from that of the non-vegetarians. By vegetarians were meant persons who did not eat meat of any kind more than two or three times a year. These results were confirmed by Harris and Benedict (1919).

Table V.

Subject Number.	Date.	Dry-bulb temperature °C	Wet-bulb temperature °C	Deviation from Harris-Benedict standards: per day.	average.
2	8th April 1934	31.5	24.5	- 4.5	- 4.5
11	8th April 1934	32.0	24.5	+ 3.5	+ 3.5
19	24th March 1934	28.5	20.0	- 1.0	- 1.0
19	25th March 1934	28.5	22.0	- 1.0	
20	24th March 1934	29.5	21.0	- 10.0	- 10.5
20	25th March 1934	28.5	22.0	- 11.0	
27	9th October 1934	29.0	25.0	+ 0.6	+ 0.6
28	9th October 1934	29.0	25.0	- 11.0	- 11.0
31	27th October 1934	25.0	19.5	- 6.5	- 6.5
32	27th October 1934	26.5	21.0	- 6.0	- 6.0
	Average.				- 4.4
1	8th September1933	...	...	- 9.0	-14.5
1	14th October 1933	28.0	25.5	-20.0	
2	8th September1933	...	...	- 9.0	- 9.0
3	8th September1933	...	...	+ 7.0	
3	18th October 1933	27.0	25.5	- 1.0	+ 2.7
3	22nd August 1934	25.0	22.5	+ 2.0	
4	27th September1933	...	...	- 5.0	- 5.0
5	-do-	...	...	- 1.0	- 1.0
6	-do-	...	...	+ 10.0	
6	8th October 1933	28.5	26.5	- 4.0	+ 2.7
6	18th October 1933	27.0	25.5	+ 2.0	
7	28th September1933	...	...	- 17.4	-17.4
8	-do-	...	...	- 10.0	-10.0
9	9th September1933	26.5	25.0	- 9.0	- 9.0
10	17th August 1933	...	...	- 14.0	-14.0
11	8th October 1933	28.5	26.5	+ 2.0	- 3.0
11	19th October 1933	26.5	25.0	- 8.0	
12	9th October 1933	29.0	26.0	+ 1.5	- 6.0
12	21st October 1933	24.5	22.0	- 13.5	
13	12th October 1933	27.5	24.5	- 16.0	-16.0
14	-do-	28.0	24.5	+ 8.0	+ 8.0
15	14th October 1933	28.0	25.5	- 1.0	- 1.0
16	15th October 1933	28.0	25.5	- 1.0	
~~16~~	~~21st October 1933~~	~~25.5~~	~~23.0~~	~~- 1.0~~	+ 3.0
16	31st July 1934	25.0	24.0	+ 8.0	
16	1st August 1934	25.0	24.0	+ 2.0	
17	21st October 1933	25.0	22.5	- 11.0	-11.0
18	18th October 1933	27.0	25.5	- 8.0	- 8.0
21	31st July 1934	25.5	24.5	- 9.0	- 3.5
21	1st August 1934	5.0	24.0	+ 2.0	
23	28th August 1934	27.0	24.0	- 14.0	-14.0
24	-do-	27.2	24.2	- 17.0	-17.0
25	14th August 1934	...	...	- 10.0	-10.0
26	22nd August 1934	26.5	24.0	- 2.5	- 4.2
26	23rd August 1934	25.5	24.0	- 6.0	
29	12th October 1934	28.0	25.0	- 12.0	-12.0
30	-do-	28.0	25.0	- 9.2	- 9.2
	Average.				- 7.1

Out of my 32 subjects, 8 are vegetarians. Out of these eight, Nos. 20 and 25 abstain totally from meat but take eggs occassionally. The rest of the eight, from No. 27 to 32 inclusive, abstain totally both from meat as well as eggs. These subjects belong to castes which have been vegetarians for generations. The average basal metabolism for all these 8 subjects works out as 8.08 per cent below the Harris-Benedict standards and 10.06 per cent below the Aub-DuBois standards. Vegetarian habbits as such, therefore, seem to have a somewhat depressing effect on basal metabolism.

Occupational factor: It is possible that the low metabolism rates obtained in India may, in part, be due to a less active life of the Indian subjects. Most of the tests made in India are on college students and it cannot be said with certainty that the college students in India lead a less active life than students in colder climates. It is only surmised that the warmer climate of India would lead to a less active life. That athletic training raises the rate of the basal metabolism has been observed by many workers (Benedict and Smith 1915, Gephart and DuBois 1916, Lauter 1926 etc.). Against this, Tilt (1930) found the basal metabolism of 10 athletic women in Florida to be no higher than that of the whole mixed group. And Krishnan and Vareed (1932) found that in the case of 6 of their subjects, "who were daily indulging in fairly severe exercise", the basal metabolism was distinctly lower than that of the mixed group.

Racial factor: In 1925, MacLeod, Crofts and Benedict emphasised for the first time the existance of a racial factor. They examined 7 Chinese and 2 Japanese women students in America and found their basal metabolism to be 10.4 per cent below the Harris-Benedict standards. As these standards have been considered to be 5 per cent too high for American college women, this leaves the Oriental women students only 5 per cent below their American colleages. This difference was considered to be due to the existance of a racial factor. Subsequently the Nutrition Laboratory of the Carnegie Institution of Washington has embarked on a comprehensive program for the study of the basal metabolism of various races. From the results obtained, Benedict and his co-workers of the Nutrition Laboratory have come to a definite conclusion that a racial factor exists. There are however difficulties in the unqualified acceptance of this conclusion.

An important series of investigations has been carried out on the Mayas of Yucatan. On three different expeditions it was found that the basal metabolism in the Mayas was definitely higher than in the case of the North American whites. And, what is more, there was a definite suggestion that a Maya of purer extraction tended to have a higher metabolism than one less pure. This, however, has not been definitely settled. Recently Pi-Suñer (1933) has obtained similar results on another aboriginal tribe, the Mapuche Indians of southern Chile. In 31 of his male subjects he found an average basal metabolism 9.8 per cent higher than the Harris-Benedict standards. The Nutrition Laboratory workers have contrasted the high basal metabolism of the Maya males with the very low basal metabolism of the South Indian females and conclude that such a wide difference cannot but be due to a racial factor.

There is, however, reason to beleive that in the case of both the Mayas and the Mapuches there are other factors which would tend to raise the basal metabolism. Both the Mayas and the Mapuches are aboriginal tribes. The living conditions amongst them are very poor. "The Maya sleeps inadequately protected by his meagre clothing and his hammock against the cold nights". The same may be said of the Mapuches of southern Chile where the temperature goes down in September (when the above-mentioned observations were made) to the freezing point. It is quite possible that in the case of these aboriginal tribes the higher basal metabolism is a result of a compensatory mechanism to offset the effect of exposure to cold nights.

Recently Benedict and Meyer (1933) have examined 18 American-born Chinese girls (12 - 22 years of age) living in the United States. They find that these girls have a basal metabolism averaging 9.2 per cent lower than that of the American Girl Scouts of the same ages and 6.1 per cent lower than the Aub-DuBois standards for American girls. Now if it is conceded, as has been suggested, that the Aub-DuBois standards are 5 per cent too high even for American women then these Chinese girls have metabolism averaging practically the same as Aub-DuBois predictions. On the other hand the metabolism of the Girl Scouts was taken while they were asleep. It is therefore doubtful whether it is quite fair to apply the Girl Scouts standards (with 10 per cent correction for sleep) in the case of the Chinese. Besides this, the authors admit that these American-born Chinese girls were not free from Chinese dietetic habits. Under the circumstances it cannot be said that these tests definitely establish the existance of a racial factor. In the words of the authors themselves, "until further measurements are made upon other girls (both Chinese and Caucasions) in this age range, however, the drawing of any final conclusion must be held in abeyance".

If we now review the numerous observations that have been made on different races in different countries we can have some idea of how far the racial factor operates. The following are some of the main observations.

Observation	Deviation from normal standards	
	Harris-Benedict	Aub-DuBois
1. Eijkmann's observations on the Malays in Batavia	....	- 0 per cent.
2. Takahira's observations on the Japanese men	....	- 5.5 ,,
3. Earle's observations on		

the Chinese	.....	- 8.0	per cent.
4. Mason's observations on the Madrasee women	-16.9	- 17.2	,,
5. Mukherjee and Gupta's observations on the Bengali young men	.....	- 13.3	,,
6. Observations on the Hyderabadi young men	- 6.8	- 8.7	,,

These figures may be compared with the following figures obtained on the Europeans in the East.

1. Montoro's observations on the white Cubans in Havana (quoted by DuBois 1927)	-15.8	- 15.5	per cent.
2. de Almeida's observations on white men in Brazil	-13.6	- 16.2	,,
3. Mason's (1934) observations on the European women in Madras	- 7.9	- 12.5	,,
4. Earle's report on European men at Hongkong and Peking	.....	- 7.0	,,

The comparison of the two sets of figures shows how closely they resemble each other. Had the racial factor been an important factor in determining the basal metabolism, it would seem strange that the basal metabolism figures of races so widely different as the Caucasions of Europe and America and the Mongolians of China and Japan should tally so closely. It would be more reasonable to think that though a racial factor may exist it is probably not so important as the climatic and the environmental factor in determining basal metabolism.

<u>Cause of the low basal metabolism in the Indians:</u> Very few observations have so far been made in India and these go to show the existance of a lower basal metabolism in the Indians. Probably all the causes discussed above operate in bringing about this low level. Mukherjee and Gupta (1931) have attributed it to the climatic and the nutritional causes. McCarrison (1927) studied the dietary habits of the different Indian provinces and found that the Bengali, the Kanaree and the Madrasee diet is of low biological value and is poor in the contents of suitable proteins, vitamins and miniral elements. The lowest figures have been obtained in the Madrasee women. But if a 5 per cent correction is made to these figures on the ground that the Aub-DuBois and the Nutrition Laboratory predictions are 5 per cent too high for women, then the average works out as 11 - 13 per cent which is about the same as for the Madrasee men.

Mason and Benedict (1931) attri -bute the low metabolism of the Madrasee women to the existance, at least in part. of a definite racial factor. Other possible factors which they suggest are; a low protein diet, tropical conditions of climate, and a state of relaxation during repose as complete as that which is found during sleep among Westerners

In a later publication Mason and Benedict (1934) give the results of their investigations of the basal metabolism in 7 Madrasee women while awake and during sleep, and have compared this result with that found in 2 western women living in Madras under the same conditions. They found that in the Madrasee women the oxygen consumption during sleep decreased on an average 9.8 per cent. The two western women gave similar results. The authors conclude that the state of relaxation is not the causal factor in the low basal metabolism of the Madrasee women. This conclusion seems to be justified, however, only if it can be proved that the amount of muscular relaxation during sleep is the same in both the Oriental and the Occidental.

Summary and Conclusions.

Basal metabolism tests and the physical character studies have been carried out in 32 young men at Hyderabad (Deccan). The ages varied from 19 - 31 years, the average being 22 years.

No difference was found in the pulse and the respiration rates as compared with the western standards.

These subjects were found to have somewhat (1.2 cm.) shorter stem height and corrospondingly longer legs compared to the measurements obtained on the Westerners.

A pelidisi of about 92

indicates the normal state of nutrition in young Indians, the average pelidisi for 30 out of the 32 subjects being 92 ± 4.

The blood pressure was found to be considerably lower compared to the western standards. The average systolic blood pressure in 30 out of the 32 subjects was 100.4 ± 11 mm., the average diastolic pressure 71.8 ± 5mm., and the average pulse pressure 28.6 ± 7.2.

The basal metabolism was found to be 6.8 per cent below the Harris-Benedict and 8.7 per cent below the Aub-DuBois standards. The factors which may tend to bring about this low level of metabolism are discussed.

The possibility of the humid climate being a factor in lowering metabolism is suggested.

Eight of the subjects who were vegetarians showed the basal metabolism on an average about two per cent lower than that obtained for the whole mixed group.

For height and age, the weight in this group of subjects was less than the American standards.

References.

Alvarez, W. C. (1920) ..... Arch. Int. Med. **26**, p. 381 (quoted from Norris et al 1928).

Alvarez, W. C. (1923) ..... Arch. Int. Med. **32**, p. 17 (quoted from Norris et al 1928).

Association of Life Insurance Directors and Actuarial Society of America, New York, 1912, pp. 38 and 67.

Aub, J. C., and DuBois, E. F. (1917) ..... Arch. Int. Med. **19**, p. 831; also DuBois, E. F. 'Basal Metabolism in Health and Disease' 1927, p. 169.

Banerji, N. D. (1931) Ind. Jour. Med. Res., **xix**, No. 1, pp. 229 - 238.

Beaumont, G. E., and Dodds, E. C. (1931) ..... 'Recent Advances in Medicine', p. 212.

Benedict, F. G. (1935) ..... Amer. Jour. Physiol.,**110**, pp. 521 - 530.

Benedict, F. G., and Meyer, M. H. (1933) ..... Chinese Jour. Physiol., **vii**, pp. 45 - 60.

Benedict, F. G., and Roth, P. (1915) ..... Jour. Biol. Chem.,**20**, p. 231 - 241.

Benedict, F. G., and Smith, H. M. (1915) .....Jour. Biol. Chem., **20**, p. 243.

Boas, E. P., and Goldschmidt, E. F. (1932) .....'The Heart Rate' pp. 23 - 24.

Burton-Opitz. (1921) ..... 'Text Book of Physiology' p. 475.

Cadbury. (1922) ..... Arch. Int. Med. **30**, p. 362. (quoted from Norris et al 1928).

de Almeida, A. O. (1921) ..... Jour. de Physiol. et de Path. Generale, **18**, pp. 713, 958. (quoted from DuBois 1927, p. 160).

Dreyer, G., and Hanson, G. F. (1921) ..... ' The Assessment of Physical Fitness', pp. 5, 6. (quoted from DuBois 1927, p. 174).

DuBois, E. F. (1927) 'Basal Metabolism in Health and Disease', pp. 119, 130, 153, 161, 162.

DuBois, D., and DuBois, E. F. (1916) ..... Arch. Int. Med **17**, p. 865; also DuBois, E. F. 'Basal Metabolism in Health and Disease' 1927, pp. 118, 119.

Earle, H. G. (1928) Chinese Jour. Physiol. Report Series, No. 1, pp. 59 - 79.

Eijkmann, Arch. f. d. ges. Physiol. 1896, **64**, p. 57; Jour. de Physiol. et de Path. Gen., 1921, **19**, p. 33. (quoted from DuBois 1927).

Fleming. (1925) ...... quoted from DuBois 1927.

Gephart, and DuBois. (1916) ..... Clin. Cal., 13, Arch. Int. Med. **17**, p. 902. (quoted from DuBois 1927, p. 163).

Halliburton, W. D., and McDowall, R. J. S. (1930) ..... 'Handbook of Physiology' p. 225.

Harris, J. A., and Benedict, F. G. (1919)..... Carnegie Inst. Wash. Pub. No. 279.

Heinbecker, P. (1928) ..... Jour. Biol. Chem., **lxxx**, p. 473.

Indian Medical Record (1931) ..... quoted from Subba Reddy (1933).

Joslin, E. P. (1923) .....'The Treatment of Diabetes Mellitus' p. 761.

King, J. T. (1924) ..... 'Basal Metabolism' p.49.

Knipping. (1923) ..... Arch. f. Schiff. u. Trop. Med., **v**, p. 283. (quoted from Mukherjee and Gupta 1931).

Körösy, K. (1910) ..... Studien über Puls- und Atmungsfrequenz., Deutsch. Arch. f. Klin. Med. **101**, p. 267. (quoted from Boas and Goldschmidt, 1932, p. 24).

Krishnan, B. T., Vareed, C. (1932) ..... Ind. Jour. Med. Res., **xix**, pp. 852, 853, 856, 857.

Krogh, and Lindhard. (1920) ..... Biochem. Jour., **14**, p. 290. (quoted from DuBois 1927).

Lauter. (1926) ..... Deutsch. Arch. f. klin. Med., **150**, p. 315. (quoted from DuBois 1927, p.163).

MacLeod, Crofts, and Benedict. (1925) ..... Amer. Jour. Physiol. **73**, p. 449.

McCarrison, R. (1927) ..... Trans. 7th. Congress of Far Eastern Assoc. Trop. Med., **iii**, pp. 322 - 323.

McCay, D. (1907) ..... Lancet, i, p. 1484.

M'Kendrick, J. G. (1889) ..... 'A Text Book of Physiology' **ii**, p. 317.

Mason, E. D., and Benedict, F. G. (1931) ..... Ind. Jour. Med. Res., **xix**, No. 1, pp. 75 - 98.

Mason, E. D. (1934) ..... Jour. Nutrition, **8**, No. 6, pp. 695 - 712.

Mason, E. D., and Benedict, F. G. (1934) ..... Amer. Jour. Physiol. **108**, pp. 377 - 383.

Melvin, and Murray (1914) ..... Quart. Jour. Exper. Physiol. **8**, pp. 15, 125. (quoted from Norris et al 1928).

Montoro (1921 - 1922) ..... San mil. Habana, **1**, 255. (quoted from DuBois 1927).

Mukherjee, H. N. (1926) ..... Calcutta Med. Jour.,**20**, p. 425.

Mukherjee, H. N., and Gupta, P. C. (1931) ..... Ind. Jour. Med. Res., **xviii**, p. 807.

Musgrave, and Sisson (1910) ..... Philippine Jour., **5**, p. 325. (quoted from Norris et al 1928).

Norris, G. W., Bazett, H. C., and McMillan, T. M. (1928) 'Blood Pressure', London. pp. 87, 125, 127, 129, 133, 135.

Okada, S., Sakuri, E., and Kameda, T. (1926) ..... Arch. Int. Med. **xxxviii**, p. 590. (quoted from Mukherjee and Gupta 1931).

Pirquet, C. (1922) .....'An Outline of the Pirquet System of Nutririon'. pp. 11 - 17, 89 - 96. quoted from Steggerda and Benedict 1932).

Pi-Suñer, J. (1933) ...... Amer. Jour. Physiol., **105**, No. 2, pp. 383 - 388.

Sanborn, F. B. (1933) .....'Instructions with Tables of Normal Consumption and Basal Metabolic Rate'. Sanborn Co. Cambridge, Mass. p.36.

Shattuck, G. C., and Benedict, F. G. (1931) ..... Amer. Jour. Physiol., **xcvi**, pp. 518, 524.

Sokhey, S. S. (1927) ..... Trans. 7th. Congress Far Eastern Assoc. Trop. Med. Calcutta, **iii**, p. 321.

Steggerda, M., and Benedict, F. G. (1932) ..... Amer. Jour. Physiol., **c**, pp. 274 - 284.

Stevenson, P. H. (1928) ..... Chinese Jour. Physiol. Report. Series., No. 1, p. 1.

Stock, and Karns (1924) ..... quoted from Subba Reddy 1933.

Subba Reddy, D. V. (1933) ..... Vizag. Med. College Mag., **6**, No. 2, pp. 8 - 12.

Sutliff, W. D., and Holt, E. (1925) ..... Arch. Int. Med. **35**, p. 224. (quoted from Boas and Goldschmidt 1932).

Symond, B. (1923) ..... Jour. Amer. Med. Assoc., **80**, p. 232. (quoted from Norris et al 1928).

Takahira (1925) ..... 'Report of the Metabolic Laboratory, the Imperial Inst. for Nutrition, Tokyo, **i**, No. 1. (quoted from DuBois 1927, p. 161).

Tilt, J. (1930) ..... Jour. Biol. Chem. **86**, pp. 635 - 641.

Tung, C. L. (1928) ..... Chinese Jour. Physiol. Report Series. No. 1, pp. 93 - 95.

Waddell, S. S., Han, C. H., and Ch'en, Y. P. (1928) ..... Chinese Jour. Physiol. Report Series, No. 1, pp. 25 - 30.

Williams, G. D., and Benedict, F. G. (1928) ..... Amer. Jour. Physiol., **lxxxv**, p. 634.

Woley, (1910) ..... Jour. Amer. Med. Assoc., **55**, p. 121.