not a particle of doubt that these children are very much better treated in the open air. Furthermore, the administration of oxygen in many cases makes all the difference between recovery and death. In addition, though the remark is not strictly appropriate in this connexion, these children, in my experience, are the better of a certain amount of alcohol if they are not too cyanosed to oxidize it. In making these statements I am fully aware that I am speaking somewhat rashly, because, regarding children suffering from severe suffocative catarrh in measles I have never learnt to make anything which can be called an accurate prognosis, and consequently have difficulty in stating the results of treatment statistically. Thus, in teaching I have demonstrated two cases to my students—one as likely to recover, and the other as likely to die—only to have to point out the next day that the child I thought was probably going to recover was now dead, and that the other, if not out of danger, was at least

considerably better than on the previous day. This rapid improvement is the rule in cases of suffocative catarrh if cure is to take place. A child may be within the immediate zone of death and within a couple of days be comparatively well. If bronchopneumonia is implanted on the catarrh, the change to convalescence is a matter of ten days to three weeks. The two conditions should not be confounded.

A further point of importance with regard to the treatment of severe cases of measles, and a treatment only easily obtained in hospitals, is the care of the eye. An attack of measles is quite frequently the starting-point of eye trouble. For the proper cleansing of the eye regular washing out is necessary, and the technique requires adequate training on the part of the attendants. Sometimes even hourly cleansing is required, and that cannot be provided at home except in the houses of the rich.

THE PHYSIOLOGICAL COST OF MUSCULAR WORK.

BEING THE SUBSTANCE OF A LECTURE TO THE CHELSEA POLYTECHNIC, FEBRUARY 23RD, 1920.

BY

A. D. WALLER, M.D., F.R.S.

THIS "lecture" is essentially intended as a demonstration of method and apparatus by means of which a fundamental problem—to the answer of which an important part might be contributed by a polytechnic school—can be approached and compassed.

Shortly stated, the general problem requires numerical answer to the question—What, or rather *how much*, is the physiological cost of various forms of mechanical work as done by a dock labourer and a printer, a carpenter and a tailor?

This cost is most readily measured by measuring the CO₂ expired in consequence of the internal combustion that takes place in all living matter—in lowest degree during deepest sleep, in highest degree during heaviest muscular work. And the particular part of the problem on which, at the suggestion of the Principal, I shall invite your answer will be as follows: What is the energy output, expressed in calories per head per hour, (a) for a class sitting listening to a lecture; (b) for a class carrying out physical exercise drill?

I should like to make it possible as an outcome of this lecture (1) that every student here should be able to give a reasonably good theoretical answer on paper, and (2) that one, or preferably two, of your number should be able of their own knowledge to get out by means of the apparatus now before you a more or less accurate statement of actual fact in, say, a month's time.

The apparatus consists of three parts:

1. The *collecting bag*, with valved mouthpiece and tap, to receive the expired air of the subject for, say, a minute or half a minute.
2. The *analyser*, to measure directly the percentage of CO₂ present in that expired air.
3. The *spirometer*, to measure its volume in litres.

And here are the results of a typical observation like that which has just been made under your eyes:

	Ventilation.		CO ₂ .		Calories.*
	Per Minute. 6 litres	Per Second. 100 c.cm.	Per Cent. 3	Per Second. 3 c.cm.	Per Hour. 60
At rest...	..	..	..	..	..
At work (walking at 3½ miles an hour)	24	400	4	16	320

* The translation into calories per hour assumes that 1 c.cm. CO₂ per second = 20 calories per hour. For this equivalence the calorific value per 1 c.cm. CO₂ has been taken = 5.55 calories.

It is obvious to you from this observation that the work of walking has caused a measurable increase of CO₂ output, and you have learned further that the

physiological cost of walking at 3½ miles an hour is 320 calories gross, or 260 calories net per hour.

The small value (60 calories per hour) represents the cost of bare life without work—that is, the basal cost; it goes on, of course, during work, and has therefore to be subtracted from the gross cost of work, leaving us with its net cost. (Obviously if we know the mechanical value of the work we can calculate out a value for the ratio

$$\frac{\text{work}}{\text{net cost of work}}$$

which is a measure of physiological efficiency; but with this measure we are not concerned to-day.)

I will now put before you a brief report of a week's observation just concluded by Miss G. De Decker at the printing rooms of the BRITISH MEDICAL JOURNAL, with the helpful co-operation of four compositors—H., C., S., and B.

The procedure was to collect every hour from each man during the six days of work the expired air for a period of one minute. Each bagful was then dealt with as you have just seen done—that is, its volume measured by spirometer and its CO₂ percentage taken by analyser, so that the rate per second of CO₂ discharge was ascertained and plotted on squared paper. The hourly CO₂ ordinate of each man was thus recorded for each day, and the value in calories of the day's energy output was computed as a simple summation of the ordinates, as for

the day given below *in extenso*. (This was the first day, and our observation started at 9.30 a.m., whereas work actually began at 8 a.m., as shown in the week's summary.)

H., aged 65; Weight, 10 st.; Height, 5 ft. 8 in.; Surface, 1.71 M.
February 16th, 1920.

Time.	Ventilation.		CO ₂ .		Calories.
	Per Minute. 8.5 litres	Per Second. 142 c.cm.	Per Cent. 2.4	Per Second. 3.4 c.cm.	
9.30	12.0 ..	200 ..	3.0	6.0 ..	383
10... ..	9.0 ..	150 ..	3.2	4.8 ..	
11... ..	11.5 ..	192 ..	3.0	5.8 ..	
1... ..	12.0 ..	200 ..	3.2	6.4 ..	
Dinner hour ...	—	—	—	—	
2... ..	9.0 ..	150 ..	3.2	4.8 ..	478
3... ..	12.0 ..	200 ..	3.0	6.0 ..	
4... ..	12.0 ..	203 ..	3.5	7.0 ..	
5... ..	11.0 ..	183 ..	3.0	5.5 ..	
6... ..	12.0 ..	200 ..	3.0	6.0 ..	861

The working out of this day's calories is as follows:

Morning: 47 + 60 + 96 + 116 + 64 = 383

Afternoon: 48 + 120 + 140 + 110 + 60 = 478

861

Total: 861 calories in 7½ hours, or 115 calories per hour.

The summary account of the results of six days of observation on four workers, recorded and calculated as above, is given in graphic form on the preceding page:

Summary for the Week February 16th to 21st, 1920.

Subject.	Day.	Calories per Day.	Hours.	Calories per Hour.
No. 1, H. Age 65. Weight 63.5. Height 1.73. Surface 1.71.	Monday ...	861	7.5	115
	Tuesday ...	733	8.75	84
	Wednesday ...	467	5.75	81
	Thursday ...	790	9.25	85
	Friday ...	771	8.75	88
	Saturday ...	281	3.5	80
No. 2, C. Age 51. Weight 62.6. Height 1.70. Surface 1.68.	Monday ...	955	7.5	127
	Tuesday ...	1,024	8.75	117
	Wednesday ...	1,003	8.75	115
	Thursday ...	1,061	9.25	115
	Friday ...	833	8.75	95
	Saturday ...	337	3.5	96
No. 3, S. Age 26. Weight 63.5. Height 1.80. Surface 1.77.	Monday ...	843	7.5	112
	Tuesday ...	737	8.75	84
	Wednesday ...	878	8.75	100
	Thursday ...	792	9.25	85
	Friday ...	736	8.75	84
	Saturday ...	269	3.5	77
No. 4, B. Age 26. Weight 72.6. Height 1.78. Surface 1.86.	Monday ...	857	7.5	114
	Tuesday ...	965	8.75	110
	Wednesday ...	1,035	8.75	125
	Thursday ...	1,229	9.25	133
	Friday ...	892	8.75	102
	Saturday ...	380	3.5	109
		18,789	183.0	103 ± 2

18,789 calories in 183 hours = 103 calories per hour.

CONCLUSION.

The average rate of energy-output (gross) at the printing rooms of the BRITISH MEDICAL JOURNAL, gauged as described above on four compositors for one week, comes out as: 101 to 105 calories per hour.

I shall be very interested to learn from your own observations at the Chelsea Polytechnic what are the average rates of energy-output per head:

(a) For a class of students sitting at lecture.

(b) For a class of students during physical exercise drill.

AN ATTENUATED TUBERCLE VACCINE.

BY

NATHAN RAW, C.M.G., M.D., M.R.C.P., M.P.,

LATE O.C. AND SENIOR PHYSICIAN, LIVERPOOL HOSPITAL, B.E.F., FRANCE.

THE object of this short paper is to bring to the notice of the profession a vaccine which in my own experience has been of great service in the treatment of tuberculosis.

Whilst not claiming it to be a specific remedy, it has a remarkable power of controlling the disease and of limiting the spread of the infection in the human body. As is well known, tuberculosis has a tendency to spontaneous cure, and if we can in any way limit the spread of the infection we are placing the patient in a better position by his natural powers of resistance to deal successfully with the original focus. In the BRITISH MEDICAL JOURNAL of January 31st, 1903, I expressed the opinion (as I believe for the first time, and based almost exclusively on clinical and pathological evidence) that

Human and bovine tuberculosis were separate and distinct diseases, but that the human body was susceptible to both, and especially to bovine tuberculosis in the early periods of life. The two diseases were so rarely seen together in the human subject that there seemed strong grounds for presuming that they were antagonistic to each other, and that bovine tuberculosis may confer an immunity against human tuberculosis, and vice versa.

To take an example: A child with primary abdominal tuberculosis or tuberculous glands in the neck—both bovine infections caused by tuberculous milk—is protected against a primary pulmonary tuberculosis; on the other hand, a case of primary pulmonary tuberculosis from inhalation—always caused by the human bacillus—is protected against the lesions caused by the bovine bacillus. In other words, the two types of the bacillus—human and bovine—cannot exist in the body at the same time, and I have never been able to recover both types from the same patient.

The lungs are frequently attacked in the course of a bovine infection either by direct lymphatic extension from the abdomen to the bronchial glands; by direct extension to the apex of the lung from glands in the neck; or in the course of a general blood-stream infection.

For these reasons, and after treating over 3,000 cases of tuberculosis in hospital with tuberculin from various sources, I have come to the conclusion that the best results are obtained by treating human infections with bovine tuberculin, and bovine infections with human tuberculin. Although the results in many cases were good, I must confess on the whole to a feeling of disappointment, and I attributed it to the uncertainty of origin of the tuberculin, which was prepared in many instances from a highly virulent culture, and also to the tuberculin becoming stale and inert by lapse of time. In many cases acute and serious reactions followed its use; in others it seemed to be inert.

For these reasons I decided over fourteen years ago to endeavour to obtain attenuated cultures of bacilli, and to try the effects of a tuberculin prepared from cultures of low virulence and less toxicity. The late Professor Koch gave me in 1905 a pure culture of human tubercle prepared from the sputum of pulmonary tuberculosis; Professor Calmette of Lille, one of bovine tubercle; and Professor Bang of Copenhagen, one of avian tubercle. These original cultures have been subcultured every month since 1905 without any intermission, and to-day they grow true to type, quite normally, although not quite so luxuriantly. The present cultures, which are growing at the Lister Institute, are, of course, highly attenuated and of very low virulence. I have injected them into animals, and they are practically non-pathogenic.

I treated several patients with this tuberculin in 1914, but the war came, and my work was interrupted by a long residence in France. The results were most satisfactory, but I propose to wait for some time before coming to a definite decision.

Tuberculosis is seriously increasing in all the late belligerent countries, due to the stress and rigour of war conditions and the malnutrition of the people, more especially children. We have not yet discovered a specific remedy for the disease, but it is our duty to adopt every possible means to prevent its further spread, and in my