there suddenly swept down the arteries gas bubbles, which drove the blood corpuscles before them and filled the capillaries.

On recompressing the frog to 70 atmospheres the gas within the vessels passed again into solution and the corpuscles appeared in the capillaries.

We have made similar observations on a bat (obtained for us by the kindness of Mr. F. Jones).

We observed the circulation in the wing. The bat was hibernating. The circulation was therefore slow, and the heart-beat infrequent. On raising the pressure to 10 atmospheres the pulse became more frequent and the capillary circulation accelerated. At 20 atmospheres of oxygen the circulation continued unimpaired. On decompression after 10 minutes the circulation became impaired, but no gas bubbles appeared in the capillaries. The animal had not, owing to the slow circulation, been under pressure for a sufficient length of time to become saturated with gas.

One of us (L. Hill) has frequently noticed gas embolism to follow decompression of mice and birds. The gas embolism is the cause of the convulsions which follow decompression.

*Conclusion.*—A rapid increase of pressure to 70 atmospheres has no mechanical effect on the circulation of the blood.

This research has been carried out with the help of a grant from the Government Grant Fund of the Royal Society.

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"The Influence of an Atmosphere of Oxygen on the Respiratory Exchange." By LEONARD HILL, M.B., F.R.S., and JOHN J. R. MACLEOD, M.B., Mackinnon Research Scholar of the Royal Society. Received May 22,—Read June 12, 1902.

Regnault and Reiset* found that the uptake of oxygen was the same in 46 per cent. and in 77 per cent oxygen as in atmospheric air.

Paul Bert† on the other hand found that the processes of oxidation were most intense in 60 per cent. oxygen, while they became lessened in a pure atmosphere of oxygen. Bert's figures for a rat placed for 24 hours in a current of air and oxygen were as follows :—

| Amount of $O_2$ in atmosphere. | $O_2$ inspired. | $CO_2$ expired. |
|---|---|---|
| 21·0 per cent. .................. | 12·6 | 7·06 |
| 48·3 ,, .................. | 13·72 | 10·32 |
| 88·2 ,, .................. | 11·35 | 6·96 |

* Regnault and Reiset, 'Annales de Chimie,' 20, 26 (1849). Translated in 'Annalen der Chemie u. Pharm.,' vol. 73, p. 92.

† Paul Bert, "La Pression Barométrique," p. 832 (Paris, 1872).

Moderate increase of the atmospheric pressure has, according to Panum and G. von Liebig,* no distinct influence on the oxygen intake or carbonic acid output of man.

Lorrain Smith also found that the oxygen tension in blood was lowered by respiration in a pure atmosphere of oxygen. The tension was estimated by the CO method.†

It will be seen from these researches that nothing conclusive can be asserted as to the influence of oxygen on the gaseous metabolism. In the following investigation, the question is studied by an entirely different method from that of previous workers, and it will be seen that we obtain very constant results.

*Method employed.*

The estimations were carried out on mice. These were placed in a small glass vessel, fitted with a ground glass stopper, through which passes an inlet and outlet tube. Connected with the outlet tube is a "T"-piece, through which a thermometer is passed so as to lie in the outgoing current of air. By this the temperature of the chamber was ascertained. The egress tubes were connected with Haldane and Pembrey's soda lime and sulphuric acid absorption tubes,‡ and the ingress tubes with a series of Woulfe's bottles containing soda lime and sulphuric acid, so as to remove all the carbonic acid and water from the atmosphere before entering the chamber.

A gas meter was attached to the egress tube beyond the absorption tubes. To study the effect of air an aspirating bottle was attached beyond the meter, and to study the effect of oxygen a cylinder of that gas was attached to the ingress tube.§ The O intake was determined by the difference between the loss of weight of the mouse, and the gain in weight of the $CO_2$ and $H_2O$ absorption tubes.

The following tables show the results obtained :—

* G. von Liebig, 'Arch. f. dv ges. Physiol.,' vol. 10, s. 479 (1878).

† Lorrain Smith, 'Jour. Phys.,' vol. 22, 1897–98, p. 307.

‡ As described in 'Journ. Physiol.,' 1892, vol. 13, p. 419.

§ The oxygen employed was Brin's. We found this to contain from 95—97 per cent. of oxygen.

*Experiment* I.

Mouse weighed—at beginning ...... 19·484 grammes.
" at end .............. 17·7816 "
Length of time of experiment......... 6 hours 20 minutes.

| Amosphere breathed | Air. | Air. | Oxygen. | Oxygen.* | Air. | Air. | Air. |
|---|---|---|---|---|---|---|---|
| Length of time in atmosphere at beginning of period | — | 1 h. 9 m. | 40 mins. | 2 h. 30 m. | 1 h. 50 m. | 2 h. 20 m. | 2 h. 40 m. |
| " of observation | 20 min. | 10 min. | 30 mins. | 60 min. | 30 min. | 10 min. | 10 min. |
| Rate of ventilation per minute | 460 c.c. | 610 c.c. | 220 c.c. | 240 c.c. | 415 c.c. | 550 c.c. | 1·100 c.c. |
| Temperature of chamber at end of period | 23° C. | 22° C. | 21° C. | 26° C. | 23°·5 C. | 24°·5 C. | 24°·5 C. |
| Rectal temperature " " | 38° C. | 36°·5 C. | 35°·6 C. | 35°·8 C. | 36°·2 C. | 36°·2 C. | 36°·4 C. |
| Loss of weight | 0·1340 gr. | 0·0555 | 0·0745 | 0·3125 | 0·1880 | 0·0590 | 0·0785 |
| Amount of $CO_2$ expired— | | | | | | | |
| (α) During period | 0·0623 | 0·0245 | 0·065 | 0·0926 | 0·0454 | 0·0160 | 0·0222 |
| (β) Per kilogramme body weight and per minute | 0·1591 | 0·1270 | 0·1134 | 0·0827 | 0·0836 | 0·0899 | 0·1240 |
| Amount of $H_2O$ expired— | | | | | | | |
| (α) During period | 0·1235 | 0·0501 | 0·0791 | 0·2875 | 0·1827 | 0·0508 | 0·0718 |
| (β) Per kilogramme body weight and per minute | 0·3131 | 0·2643 | 0·1470 | 0·2525 | 0·3322 | 0·2810 | 0·3967 |
| Amount of $O_2$ inspired† during period | 0·0518 | 0·0191 | 0·0696 | 0·0676 | 0·0401 | 0·0078 | 0·0155 |

* The actual estimation was done in an atmosphere of air.

† The calculations were not carried further in this experiment, because there were several technical errors in the weighings of the mouse between the periods.

*Experiment* II.

Mouse weighed—at beginning .............. 13·8600 grammes.
" at end ...................... 13·1399 "
Length of time taken in experiment ......... 6 hours 30 minutes.

| Atmosphere breathed .................... | Air. | Air. | Air. | Oxygen. | Oxygen. | Oxygen. | Oxygen. | Air. | Air. | Air. |
|---|---|---|---|---|---|---|---|---|---|---|
| Length of time in atmosphere at beginning of period | 55 min. | 2 hours | 2½ hours | — | 40 min. | 1 h. 20 m. | 2 hours | — | 1 h. 20 m. | 2 hours |
| Length of time of observation ............. | 50 min. | 30 min. | 30 min. | 40 min. | 30 min. | 30 min. | 30 min. | 30 min. | 15 min. | 15 min. |
| Rate of ventilation per minute ............ | 300 c.c | 320 c.c. | 330 c.c. | 450 c.c. | 410 c.c. | 305 c.c. | 280 c.c. | 380 c.c. | 400 c.c. | 450 c.c. |
| Temperature of chamber at end of period.... | 22 | 20·5 | 22 | 23 | 21·5 | 21·5 | 21·5 | 22·5 | 23·5 | + |
| Rectal temperature " " .... | 37·2 | 37·4 | 37·2 | 36·8 | 36·8 | 37 | 36 | 36 | 36 | 36·8 |
| Loss of weight .......................... | 0·1415 | 0·0888 | 0·1102 | 0·0630 | 0·0305 | 0·0195 | 0·0460 | 0·1340 | 0·0245 | 0·0250 |
| Amount of $CO_2$ expired— | | | | | | | | | | |
| (α) during period .................... | 0·1026 | 0·0528 | 0·05975 | 0·0780 | 0·0536 | 0·0453 | 0·0489 | 0·0433 | 0·0266 | 0·0278 |
| (β) per kilogramme body weight and per minute | 0·1478 | 0·1278 | 0·1457 | 0·1456 | 0·1333 | 0·1132 | 0·1228 | 0·1058 | 0·1291 | 0·1369 |
| Amount of $H_2O$ expired— | | | | | | | | | | |
| (α) during period .................... | 0·1422 | 0·0885 | 0·1014 | 0·0810 | 0·0371 | 0·0248 | 0·0583 | 0·0311 | 0·0263 | 0·0272 |
| (β) per kilogramme body weight and per minute | 0·2020 | 0·2106 | 0·2416 | 0·1493 | 6·0800 | 0·0600 | 0·1460 | 0·0755 | 0·1291 | 0·1370 |
| Amount of $O_2$ inspired— | | | | | | | | | | |
| (α) during period .................... | 0·1033 | 0·0525 | 0·0509 | 0·096 | 0·0602 | 0·0506 | 0·0612 | 0·0596 | 0·0284 | 0·0300 |
| (β) per kilogramme body weight and per minute ...................... | 0·1443 | 0·1235 | 0·1264 | 0·179* | 0·1500 | 0·1200 | 0·1536 | 0·1436 | 0·1367 | 0·1522 |
| Respiratory quotient .................... | 0·99 | 0·99 | 1·18 | 0·81 | 0·90 | 0·90 | 0·80 | 0·71 | 0·96 | 0·93 |

* Water result too low, which accounts for $O_2$ result being too high.

*Experiment* III.

Mouse weighed—at beginning ........... 19·137 grammes.
„ at end .................... 18·867 „
Length of time of experiment ........... 5 hours.

| Atmosphere breathed | Oxygen. | Oxygen. | Oxygen. | Air. | Air. | Air. | Air. | Air. |
|---|---|---|---|---|---|---|---|---|
| Length of time in atmosphere at beginning of period | — | 90 min. | 115 min. | — | 56 min. | 95 min. | 135 min. | 175 min. |
| Length of time of observation | 70 min. | 20 min. | 30 min. | 45 min. | 30 min. | 30 min. | 30 min. | 30 min. |
| Rate of ventilation per minute | 320 c.c. | 260 c.c. | 240 c.c. | 250 c.c. | 315 c.c. | 240 c.c. | 300 c.c. | — |
| Temperature of chamber at end of period | 20° C. | 20° C. | 23° C. | 23° C. | 22° C. | 22° C. | 22°·5 C. | 23° C. |
| Rectal temperature „ „ | 36° C. | 35°·5 C. | 35°·5 C. | 35°·5 C. | 36° C. | 36° C. | 36 + ° C. | 36 + ° C. |
| Loss of weight | 0·1025 gr. | 0·0180 | 0·0125 | 0·0405 | 0·0435 | 0·0655 | 0·0435 | 0·0417 |
| Amount of $CO_2$ expired— | | | | | | | | |
| (α) During period | 0·1432 gr. | 0 0375 | 0·0562 | 0·0816 | 0·0575 | 0·0596 | 0·0638 | 0·0641 |
| (β) Per kilogramme body weight and per minute | 0·1066 | 0·0978 | 0·0979 | 0·0949 | 0·1004 | 0·1044 | 0·1121 | 0·1129 |
| Amount of $H_2O$ expired— | | | | | | | | |
| (α) During period | 0·1146 | 0·0212 | 0·0320 | 0·0407 | 0·0478 | 0·0593 | 0·0547 | 0·0417 |
| (β) Per kilogramme body weight and per minute | 0·0835 | 0·05541 | 0·0554 | 0·04722 | 0·07886 | 0·1039 | 0·09624 | 0·0742 |
| Amount of $O_2$ inspired— | | | | | | | | |
| (α) During period | 0·1553 | 0·0407 | 0·0757 | 0·0818 | 0·0618 | 0·0534 | 0·0750 | 0·0644 |
| (β) Per kilogramme body weight and per minute | 0·1180 | 0·1062 | 0·1319 | 0·0953 | 0·1083 | 0·0939 | 0·1322 | 0·1134 |
| Respiratory quotient | 0·93 | 0·92 | 0·75 | 0·99 | 0·92 | 1·11 | 0·85 | 1·0 |

(*Date*, *March* 10.)

*Experiment* IV.

Mouse weighed 16·75 grammes.

Estimations for periods of 5 minutes.

| Atmosphere breathed .... | Air. | Air. | Air. | Oxygen. | Oxygen. | Oxygen. | Air. | Air. | Air. | Air. | Oxygen. | Oxygen. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length of time in atmosphere ............... | — | 19 min. | 40 min. | — | 20 min. | 35 min. | — | 17 min. | 30 min. | 35 min. | 20 min. | 40 min. |
| Rate of ventilation ...... | 2·7 lit. | 3 lit. | — | 3·3 lit. | 3·2 lit. | 2·6 lit. | 4·6 lit. | 2·7 lit. | 4 lit. | 2·3 lit. | 2·8 lit. | 4 lit. |
| Temperature of chamber. | 20° C. | 21° C. | 21°.5 C. | 21°·5 C. | 22° C. | 22° C. | 22°·5 C. | 22°·8 C. | 23° C. | 23° C. | 23° C. | 23° C. |
| Amount of $CO_2$ exhaled.. | 0·014 gr. | 0·011 gr | 0·013 gr. | 0·012 gr. | 0·009 | 0·007 gr. | 0·004 gr. | 0 008 gr. | 0·008 gr. | 0·013 gr. | 0·008 gr. | 0·005 gr. |
| Amount of $H_2O$ exhaled . | 0·036 gr. | 0·022 gr. | 0·026 gr. | 0·031 gr. | 0·022 | 0·011 gr. | — | 0 011 gr. | 0·008 gr. | 0·014 gr. | 0·008 gr. | 0·006 gr. |

*Experiment* V.

Mouse weighed 19·26 grammes.

Estimations for periods of 5 minutes.

| Atmosphere breathed ................ | Air. | Air. | Air. | Oxygen. | Oxygen. | Oxygen. |
|---|---|---|---|---|---|---|
| Length of time in atmosphere.......... | — | 25 min. | 1 hour. | 30 min. | 60 min. | 90 min. |
| Rate of ventilation.................... | 2·1 lit. | 1·4 lit. | 1·8 lit. | 3 lit. | 3·6 lit. | — |
| Temperature of chamber............... | 24°·5 C. | — | — | — | 22° C. | — |
| Amount of $CO_2$ exhaled ............... | 0·019 gr. | 0·017 gr. | 0·018 gr. | 0·014 gr. | 0·012 gr. | 0·007 gr. |
| Amount of $H_2O$ exhaled.............. | 0·026 gr. | 0·028 gr. | 0·028 gr. | 0·044 gr. | 0·033 gr. | 0·025 gr. |

### *Consideration of Results.*

It will be noticed that the most constant results are those of the carbonic acid. If the amount of this expired per minute and per kilo. body weight for the different periods be examined, it will be seen that there is a *very distinct diminution in the amount during respiration in a pure atmosphere of oxygen.* This diminution does not occur immediately, but is generally quite distinct in about 30 minutes.

In taking an average of the amount of this gas for any period, therefore, we have included the first period of the respiration in air which followed it.

The average of carbonic acid per minute and per kilo. body weight for a period (varying from 1 to 3 hours) *in air*, is as follows :—

| No. of experiment. | Weight of mouse.* | $CO_2$ exhaled. |
|---|---|---|
| 1 | 19·4 grammes | 0·1331 gramme. |
| 2 | 13·8 ,, | 0·1417 ,, |
| 3 | 19·1 ,, | 0·1074 ,, |

The low result in No. 3 is explained by the fact that the estimation was made after the animal had been for over 2 hours in an atmosphere of oxygen, that it had received no food during this period, and that all through the metabolism in this animal was on a lower plane than in the others.

It will further be noticed that the mouse in Experiment 2 had a higher average than that in No. 1, the difference in this case being due to the fact that the animal weighed less.†

The average for a period *in oxygen* is as follows :—

| No. of experiment. | Weight of mouse. | $CO_2$ exhaled. |
|---|---|---|
| 1 | 19·4 | 0·0831 |
| 2 | 13·8 | 0·1187 |
| 3 | 19·1 | 0·0993 |

From this it will be seen that in No. 1 there was a diminution amounting to nearly 40 per cent., in No. 2 to nearly 20 per cent., and in No. 3 to nearly 8 per cent. As it might well be argued that the diminution was not due to the effect of the oxygen, but to the fact that the animal was receiving no food, and was kept in a confined space, we must consider the *effect of an atmosphere of air following that of oxygen.* In the case of Experiments 1 and 2 a very distinct increase (viz., 20 per cent. in No. 1 and 12 per cent. in No. 2) occurred when the atmosphere was again changed to air. This increase is not marked till about 2 hours after the commencement of the period. In Experiment 3, the increase on changing from oxygen to air is about

* Weighed at beginning of experiment.

† See Schäfer's "Text-book of Physiology" (1898), vol. 1, p. 720.

8 per cent., the smaller figure in this case being accounted for probably by the more sluggish metabolism in this animal.

These results regarding the carbonic acid excretion are confirmed by those of *water excreted* and *oxygen absorbed.* For these two bodies the figures are by no means so constant as for the carbonic acid, the reason for this being no doubt that the technique for the estimation of them is much more complicated, and the chance of experimental error so much greater. The results have been further confirmed by observing the *rectal temperature* during the various periods. It will be noticed that even in an atmosphere of air a distinct fall is recorded after the animal has been in the chamber for about an hour. This fall is, however, more marked when the animal is placed in oxygen, and it again rises somewhat when the oxygen is replaced by air.

Besides the experiments here recorded, we have performed a considerable number in which the carbonic acid and water excretions alone were recorded, and in every case we have obtained the above result. Two of the most typical of these tables are given here as examples (see Experiments 4 and 5).

This research has been carried out with the help of a grant from the Government Grant Fund of the Royal Society.

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## "Effects of Strain on the Crystalline Structure of Lead."

By J. C. W. Humfrey, B.Sc. (Vict.), 1851 Exhibition Research Scholar (University College, Liverpool), St. John's College, Cambridge. Communicated by Professor Ewing, F.R.S. Received May 28,—Read June 5, 1902.

(Abstract.)

The paper describes experiments carried out in the Engineering Laboratory at Cambridge, under Professor Ewing. The material used was a pure variety of lead which crystallised on a particularly large scale. Test pieces were obtained from it in which the part under observation (which extended right across the centre of the specimen as well as through from front to back) was a single crystal uniformly oriented throughout, and the paper deals with the behaviour of such uniformly oriented parts under the influence of strain. It was found that by suitable etching a very beautiful system of geometrical pits (which took the form of negative cubo-octahedra) could be produced on the surface of the specimen, and by means of these any change of orientation could be readily observed.

In the first experiments described the specimens were strained in