NOTE ON THE COMPOSITION OF ALVEOLAR AIR AT EXTREME HEIGHTS.

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During the Everest expedition of 1924 I made observations on the composition of alveolar air of several members of the party at three different heights above sea-level. The samples of air were collected in football bladders. In collecting a sample the subject first breathed out, held his breath for two seconds whilst putting the bladder to his lips, then expired as strongly as possible into it. This was done in exactly the same way in every case. It was not practicable to analyse at once the samples collected above the level of the base camp, on account of the freezing of the solution and other conditions. These, then, were taken to the base camp and analysed there; it will be seen from the analysis and considerations given below that there was no appreciable diffusion of gases through the wall of the bladder. I was unable to procure a Haldane apparatus in Calcutta, but by the kindness of Major Shorten, I.M.S. and his staff at the Calcutta Medical College, I managed to put together a similar apparatus of 150 c.c. capacity which gave consistent results in control experiments.

The air was collected by asking a man to breathe out, stop two seconds while putting the football bladder to his lips and gasp out into that. This was done in exactly the same way in every case in order that all results of analysis might be as far as possible comparable. Analysis was effected in the usual way by strong caustic soda for the CO_2, followed by the mixture of pyrogallic acid, exactly as in a Haldane apparatus, except that a longer time was allowed for the absorption of the oxygen. In each case a little water was left above the mercury. The gas burette was kept at an even temperature by the constant pouring of water at a fixed temperature over it. At the Base Camp this was easily managed owing to the presence of a spring.

At Phari Dzong, the first series of observations was taken.

TABLE I. Altitude 14,300 feet. In each case 140 c.c. of alveolar air were analysed. Barometer taken as 457 mm. Aq. vapour in lung as 47 mm.

	CO_2		O_2		
Name	P.c.	Partial pressure	P.c.	Partial pressure	Alveolar resp. quot.
Norton	7·6	31	13·9	57	1·07
Beetham	6·9	28	11·8	48	·74
Somervell (1)	6·8	28	13·2	54	·87
(2)	8·2	34	9·8	40	·74
Irvine	6·9	28	11·7	48	·74
Shebbeare	5·2	21	14·6	60	·81
G. Bruce	7·3	30	12·6	52	—
Average	6·76	28	—	—	—

Another series at the base camp, three weeks later, when all were partially acclimatised, is as follows:

TABLE II. 16,500 feet above sea-level. Barometer taken as 425 mm. Aq. vapour in lung as 47 mm.

Irvine	5·1	19	15·3	58	·91
Mallory	6·1	23	14·6	55	·97
Beetham	6·0	23	14·0	53	·94
Somervell	5·3	20	12·7	48	·64
Norton	5·3	20	14·7	55	·82
Atmospheric air	·3	—	19·5	—	—

TABLE III. 23,000 feet above sea-level. Barometer taken as 330 mm. Aq. vapour in lung as 47 mm.

Mallory	2·5	7	13·6	39	·33
Irvine	2·7	8	12·7	37	·35
Norton	2·9	8	13·8	39	·39
	3·0	9	13·6	39	·43
Somervell	2·7	8	13·4	39	·39
	2·4	7	12·9	37	·31
	3·0	9	13·3	38	·44

TABLE IV. Controls at Base Camp, 16,500 feet above sea-level subsequent to ascent. Barometer taken as 425 mm. Aq. vapour in lung 47 mm.

Air	3	—	20·6	—	—
Somervell	5·6	22	14·2	54	·88
Air	·3	—	19·6	—	—
Norton	4·9	18	14·9	56	·69

The most remarkable point about the above figures is the low respiratory quotient at 23,000 feet. This was caused by an extremely small value for the CO_2 in the alveolar air. With a normal respiratory quotient the combined percentages of oxygen and CO_2 in the alveolar air should add up to nearly 20 p.c. of the dry air. At all stations except 23,000 feet this was the case.

TABLE V.

Altitude	Average p.c. CO_2	Average p.c. O_2	Total p.c. $CO_2 + O_2$
14,300	6·76	12·31	19·07
16,000	5·58	14·17	19·75
23,000	2·78	13·59	16·37
16,000 on return	5·25	14·55	19·80

The controls on the way down were done because the total $CO_2 + O_2$ was obviously less than would have been expected, in order to ascertain that there was nothing the matter with the apparatus. They seem to indicate that the low value for the R.Q. at 23,000 was not due to gross error in technique, although the air analyses show a tendency for the oxygen readings of atmospheric air to fall somewhat short of the theoretical value. In calculating the respiratory quotient the theoretical value has been used. Had the average value given by the apparatus for the oxygen in air been used the respiratory quotient would have come out a little higher, but the difference would only be one of detail.

The fact that the apparatus gives rather low results for atmospheric air suggests that the alveolar oxygens as given are not too high.

At a great height breathing is so rapid (about 50 respirations to the minute) that the CO_2 is washed quickly out of the alveoli and hence in this series the percentage of CO_2 is naturally small: but I fail to see why the $CO_2 + O_2$ is also so small: yet there seem to be no gross errors in analysis, partly for the reason given and partly because the figures at 23,000 feet are very consistent.

The question of diffusion from the football bladders will not explain it, as nitrogen will diffuse slightly more quickly than CO_2 or O_2, and if diffusion occurred the $CO_2 + O_2$ percentage should show a very slight increase if anything; personally I feel satisfied that at a great height such as 23,000 feet the ($CO_2 + O_2$) percentage is undoubtedly smaller by some 3 p.c. than at less elevations such as 14,000–16,000 feet.

It may be of interest to record one or two personal observations which I made while climbing in the neighbourhood of 27,000–28,000 feet.

Pulse. The heart during actual motion upwards was found to be beating 160–180 per minute, sometimes even more; regular in rhythm and of good volume. All who had gone above 27,000 feet were found by Major Hingston, I.M.S. (the official doctor of the Expedition) to have dilated hearts, which took one to three weeks to recover.

Respiration. About 50–55 per minute while climbing. Approaching 28,000 feet, I found that for every single step forward and upward, seven to ten complete respirations were required. Breathing quickly

and deeply is very easy at a great height owing to the low density of the air.

Mentality. While the simplest little bit of extra work, such as cooking a meal, fetching snow for melting, or even taking a photograph, is very irksome, yet in 1924 I should say that we were none of us affected by the altitude mentally to the same degree as in 1922; our minds were clear and our tempers and resolution both fairly good even at a height of 28,000 feet.

Appetite. At our highest camp, 26,700 feet, the appetites of Colonel Norton and myself were both profoundly affected; we could with difficulty bring ourselves to eat meat at all; chocolate and biscuits were managed as a duty, and only for pemmican soup and coffee did we show any real relish: liquids in this high, dry air are, of course, one's primary need.

Colour index. (Hæmoglobin value.) At the Base Camp, May 2, the colour indices of various members of the party were:

116, 120, 122, 114, 116, 142, 126, 118.

At 21,000 feet, May 25, they were respectively

120, 120, —, 116, —, 136, 112, —.

The extra height and three weeks' acclimatisation had not apparently affected the colour index at all. Blood-pressure seems to be unaffected by altitude. The colour indices of two Tibetans, taken at 16,500 feet, at which height most of their lives had been spent, were 92 and 82; remarkably low figures for men who can race up steep slopes about twice as fast as we could with our colour indices of 120.