excellent it is that both persevered in spite of everything. It is not possible to overrate the hardships which these pioneers endured; nor to overstate the satisfaction of the writer in having been present, though the part of a mere spectator has its inevitable regrets.

I gratefully thank several friends, both Alpine and Himalayan, for their assistance in the compilation of these rambling notes. I cannot close without some brief acknowledgment of our debt to the labours of the First Expedition, and in particular to Wheeler's admirable survey, accomplished as it was under conditions of such extreme difficulty and continuous hardship.

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## Equipment for High Altitude Mountaineering, with Special Reference to Climbing Mt. Everest.

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In climbing Mt. Everest, high altitude may be said to begin at 22,000 ft. when the North Col is approached from the east. Although there is no sharp line of demarcation between what constitutes low and high altitudes, I select the above figure for the following reasons: Firstly, all the strongest and most physically fit members of the Expedition are of the opinion that at 21,000 ft. (Camp No. 3) one's physical functions are practically unimpaired, and good sleep and recuperation from fatigue are possible; but at 23,000 ft. (North Col), owing to the altitude, one's physical functions are impaired; sleep becomes fitful, in some individuals the appetite falls off, and there is a general loss of physical fitness. The conclusion may therefore be drawn that in the case of the most favoured individuals acclimatization to altitude ceases between 21,000 and 23,000 ft. Secondly, up to a height of 22,000 ft., snow and ice conditions approximate very closely to summer conditions in the Alps; above 22,000 ft., however, the state of the snow resembles that met with in mid-winter in the Alps. This high-altitude zone may be further divided into two subzones—the first from 22,000 ft. (foot of the steep snow and

ice slopes leading up to the North Col) to 23,000 ft., and the second from 23,000 ft. onwards. The first zone is protected by the North Col from the prevailing westerly wind, whereas the second is fully exposed.

*Equipment for First Zone.*—Oxygen should be used from the foot of the North Col slopes onwards. No useful purpose is served by tiring oneself through not using oxygen, when, as we have seen, full recovery from fatigue is no longer possible at 23,000 ft.

Clothing somewhat warmer than that used in the Alps in summer is quite sufficient. A solar topee is advisable as protection against the sun, and Crookes' glasses of smoke-blue colour afford complete protection from glare without causing eyestrain and subsequent headache. It is also advisable to wear a veil or similar protection, and not to expose the hands to the rays of the sun. Sunburn is invariably followed by a condition of feverishness which cannot but impair one's fitness.

*Equipment for Second Zone.*—Above 23,000 ft. conditions change radically. The wind is almost invariably blowing and the cold is intense. The degree of intensity of the latter is comparable with that met with at the Poles, and, indeed, probably often exceeds it. Also, owing to the rarefied state of the atmosphere, cold is much more severe in its effects than would be the case at sea-level. A far greater volume of air is expelled from the lungs, and the air is saturated with moisture at blood heat and under a low pressure. A proportionately more rapid loss of animal heat is the result. The partial pressure of oxygen is so low that, unless the climber has recourse to a supply of oxygen carried by himself, his climbing efficiency is enormously lessened. It follows that the climbing equipment of the mountaineer in this second high-altitude zone should include (1) a supply of oxygen, and (2) warm and windproof clothing and foot gear. (3) The use of oxygen increases the appetite, and due provision must be made for a sufficiency of suitable food and drink.

*Oxygen Equipment.*—The oxygen equipment should consist of an improved form of the apparatus, using cylinders of compressed oxygen, described by Mr. P. J. H. Unna in the ALPINE JOURNAL. Numerous other methods of supplying oxygen have been suggested, but these all fail in one or more respects.

In the Leonard Hill bag oxygen is generated from sodium peroxide and water. Already at an altitude as low as 16,500 ft. there is thrown up into the oxygen developed a fine spray (probably caustic soda solution) which settles so slowly that,

even after standing for two hours, the oxygen is still unfit to be breathed. In addition, water is required for developing the oxygen, and at high altitudes water is almost too precious a commodity to be used for this purpose.

Mr. Harkness advocates the use of oil of garlic. He found from practical experience in the Andes (at an altitude of 16,000 ft.) that the smelling of oil of garlic dispelled his symptoms of mountain sickness. He offered as explanation that oil of garlic contains much oxygen and emits this oxygen freely. Oil of garlic certainly does not do this, but it may possibly act in another way by stimulating normal involuntary breathing.

*The Administration of Oxygen by Subcutaneous Injections.*—I shall refrain from discussing the possible value of oxygen administered in this manner, but will content myself with merely pointing out what seem to me to be weaknesses in the proposed method of administration. Presumably such subcutaneous injections would be employed only at high altitudes, say, 25,000 ft. or more, in the hope of thus dispensing with the heavy and bulky oxygen apparatus. At such altitudes, however, the climber must concentrate all his powers of resolution upon one object, namely, the getting to the top of Mt. Everest. I think that the pushing of a needle into his skin and injecting a large volume of oxygen—it must be large to be of any use—would irritate him to such an extent as to divert his mind from the main object. Furthermore, unless the man who operates upon himself is possessed of a certain amount of skill and is mentally still sufficiently alert in spite of the high altitude, he will run the risk of doing himself an injury. The method of administration also leads one to suppose that the needle should be left in position. Owing to the intensity of the cold, this would result in the formation of a considerable area of frost-bite all round the heat-conducting needle. Again, I believe it is suggested that the injection be made in the thigh; with the needle in position and passing through or covered by clothes, laceration of the muscles while climbing would be almost inevitable. I do not know whether it would be possible for an extremely clumsy man to push the needle into a major vein. Should this occur, the results of injecting oxygen would be disastrous. There is one other point. I am not sure that we ought to ask even a climber to insert a needle into his skin when, in order to do so, he must, owing to the cold, push the needle through clothes that are bound to be septic and dirty, and so run the grave danger of infection.

With reference to the injection of oxygen under the skin, however, I would like to suggest that physiologists consider the advantage of occasionally flushing out the stale air surrounding the body by allowing a few litres of oxygen to flow from the apparatus into rubber tubes leading down inside the clothing, say, to as far as the knees.

Another suggestion was to take potassium chlorate. The oxygen of potassium chlorate is chemically very stable, and it is not absorbed by the blood, and for all the oxygen you would obtain by this means you might just as well take sodium chloride.

Recently the proposal was made to me very earnestly indeed that hydrogen peroxide could be used. The method has this in its favour at first glance : the ratio of the oxygen to the total weight of the hydrogen peroxide is a very favourable one (about 16 to 34)—far more favourable than in our oxygen apparatus, which weighs about 35 lbs. to about 3·3 lbs. of oxygen actually available. The unfortunate thing about hydrogen peroxide, however, is that—although I believe it has been prepared pure—it is by reason of its products of decomposition a highly endothermic compound, and as such extremely dangerous and liable to explode. Further, the rate at which the oxygen would be given off by a commercial hydrogen peroxide, although controllable in the laboratory, would not be so on the slopes of Mt. Everest.

*The Effects of Tobacco.*—Captain Geoffrey Bruce, Lance-Corporal Tejbir, and I arrived at an altitude of 25,500 ft. and pitched camp about half-past two in the afternoon. From half-past two until seven o'clock the following evening (that is, for more than twenty-eight hours) we used no oxygen at all. Very fortunately, I had brought with me three packets containing in all thirty cigarettes. About half an hour after arriving in camp, I do not mind confessing that we felt a little bit miserable. We had been exposed to a considerable degree of cold and wind, and warmth once lost does not, at that height, return very quickly to one's members. I also noticed in a very marked fashion that unless I kept my mind on the question of breathing—that is, made of breathing a voluntary process instead of the involuntary process which it ordinarily is—I suffered from lack of air and a consequent feeling of suffocation. By forcing my lungs to work faster than they would have done of their own accord, I would recover and again become normal. There is a physiological explanation of this phenomenon. The partial pressure of carbon dioxide in the blood falls below

normal because it is washed out of the system owing to the enormous volume of air which one inhales in order to obtain a sufficient supply of oxygen. Carbon dioxide stimulates that nerve centre which controls one's involuntary breathing.

About 4 o'clock that afternoon I smoked a first cigarette, remembering how often in quite different situations the mere act of smoking had distracted the attention from unpleasant things. I was joined by Geoffrey Bruce and Tejbir, both of whom had been experiencing the annoying necessity of having to concentrate on breathing the whole time. After the first few deep inhalations of the smoke, this was no longer necessary, although at first we had to pant a little on account of the time during which the lighting of the cigarettes had interfered with our breathing. Evidently something in the cigarette-smoke acted as a nerve stimulant in the place of the carbon dioxide in which the blood was deficient and, making breathing once more an involuntary process, relieved us of the need for constantly keeping our minds fixed on the controlling of the lungs. The effect of a cigarette lasted for about three hours, so that by 5 o'clock the next afternoon our supply was consumed. At 7 o'clock, rather sorely craving a substitute, we had recourse to the oxygen apparatus. Instead of breathing the normal two litres per minute each, we contented ourselves with about half a litre between us. This amount not only sufficed to make us feel much more comfortable and less cold, but it also enabled us to obtain the first sleep which we had had at this great altitude.

It is not yet known what the stimulant contained in cigarette-smoke is. It is not likely to be carbon monoxide. I have carried out laboratory experiments, in which an intermittent current of air at a pressure of 380 mm. was drawn through a cigarette, lighted at the beginning of the experiment by means of an electrically heated platinum wire. The gases after washing through glass-wool moistened with dilute sulphuric acid were colorimetrically tested for presence of carbon monoxide on absorption through iodine pentoxide. The results were negative. Perhaps the stimulant is pyridine, which is present in comparatively large quantities in tobacco-smoke. Pyridine is frequently used in the laboratory for the extraction of certain constituents from coal, and it has been independently observed by several research workers that the slight traces of the pyridine in the air of the laboratory have, for the first few days, a distinct stimulating effect upon respiration.

Morphia is another stimulant which has been suggested.

I cannot speak with authority about morphia, but I should be very glad to have medical opinion as to the exact nature of its effects at high altitudes. It must always be borne in mind, however, that a man has no business to be at 23,000 ft. on the slopes of Mt. Everest unless he is feeling fit and practically immune at that height from the evil effects of high altitude.

*Clothing.*—I would recommend clothing on the following lines: One suit of thin silk underwear, followed by a suit of (1) light woollen underwear, (2) medium-weight woollen underwear, (3) heavy-weight woollen underwear, and a loosely fitting woollen sweater with trousers of the same material. In order to keep the abdomen completely unrestricted, nether garments should be supported by braces. Two-piece under garments are preferable to one-piece, as they provide a double protecting layer round the abdomen. Over all should be worn a suit of warm and windproof clothing consisting of (beginning from the inside) a layer of thin flannel followed by a layer of duropreened light canvas, green in colour, another layer of light flannel, and a layer of transparent oiled silk of yellow colour. The coat should be made in blouse form with a hood, fur collar round neck to act as a brake upon the efflux of air from between the clothing and the body, a narrow fur band round the abdomen for the same reason, and likewise fur bands round the inside of the cuffs. Suitable tapes should be provided at the neck, round the waist and round the wrists, by means of which these openings can be comfortably closed. The trousers, fashioned on the same lines, should reach to the ankles and be provided with tapes for binding at the ankles and just below the knees (to prevent dragging on and hence impeding the action of the knees). Trousers should be supported by braces.

*Gloves.*—I wore one pair of thin woollen finger gloves, one pair of lambskin gloves, and one pair of duropreened canvas gauntlets with a lining of flannel. My hands kept warm, and I was able comfortably to manipulate the oxygen apparatus.

*Headgear.*—The R.N.A.S. pattern helmet is the most suitable form of headgear, with a chin-piece covering the whole of the face up to the nose. Crookes' glasses, let into a mask lined with soft fur and large enough to cover the remaining exposed portion of the face, complete the headgear.

*Footgear.*—Leather is too good a heat-conductor, and reliance should not be placed upon it for warmth. The uppers of the boots should be of felt, strengthened where necessary to prevent

stretching by sewn-on leather straps. The felt should be covered by duropreened canvas. Toe and heel caps must be hard and strong; the former should be high. The sole should consist of thin leather, a layer of three-ply wood hinged in two sections at the instep, and a thin layer of felt. The boot should be large enough to accommodate in comfort two pairs of thick socks. As regards nailing, ten tricouni nails per boot would be sufficient. These should be fastened by screws passing through the leather sole and entering into, but not penetrating, the three-ply wood.

Short-length ankle putties will prevent ingress of snow into the boots. Climbing irons are unnecessary.

*Food.*—Altitude does not impair the appetite, at all events when oxygen is used. Food, together with the necessary fuel (Meta) for cooking, should be made up in 10-lb. parcels contained in three-ply wood cases and clearly marked 'for high altitudes only.' A light tin-opener, a box of matches (Swan wax vestas or equally reliable 'strike everywhere' brand), and a supply of cigarettes should be included in each parcel. The greatest care must be taken in the selection and making up of the contents of these parcels in this country; the best organizer is likely to be somewhat below par when at the North Col.

*Cameras* should be of the roll-film type.

*Aneroids.*—I would suggest considering the advantages of the Pallin barometer. It is a zero instrument and light and robust.

*Thermometer.*—This should be graduated below zero only, and should be lighter, smaller, and better protected against rough handling than those with which we were supplied in 1922.

*Rope.*—There are no crevasses above the North Col. A light sash line, say 6 mm. or at the most 8mm. diameter, is sufficient. Fifty feet should be allowed for two men.

*Axes.*—Light axes with long picks and short hafts are best. The axes should be soaked for a day or two at the base camp and then well rubbed with linseed or similar drying oil.

A discussion followed in which Professor J. B. Haldane, Mr. Freshfield, Dr. Longstaff, Major Stewart (Air Ministry), and Lord Edward Gleichen took part, and Captain Finch replied to questions and gave further information. A full report appears in the Royal Geographical Society's Journal mentioned.