The Influence of Increased Barometric Pressure on Man. No. 3. —The Possibility of Oxygen Bubbles being set free in the Body.

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The avidity of the tissues for oxygen is such that this gas has never been regarded as a factor in the production of decompression symptoms with respect to the formation of bubbles.

Bert's (1) analyses of the gas set free in the hearts of dogs rapidly decompressed from 10 atmospheres gave—

	Per cent. CO_2.	Per cent. O_2.	Per cent. N_2.
(1)	15·2	2·0	82·8
(2)	15·9	0	84·1
(3)	20·8	a trace	79·2

v. Schrötter and his colleagues (2) found a higher percentage of oxygen in similar analyses—

	Per cent. CO_2.	Per cent. O_2.	Per cent N_2.
(1) 4 dogs yielded	4·71	15·31	79·98
(2) "	12·45	7·18	80·37

Leonard Hill and C. Ham (3) killed rats by rapid decompression from +10 atmospheres, or more, and, cutting up their bodies under a funnel filled with acidulated water, obtained the following results:—

	Per cent. CO_2.	Per cent. O_2.	Per cent. N_2.
(1)	10·7	2·1	87·2
(2)	16·0	4·0	80·0

Hill and Macleod (4) submitted frogs and toads to 20 atmospheres of oxygen (Brin's oxygen, containing 93—95 per cent. O_2) for five minutes, and rapidly decompressed them. They found that the animals were convulsed and enormously distended with gas. In the case of mice submitted to 10 atmospheres for five minutes and rapidly decompressed, no such distension was observed, but the animals went into tetanic convulsions. These convulsions could be excited by a touch, the mice usually recovering and appearing normal on the following day. Mice killed in the convulsive state showed, here and there, a few bubbles in the vessels, some being found, on microscopic examination, in the central nervous system, distending the capillary sized vessels and compressing the nerve-cells. The convulsions were due to oxygen poisoning, and the bubbles, being formed of oxygen, were eventually absorbed by the tissues. These bubbles supplied the nerve-cells with oxygen until the circulation became re-established, so that no lasting paralysis resulted, as occurs with nitrogen bubbles. It seemed, therefore, probable that, if an animal be kept in oxygen until symptoms of poisoning are well marked and there is danger of death, then the tissues will be unable to combine with the oxygen liberated on sudden decompression, and embolism will result. We decided to settle this question by analyses in the peritoneal cavity, blood-vessels, and subcutaneous tissues.

The technic employed was that described in the paper of Hill and Ham (3), the animal being cut open under a funnel filled with water and inverted over a basin of water. Before being passed under the funnel, the gas is carefully washed out of the fur, and pains are taken to avoid opening the digestive tract or lungs. The results obtained on frogs were as follows:—

(1) Frog exposed to +20 atmos. O_2 during 1 hr. 10 mins. Rapid decompression. Composition of gas obtained from the body ,—

O_2 ...... 80 per cent.
N_2 ...... 20 „

(2) Large Dutch frog. +16 to 20 atmos. O_2 during 35 mins. Rapid decompression.

CO_2 ...... 2·2 per cent.
O_2 ...... 75·6 „
N_2 ...... 22·2 „

(3) Frog. +20 atmos. O_2 during 33 mins. Rapid decompression. Dead on removal.

CO_2 ...... 2·5 per cent.
O_2 ...... 62·0 „
N_2 ...... 35·5 „

The saturation time in frogs differs so much from that of the Mammalia that no very direct conclusions could be drawn from these results, and we therefore extended our observations to rats, the following experiments being performed:—

(1) Three rats were exposed to +70 lbs. O_2 for one hour. Two were convulsed in 35 minutes, and at the end of the experiment they were all moribund. One, however, still breathed after decompression, which took 3½ seconds. Analysis of the peritoneal gas yielded:—

O_2 ...... 54·5 per cent.
N_2 ...... 45·5 „

(2) Three rats were exposed to +75 lbs. O_2 for three-quarters of an hour. Decompression time, 4 seconds. All three were paretic. The peritoneal gas of one contained—

CO_2	2·2	per cent.
O_2	28·3	"
N_2	69·5	"

(3) Three rats exposed for one hour to +75 lbs. O_2. Decompression in 3 seconds. Two rats were dead, the third moribund. Peritoneal gas—

CO_2	6·7	per cent.
O_2	26·7	"
N_2	66·6	"

(A sample of the chamber air contained only 75 per cent. O_2, showing that it had not been completely washed out at the commencement of the experiment, since the gas in the cylinder used in this experiment contained 87·3 per cent. O_2.)

(4) Experiment, 12.12.06—

11.55 A.M.—Six rats and six mice were placed in the pressure chamber, which was washed out with oxygen and then raised to +75 lbs. O_2.

12.0.—Two of the mice convulsed.

12.5.—One rat exhibits a twitching of limbs, all the mice affected.

12.20.—All the rats affected, one convulsed.

12.35.—Decompression in 4 seconds. Several rats immediately thrown into convulsions.

On opening the chamber, four mice were found to be dead, two others affected, one of them dying in a few minutes. Of the rats, one was dead, two convulsed, three moderately affected. Of these five, three died, one was killed, and the fifth recovered. A sample was collected. One mouse (dead) yielded a good deal of gas, one rat (dead) very little, and one rat (killed for analysis) a considerable amount.

The analysis gave—

CO_2 and O_2	67·9	per cent.
N_2	32·1	"

These experiments are not sufficiently numerous to permit of very exact statements being made, but they seem to show that free oxygen is liberated during decompression if the animal exhibit symptoms of oxygen poisoning.

The onset of convulsions immediately after decompression, mentioned in the above account, is very suggestive, and may well have been due to the sudden liberation of gas bubbles acting on the already poisoned tissues.

The breathing of pure oxygen has been suggested by v. Schrötter (5) as a means of washing the dissolved nitrogen out of the body before decompression. He suggested that deep-sea divers might take down a small cylinder, wash themselves out for five minutes, and then ascend rapidly without risk.

The experiments of Durig (6) show that, on breathing almost pure oxygen, the body nitrogen is washed out in about five minutes, as shown by the quantity of nitrogen in the expired air sinking in that time to a constant level. L. Hill and C. Ham (7) have pointed out the extreme danger of breathing oxygen for even five minutes at high pressures, and v. Schrötter (8) himself has come to the conclusion that the use of oxygen should be confined to an inhalation immediately after decompression.

The gas set free in the blood on rapid decompression contains 79—87 per cent. N_2. Of the alveolar air, nitrogen forms 79 per cent., so that the difference of tension promoting an escape of bubbles is very small or nil (5—0 per cent.).

If pure oxygen be breathed, the difference of tension will become 79—87 per cent., and this will greatly favour the escape of nitrogen bubbles from the pulmonary vessels (Zuntz). There is little advantage in breathing oxygen during the course of a rapid decompression, because the exchange is between the tissues saturated with nitrogen and the blood. The amount carried away by the blood depends on the respective tensions of nitrogen in the tissues and the blood.

Oxygen inhalation cannot affect this, except in so far as it clears the arterial blood of nitrogen in the lungs. If the pressure falls rapidly the tissues will still be saturated—say, at 5 atmospheres—and hold 5 per cent. of nitrogen, while the blood can only carry, say, 3 per cent., the pressure having fallen to 3 atmospheres. Oxygen can have little or no effect in arresting this decreasing power of the blood to carry nitrogen (v. Schrötter).

The only safe method is slow decompression at a uniform rate when the body has been exposed long enough to become saturated.

REFERENCES.

(1) Bert, 'La Pression Barométrique,' p. 955.

(2) Heller, Mager, and Schrötter, 'Luftdruckerkrankungen,' etc., p. 800.

(3) Hill and Ham, "Phys. Soc. Proc.," 'Journ. Physiol.,' vol. 33.

(4) Hill and Macleod, 'Journ. Hygiene,' vol. 3, pp. 401, etc.

(5) v. Schrötter, 'Der Sauerstoff in der Prophylaxe, etc., der Luftdruckerkrankungen, etc.,' p. 71 etc.

(6) v. Schrötter, *op. cit.*, p. 49.

(7) Hill and Ham, "Phys. Soc. Proc.," 'Journ. Physiol.,' vol. 33.

(8) v. Schrötter, 'Zur Prophylaxe der sogenannten Taucherlahmung' (Congresso Internazionale per le Malattie del Lavoro).