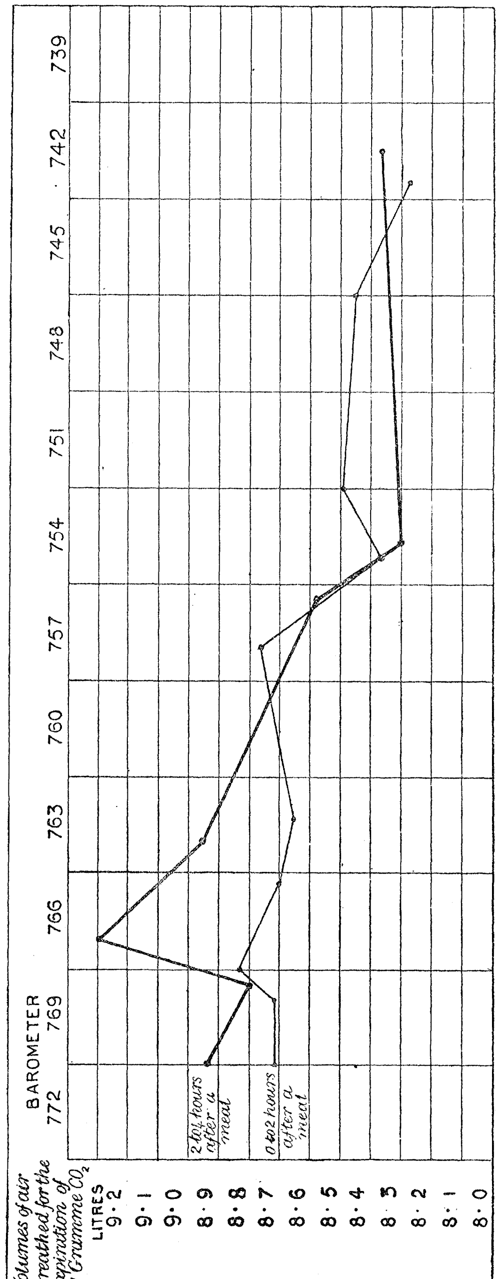
III. "On the Chemical Phenomena of Human Respiration while Air is being re-breathed in a closed Vessel." By WILLIAM MARCET, M.D., F.R.S. Received January 3, 1891.

In June, 1889, I had the honour of communicating a paper to the Royal Society, which appeared subsequently in the 'Philosophical Transactions' for 1890.* In this paper it was shown that the volumes of air breathed to form in the body and expire a given weight of carbonic acid exhibited a distinct tendency to fall with a local subsidence of atmospheric pressure, and *vice versâ*. Since then an additional series of experiments, to which my present assistant, Mr. E. Russell, kindly submitted, confirmed this result. Fifteen experiments were made from 0 to 2 hours after a meal, and fifteen also from 2 to 4 hours after a meal. The results are disposed as follows, in the form of a chart (see next page), in which the curves for the volumes of air breathed to expire 1 gram CO_2 are seen to fall most distinctly from nearly 767 mm. pressure to 742 mm.

The object of the present investigation was to ascertain the effects produced on the chemical phenomena of respiration by re-breathing a given volume of air for a given time, and I gladly acknowledge the valuable aid of my assistant, Mr. Edward Russell, F.C.S., in the course of this inquiry. It was obvious that I could not risk the health of those who, together with myself, submitted to experiment; hence the necessity of limiting the duration of the time for re-breathing air, and I selected for this purpose a period of five minutes. A certain volume of air to be re-breathed was settled upon from the beginning, and it was decided to take 35 litres, measured under atmospheric pressure with every care. This air was held in a bell-jar of a capacity of 40 litres, and supplied with a scale, a thermometer, and an oil-gauge; it was maintained in suspension by a counter-poise, while immersed in a trough full of salt water. The bell-jar was, moreover, possessed of a regulating apparatus, keeping it in perfect equilibrium in every position, as it rose or fell in the tank.

Four persons submitted to these experiments. I head the list, with six complete experiments. Next, my assistant, Mr. Russell, had ten complete experiments made upon himself; a former assistant, Mr. Hoskins, F.C.S., in accordance with my request, kindly submitted to eleven experiments, and, finally, W. Alderwood, my laboratory attendant, who has been in my service for seven years, and is well qualified for this kind of work, had ten experiments made upon him.

* 'Phil. Trans.,' B, 1890, "A Chemical Inquiry into the Phenomena of Human Respiration."


BAROMETER
772
769
766
763
760
757
754
751
748
745
742
739
Volumes of air breathed for the expiration of 1 Gramme CO2
LITRES
9·2
9·1
9·0
8·9
8·8
8·7
8·6
8·5
8·4
8·3
8·2
8·1
8·0
2 to 4 hours after a meal
0 to 2 hours after a meal

The results from all these experiments will be found disposed in the form of tables (pp. 113—116).

I shall first give a short account of the method adopted in the present inquiry, then describe the experiments, and finally state the results with which they have been attended. Two bell-jars were made use of.

The air, in every one of the experiments quoted in this paper, was inspired through the nose and expired through the mouth, a mode of breathing easy to acquire, and soon becoming perfectly natural; the person under experiment assumed the recumbent position in a deck-chair, with the feet resting on a stool.

It was necessary to begin by determining the volumes of air and weights of carbonic acid expired normally, or in ordinary breathing, with the object of using these figures as standards for comparison. I need not say that every precaution was taken to obtain correct data on ordinary breathing. Next, the other bell-jar was supplied with atmospheric air to be re-breathed. A correction might have been introduced for the CO_2 naturally present, but from its small proportion this correction was thought unnecessary. On no occasion was the laboratory used for the evolution of acids or alkalis, and its ventilation was kept up by one or two open windows.

After re-breathing 35 litres of air during five minutes, the person under experiment was placed in communication with the other bell-jar, in such a manner that no air whatever was lost, or, in other words, while fresh air was *inspired*, the *expiration* following immediately the last expiration of re-breathed air was collected in the other bell-jar, now emptied of the expired air it formerly contained. While this bell-jar was being filled, the re-breathed air, from the other bell-jar (after its volume had been read, and temperature taken), was driven into an india-rubber bag faced with oil-skin, to prevent any loss of any CO_2 by diffusion. This bag had been kept flattened down between boards weighted with a piece of iron weighing 20 lbs., a precaution taken to empty perfectly the bag before it was used for storing the re-breathed air. The bell-jar, having thus discharged its contents, was ready to be used afresh.

The person expired from 34 to 38 litres of air immediately after the re-breathing stage of the experiment, and he was now placed in communication with the empty bell-jar; there was no loss of expired air through this passage from one bell-jar to another, and while fresh air was inhaled, the air expired was entirely collected, to the extent of from 34 to 38 litres, for subsequent analysis. A chronograph showed, to a second, the time required in the various stages of the experiment.

Thus the whole history of the effects of re-breathing air was obtained, being divided into four stages:—1st, natural respiration; 2ndly, air

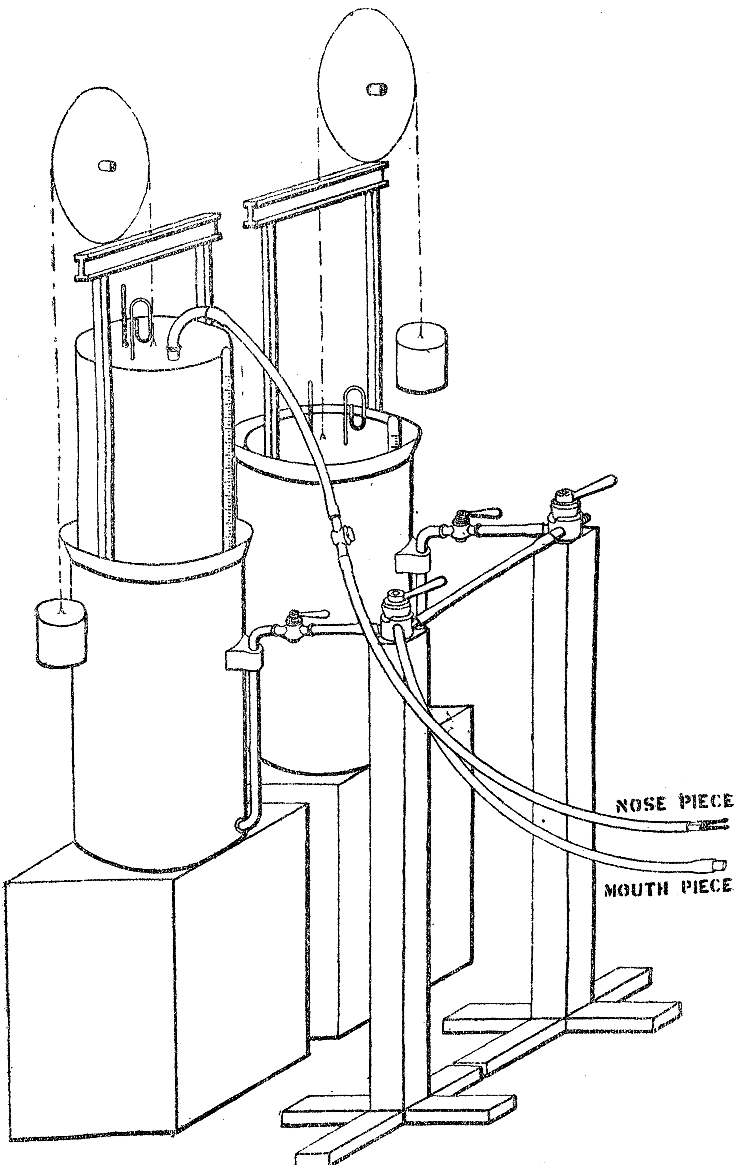
re-breathed; 3rdly, air expired immediately after re-breathing and with the inspiration of fresh air; 4thly, air breathed while no longer under the direct influence of re-breathing.

The above is a general sketch of the investigation. I must now beg leave to go into the details of the work. The diagram on the next page illustrates the disposition of the instrument.

The person under experiment, in the recumbent position in a deck-chair, held in his right hand an india-rubber tube connected with the bell-jar through a double-way cock, as I have explained in my last paper to the Royal Society. The cock was turned in such a position that the air inspired through the nose was expired into the open air, a little flag showing the movement of the expired air through the tube. The experiment begins with the operator expiring through this tube into the external air. When respiration has become perfectly quiet and regular, the double-way cock is turned during an inspiration, and the air of the next expiration is collected in the bell-jar, which begins its ascending course. At the same time the hands of a chronograph are set in motion. After about 36 litres of air have been expired, the tube leading into the bell-jar is closed at the end of an expiration, and the chronograph is stopped.

Some trouble was experienced in obtaining similar volumes of air expired in a given time, say, about every seven minutes. I have come to the conclusion that most people do not breathe, even when perfectly still, exactly the same volume of air in a given time, and after an experience of many years, it was found that the best plan was to repeat the breathing two or three times, or more, in succession, and to take, according to circumstances, either the mean of the different experiments, or the result of the last made. Any experiment differing widely from the others was rejected. The air collected finally was read off on the scale attached to the bell-jar, its temperature was taken, the barometer read, and the air was analysed for the determination of its carbonic acid, by the same method as that which has been described in the paper in the 'Philosophical Transactions' already referred to. The air left in the bell-jar was then driven out, and the jar made ready for further use.

The next part of the work is the re-breathing. Perhaps half an hour has elapsed since air was first collected for the determination of CO_2 in normal breathing; during that time the person under experiment has remained perfectly still in the deck-chair. The bell-jar, which has not yet been used, is now thoroughly rinsed with common air and filled with air to the extent of 35 litres. It carries an india-rubber tube, connected with the dome of the jar and supplied at the end with a fork-shaped nose-piece (see diagram). This nose-piece has been ascertained to fit the nostrils of the operator, air-tight; a second india-rubber tube, with a mouth-piece at one end, is connected



at the other with a U-shaped pipe, opening under the bell-jar in the ordinary way. The bell-jar holding 35 litres of air is perfectly counterpoised, so that the operator moves it up and down unconsciously in the act of respiration, while the oil-gauge on the bell-jar registers

barely from 1 to 2 mm. of difference of pressure, which is inappreciable.

Placing the nose-piece in his nostrils, the operator breathes through his mouth for a few seconds, then he takes the mouth-piece in his mouth, and inhales the air of the bell-jar through the nose-piece, the bell-jar falling; at that very instant the chronograph is started. The next expiration is from the mouth through the U-tube into the bell-jar, and so on, the air re-breathed circulating through the bell-jar. After five minutes have elapsed, every attention is given to stop the inspiratory tube and arrest the chronograph at the very end of an *expiration*, while another assistant opens the double-way cock, connected through tubing with the operator, and disposed so as to lead the air now expired into the other bell-jar; the operator drops the nose-piece and takes an inspiration of fresh air, through the nose, then he expires out of the mouth into the empty bell-jar. He was, perhaps, beginning to feel a little uncomfortable; sometimes a slight sensation of want of air was experienced, but not always, and one of my subjects hardly noticed any effect. I think I was affected most of the four who submitted to experiment, although it repeatedly happened that I felt no discomfort of any kind, beyond perhaps a slight want of air.

Fresh air is inhaled with an undoubted sensation of comfort, and the volume of this air is in marked excess of the volume inhaled in ordinary breathing. During the first two or three minutes, large volumes of fresh air are inspired, then the breathing quickly subsides, and before 36 or 37 litres have been expired it has apparently resumed its usual rate, with the disappearance of all feeling of discomfort.

I have stated above that the air re-breathed had been transferred from the bell-jar into an india-rubber bag, allowing the bell-jar to be utilised for collecting the air expired in the last stage of the experiment. The india-rubber tube and double-way cock were so arranged that by turning the cock the operator was placed in connexion with the empty bell-jar, and during an inspiration of fresh air the cock was turned, when the expired air was directed into that bell-jar.

The rate of breathing had now become all but natural, or the same as at the beginning of the experiment, giving indications that the effects of re-breathing had apparently passed away; this question was to be settled by the analyses.

There were consequently four different samples of expired air to be submitted to analysis for the determination of the carbonic acid they contained. The first sample was from air expired normally, the second from air re-breathed, the third from air expired immediately after re-breathing, the fourth from air expired after apparent recovery from the effects of breathing impure air.

By the time breathing in the closed vessel had commenced, the air expired normally had already been shaken with barium hydrate;

samples from the bag and other two bell-jars were treated in the same way. The next day the barium carbonate had subsided, and the clear fluid was titrated according to Pettenkofer's method. The reductions to dryness, to 0° and 760 mm., were speedily made with the help of the table I have given in the paper previously referred to.

Let us now follow the changes occasioned by the re-breathing of 35 litres of air for a period of 5 minutes; there were a few additional seconds included, as the re-breathing had to be stopped at the end of an expiration, which of course might not exactly correspond with a lapse of five minutes. The following are the mean percentages of CO_2 contained in the bell-jar after its air had been re-breathed:—

Myself..............	after 5 m.	2 sec.	3·42	per cent	CO_2.
Mr. Russell..........	,, 5 m.	4 sec.	3·87	,,	,,
Mr. Hoskins	,, 5 m.	10 sec.	3·44	,,	,,
W. Alderwood	,, 5 m.	5 sec.	3·29	,,	,,

consequently in every case the air was becoming considerably vitiated; yet it was only in the last minute that an unpleasant sensation, if any, was felt.

If we compare the amount of carbonic acid expired by re-breathing 35 litres of air for five minutes with the amount of carbonic acid which would have been expired in the same time in ordinary breathing, we find invariably less CO_2 in the re-breathed air than in normal respiration; this is shown clearly in the following table, in which the CO_2 expired in ordinary breathing has been calculated for the time taken in the re-breathing stage of the experiment.

	Time.	CO_2 in re-breathed air.	CO_2 expired normally in same time.	Relations of CO_2 expired in re-breathed air to CO_2 expired in natural breathing.
Myself	5 m. 2 sec.	2·135	2·224	1 to 1·041
Mr. Russell	5 m. 4 sec.	2·418	2·797	1 to 1·157
Mr. Hoskins......	5 m. 10 sec.	2·151	2·428	1 to 1·221
W. Alderwood....	5 m. 5 sec.	2·066	2·221	1 to 1·075
Mean	5 m. 5 secs.	2·192	2·417	1 to 1·123

It follows that there is always less carbonic acid expired in a given time when air is re-breathed than in ordinary breathing. In the present experiments the mean proportions varied for four different persons between 1 to 1·041 and 1 to 1·221; or, in other words, a mean of 9·3 per cent. carbonic acid which would have been expired in a certain time in ordinary breathing is found to have disappeared in 35 litres of air re-breathed during the same time.

[This amounts to 225 c.c. CO_2, which have been retained in the blood; but it occurs to me that less oxygen may possibly be consumed from re-breathed air than from fresh air, although in my experiments re-breathing is hardly carried far enough to admit of such a contingency.—*Jan.* 22.]

We find, by a consideration of the next table, that the reduced elimination of carbonic acid in re-breathed air is regulated in a marked degree by the weights of CO_2 expired in ordinary breathing.

	CO_2 produced by re-breathing.	CO_2 expired in ordinary breathing in the same time.
W. Alderwood......	2·066 grams	2·221 grams
Myself.............	2·135 "	2·224 "
Mr. Hoskins........	2·151 "	2·428 "
Mr. Russell........	2·418 "	2·797 "

Thus it is seen that the CO_2 in re-breathed air and in ordinary breathing increase together from the lowest to the highest figures. This might have been expected, as the whole experiment must be controlled more or less by the phenomena of ordinary breathing for each of the persons under experiment.

There is another point of interest to be noticed with reference to the re-breathed air in the present experiment—the volume of this air, which originally was 35 litres, is no longer 35 litres at the conclusion of the experiment, but has undergone a slight reduction. The enquiry into this portion of the subject was not found so simple as it appeared to be at first, and, as the work progressed, precautions against errors had to be taken which had not been apparent until a late period of the investigation. I, therefore, prefer to leave this part of the subject for future consideration.

It has been stated that after re-breathing for five minutes the air of the bell-jar, and then admitting fresh air into the lungs, an increased volume of air was inhaled attended with the expiration of a greater amount of carbonic acid than in ordinary breathing. This will be seen in the following table, showing, for the same lapse of time, the mean results obtained on four different persons for ordinary respiration and while inhaling fresh air, immediately after the re-breathing stage of the experiment.

A consideration of these tables shows, with reference to the CO_2 expired, that there was invariably an excess, after re-breathing air for five minutes, over the weight expired in the same time in normal respiration; the mean relation being 1 to 1·237. In the case of

CO_2 before re-breathing calculated on time after re-breathing.

	Time.	Before re-breathing. CO_2, grams.	After re-breathing. CO_2, grams.	Relation.
Self	5 m. 40 sec.	2·474	3·134	1 to 1·267
Mr. Russell	4 m. 41 sec.	2·507	3·224	1 to 1·294
Mr. Hoskins......	5 m. 26 sec.	2·802	3·614	1 to 1·290
W. Alderwood....	6 m. 57 sec.	3·018	3·311	1 to 1·097
Mean	5 m. 41 sec.	2·700	3·326	1 to 1·237

Litres of Air expired before re-breathing calculated on time after re-breathing.

Before re-breathing.	After re-breathing.	Relation.
26·56	33·93	1 to 1·278
24·96	35·70	1 to 1·430
26·24	35·27	1 to 1·344
29·17	34·34	1 to 1·177
26·73	34·81	1 tc 1·307

W. Alderwood, who was the least affected of the four persons under experiment, the excess of CO_2 after re-breathing, amounting to 1 to 1·097, is the smallest. A similar remark applies to the volumes of air expired; they are invariably increased after re-breathing, or while the person under experiment is still under the influence of the want of air; the mean relation is 1 to 1·307; again, in the case of W. Alderwood the increase is the smallest, the proportion amounting to 1 to 1·177.

The excess of CO_2 and of air expired when fresh air is breathed immediately after the re-breathing stage of the experiment must be due in a great measure to the increased amount of carbonic acid retained in the blood, together with an instinctive desire of taking into the lungs increased volumes of air, in order to rid the blood of the carbonic acid it has retained.

We now have to deal with the air expired finally or in the bell-jar filled at the termination of the experiment. The mean volumes of air and weights of CO_2 expired per minute will be seen to approximate to the corresponding volumes and weights expired in ordinary breathing to such an extent that respiration may be considered as having returned to the normal condition.

Table showing the Volumes of Air and Weights of CO_2 expired in the final stage of the experiment compared with the corresponding volumes and weights expired normally.

	Vol. air expired per minute unreduced.		Weight CO_2 expired per minute.		Difference.	
	Normal.	Last stage of experiment.	Normal.	Last stage of experiment.	Vols. air.	Weights.
Self	4·687	4·935	0·442	0·457	+0·248	+0·015
Mr. Russell ...	5·195	5·546	0·552	0·550	+0·351	−0·002
Mr. Hoskins ..	4·954	4·986	0·470	0·454	+0·032	−0·016
W. Alderwood.	4·197	4·276	0·437	0·422	+0·079	−0·015
Means	4·758	4·936	0·475	0·471	+0·178 = 3·6 per cent. increase vol. air.	−0·004

This table shows unmistakably that the respiration had again become normal before or by the end of the last stage of the experiment; the CO_2 is all but exactly the same, while there is a very slight increase by 3·6 per cent. in the volume of air expired, indicating that there was perhaps an instinctive tendency to continue breathing a volume of air slightly larger than usual, although the CO_2 expired was the same as in normal respiration.

The following are the results obtained from the present inquiry :—

1. On re-breathing air in a closed vessel less carbonic acid is expired within a given time than in ordinary breathing.

2. Those persons who emit most CO_2 in re-breathed air are those who expire most air and CO_2 in the same time in ordinary breathing, and *vice versâ*

3. On re-breathing 35 litres of air in a closed vessel for a period of five minutes, the volume of this air undergoes a slight reduction.

4. When fresh air is taken into the lungs immediately after re-breathing air in a closed vessel, the volumes of air breathed and weights of CO_2 expired are greater than in ordinary breathing.

5. The effects produced on the chemical phenomena of respiration by re-breathing 35 litres of air in a closed vessel for a period of five minutes have passed away in less than six minutes after the breathing of fresh air has been resumed.

It may be added that the number of experiments is insufficient to admit of any inquiry into the influence of barometric pressure on respiration.

The tables showing the general results of the experiments are as follows :—

Dr. Marcet under experiment.

No. of exp^t.	Lab^y. temp.	Bar.	Normal respiration.			Air re-breathed.		Respiration immediately after re-breathing air.			Respiration at end of experiment.		
			CO_2 expired in ordinary breathing per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.	Time of re-breathing.	Per cent. vol. CO_2 in re-breathed air.	CO_2 expired immediately after re-breathing, per minute.	Per cent. vol. CO_2	Vol. in litres of air expired immediately after re-breathing for 1 gram CO_2.	Final CO_2 expired per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.
	°	mm.	gram.			min. sec.		gram.			gram.		
1	67·2	767·0	0·437	5·09	9·96	5 2	3·41	0·492	5·21	9·73	0·448	5·09	9·96
2	67·5	745·5	0·456	5·49	9·24	4 56	3·13	0·514	5·55	9·15	0·450	5·60	9·06
3	58·7	744·0	0·445	5·09	9·97	5 0	3·31	0·510	5·22	9·72	0·453	4·92	10·31
4	63·8	758·8	0·429	5·18	9·80	5 6	3·52	0·528	5·25	9·66	0·479	5·22	9·71
5	67·2	759·5	0·423	5·03	10·08	5 3	3·81	0·579	5·21	9·73	0·482	5·25	9·66
6	67·6	758·6	0·463	5·11	9·92	5 3	3·36	0·488	5·01	10·12	0·428	4·76	10·66
Means	65·3	755·5	0·442	5·16	9·83	5 2	3·42	0·518	5·24	9·68	0·457	5·14	9·89

Volumes reduced to 0° and 760 mm.

Mr. Russell under experiment.

No. of expt.	Laby. temp.	Bar.	Normal respiration.			Air re-breathed.		Respiration immediately after re-breathing air.			Respiration at end of experiment.		
			CO_2 expired in ordinary breathing per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.	Time of re-breathing.	Per cent. vol. CO_2 in re-breathed air.	CO_2 expired immediately after re-breathing, per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired immediately after re-breathing, for 1 gram CO_2.	Final CO_2 expired per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.
	°	mm.	gram.			min. sec.	gram.	gram.			gram.		
1	68·0	755·1	0·503	6·07	8·34	5 5	3·46	0·632	5·81	8·72	0·487	5·58	9·08
2	54·0	750·8	0·553	6·15	8·25	5 0	3·88	0·796	5·61	9·04	0·586	5·48	9·27
3	57·5	763·0	0·523	5·85	8·66	5 10	3·71	0·861	7·03	7·21	0·572	5·37	9·44
4	60·0	756·7	0·555	5·80	8·75	5 2	3·85	0·810	5·69	8·92	0·558	5·54	9·16
5	61·7	751·5	0·513	5·90	8·60	5 7	3·68	0·718	5·34	9·51	0·454	5·35	9·47
6	59·6	750·2	0·571	5·56	9·12	5 4	4·00	0·780	5·13	9·88	0·491	4·93	10·29
7	61·0	745·7	0·549	5·88	8·63	5 2	4·16	0·766	5·55	9·14	0·543	5·50	9·22
8	63·5	748·7	0·567	5·85	8·67	5 5	4·16	0·841	5·58	9·09	0·538	5·34	9·50
9	67·5	758·2	0·590	5·86	8·66	5 3	3·84	0·782	5·46	9·29	0·584	5·33	9·51
10	68·7	755·3	0·592	5·63	9·01	5 3	3·97	0·773	5·36	9·46	0·615	5·38	9·43
Means	62·1	753·5	0·552	5·85	8·67	5 4	3·87	0·776	5·66	9·03	0·550	5·38	9·44

Volumes reduced to 0° and 760 mm.

Mr. Hoskins under experiment.

No. of exp[t].	Lab[y]. temp.	Bar.	Normal respiration.			Air re-breathed.		Respiration immediately after re-breathing air.			Respiration at end of experiment.		
			CO_2 expired in ordinary breathing per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.	Time of re-breathing.	Per cent. vol. CO_2 in re-breathed air.	CO_2 expired immediately after re-breathing per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired immediately after re-breathing for 1 gram CO_2.	Final CO_2 expired per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.
	°	mm.	gram.			min. sec.	gram.	gram.			gram.		
1	68·2	757·0	0·464	5·08	10·00	5 7	3·55	0·548	5·00	10·15	0·425	5·01	10·12
2	69·5	760·1	0·454	5·03	10·08	5 0	3·68	—	—	—	0·414	5·53	9·18
3	68·4	766·5	0·458	5·14	9·88	5 3	2·94	0·547	4·98	10·19	0·436	4·96	10·24
4	57·8	767·1	0·490	5·54	9·15	5 5	3·37	0·608	5·39	9·42	0·424	5·28	9·61
5	56·0	762·2	0·472	5·57	9·12	5 5	3·46	0·657	5·25	9·58	0·460	5·37	9·46
6	55·5	750·2	0·501	5·33	9·53	5 0	3·46	0·565	5·00	10·15	0·418	4·84	10·48
7	54·2	753·5	0·426	4·47	11·34	5 0	3·10	0·582	4·42	11·47	0·408	4·34	11·70
8	57·0	745·7	0·439	4·65	10·91	6 3	3·86	0·669	4·74	10·70	0·546	4·49	11·29
9	59·0	743·4	0·488	5·47	9·28	5 3	3·43	0·713	4·95	10·25	—	—	—
10	59·0	743·7	0·505	4·99	10·17	5 10	3·41	0·593	4·98	10·18	0·545	4·87	10·40
11	56·5	751·0	0·476	5·19	9·76	5 10	3·55	0·646	4·69	10·81	0·462	4·64	10·88
Means	60·3	754·6	0·470	5·01	9·93	5 10	3·44	0·613	4·94	10·29	0·454	4 93	10·34

Volumes reduced to 0° and 760 mm.

William Alderwood under experiment.

No. of exp^t.	Lab^y. temp.	Bar.	Normal respiration.			Air re-breathed.		Respiration immediately after re-breathing air.			Respiration at end of experiment.		
			CO_2 expired in ordinary breathing per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.	Time of re-breathing.	Per cent. vol. CO_2 in re-breathed air.	CO_2 expired immediately after re-breathing per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired immediately after re-breathing for 1 gram CO_2.	Final CO_2 expired per minute.	Per cent. vol. CO_2.	Vol. in litres of air expired for 1 gram CO_2.
	°	mm.	gram.			min. sec.	gram.	gram.			gram.		
1	65·2	758·5	0·477	5·90	8·60	5 0	3·40	0·476	5·68	8·93	0·474	5·61	9·04
2	64·5	746·0	0·409	5·65	8·98	5 7	3·44	0·502	4·88	10·40	0·410	5·06	10·02
3	53·7	755·8	0·494	5·79	8·76	5 0	3·41	0·560	5·16	9·84	0·478	5·17	9·82
4	60·0	756·0	0·453	5·93	8·55	5 5	3·25	0·507	5·27	9·62	0·449	5·51	9·20
5	61·0	760·0	0·505	5·65	8·98	5 3	3·41	0·573	5·16	9·84	0·435	5·64	9·00
6	59·5	750·2	0·431	5·67	8·95	5 10	3·41	0·445	5·39	9·42	0·418	5·38	9·42
7	59·5	758·0	0·376	5·59	9·08	5 5	2·96	0·420	5·12	9·92	0·351	5·17	9·82
8	62·0	759·2	0·367	5·42	9·37	5 7	3·16	0·376	5·19	9·77	0·359	5·61	9·04
9	64·0	757·9	0·430	5·55	9·14	5 6	3·26	0·453	5·08	9·98	0·457	5·28	9·60
10	65·0	756·0	0·425	5·64	8·99	5 5	3·20	0·444	5·36	9·46	0·385	5·27	9·62
Means	61·4	755·8	0·437	5·68	8·94	5 5	3·29	0·476	5·23	9·72	0·422	5·37	9·46

Volumes reduced to 0° and 760 mm.

The foregoing tables suggest the following remark :—" The volumes of air expired for 1 gram CO_2 immediately after re-breathing air vary but slightly from the corresponding volumes of air emitted in ordinary breathing; in every case except one, the volumes of air are a little higher immediately after re-breathing."

Presents, January 15, 1891.

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