than the lightest apparatus possible, with a less quantity of gas, to be used, if found beneficial, on this final portion of the climb to the summit; or, on the other hand, to be available merely as an emergency measure. To take it in large quantities on the lower parts of the mountain, apart altogether from the important question of increased transport necessitated, prevents proper acclimatisation, and thereby renders the user more liable to collapse in the event of the apparatus failing.

Physiological Difficulties in the Ascent of Mount Everest.

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THE primary object of the Mount Everest Expedition was to reach the highest summit on the Earth. Everything else was subordinate to this. Elaborate scientific investigations were impossible, and anything involving complicated apparatus was altogether out of the question. We had to content ourselves with simple experiments and with the records of the experiences of individual climbers. These, nevertheless, may be worth discussion. They will give us some idea of the physiological difficulties involved in an ascent to so great a height.

Alterations in Breathing.—The most obvious of these is the difficulty in breathing. Owing to the gradual nature of our ascent this shortness of respiration was scarcely noticeable below 10,000 feet. It was definitely apparent above 14,000 feet, and above 19,000 feet the slightest exertion made breathing laboured and severe. When the body was at rest, even at extreme altitudes, the rate of breathing was apparently normal and as comfortable as at sea-level. But the very slightest exertion, such as the tying of a bootlace, the opening of a ration-box, the getting into a sleeping-bag, was associated with marked respiratory distress. The difficulties of the ascent were thus enormously increased. The breathing was quicker rather than deeper, but it was necessary to stop at frequent intervals and take a series of long, deep breaths. This very quickly brought relief and made one ready for a further advance. Norton

told me that, when he found himself dropping behind, his only chance of catching up the party was by taking a number of these long, deep breaths. Somervell gives a record of his breathing at 27,000 feet. At that altitude he had to take seven, eight, or ten complete respirations for every single step forward; and even at that slow rate of progress he had to rest for a minute or two every 20 or 30 yards. At 28,000 feet Norton, in an hour's climb, ascended only about 80 feet. This was the highest point reached without the aid of oxygen. The strain at that altitude was certainly intense, but when we remember that the supply of oxygen is only about one-third of that available at sea-level, we are surprised that men can make these strenuous efforts, and still more that they can remain in comparative comfort when they sit down to rest.

The alteration in the rhythm of the breathing—commonly known as Cheyne-Stokes respiration—was frequently noticed during the expedition. I heard one member of the party breathing in this way as low as 12,000 feet. Though as a rule it seldom occurs when awake, yet at the base camp I was conscious of this type of breathing before passing off to sleep. Illness at high altitudes markedly increases it. It was most pronounced in one member when suffering from fever at 15,000 feet, and still more so in a Gurkha when dying of cerebral hæmorrhage at 18,000 feet. The rapid breathing of cold dry air produces some important secondary effects. It causes inflammation of the respiratory passages. Every member suffered from sore-throat, from hoarseness, or from loss of voice. Most had irritating coughs, but with little expectoration. Some of the porters developed severe bronchitis: one had a profusely ulcerated throat, another persistently coughed up blood. Dr. Kellas was of opinion that the breathing was less laboured in a high wind. He thought that the wind might have the effect of packing the air into the lungs; also that it swept away the exhaled air and thus prevented it from being inhaled by the next breath. Our experiences did not agree with his. Mount Everest is noted for its heavy winds. They caused considerable obstruction to the breathing. A moderate breeze had a freshening effect, but a strong wind impeded progress, and there was a feeling of suffocation when facing powerful gusts.

I made some experiments on the respiration. The power of holding the breath is a simple test to which pilots are submitted in the Royal Air Force. The following table shows the diminution in this power at successive altitudes in the ascent.

The first column is the most complete. Where at sea-level the breath was held for 64 seconds, at 21,000 feet it was held for only 14 seconds.

Time breath held (in secs.).

Altitude in feet.	R.W.H.	E.O.S.	B.B.	G.B.	E.F.N.	G.L.M.	J.V.H.	A.C.I.	T.H.S.	N.E.O.
Sea-level	64	—	120	—	—	—	90	120	—	—
7,000 ...	40	40	60	40	40	50	42	80	60	55
14,300 ...	39	32	35	32	37	40	—	47	48	—
16,500 ...	20	23	35	20	31	—	23	30	41	28
21,000 ...	14	17	—	20	—	—	17	—	—	—

Another test used amongst airmen is the measurement of the expiratory force. This consists in blowing a column of mercury up a graduated glass tube. The height reached by the mercury is read off, and this gives a measure of the expiratory force. If the expiratory force is much below the average it suggests that the airman will be incapable of sustained effort. The following table gives the results of our experiments. It suggests that with increasing altitude the expiratory force tends to improve. Look again at the first column. At sea-level the expiratory force was 110 mm. Hg; at 21,000 feet it was 150 mm. Hg. The third, fourth, fifth, sixth, seventh and eight columns also show that an improvement has occurred.

Expiratory force in mm. of Hg.

Altitude in feet.	R.W.H.	E.O.S.	B.B.	G.B.	E.F.N.	G.L.M.	J.V.H.	A.C.I.	T.H.S.	N.E.O.
Sea-level	110	—	—	—	—	—	—	—	—	—
7,000 ...	110	120	140	160	110	110	130	160	120	110
14,300 ...	110	90	160	190	120	120	—	160	120	—
16,500 ...	140	130	210	200	170	—	120	170	120	100
21,000 ...	150	120	—	210	—	—	150	—	—	—

I did not anticipate this improvement in the expiratory force. But the test has little to do with the function of respiration. It is more an indication of physical fitness and muscular strength. And this tends to improve during an ascent, when the progress is slow enough to be accompanied with acclimatization and before the wasting of high altitudes becomes marked. The march across Tibet made us tougher and harder. Hence the expiratory force improved. Mosso came to a similar conclusion in the Alps. He made his men perform exercises with dumb-bells, and was surprised to find that they did much more work at a height of 4560 metres than when they performed the same exercises at Turin.

Circulation.—I pass to the changes in the circulation. Blueness of the face and lips, lividity of the nails, coldness of the extremities, were the indications noticed of the impaired circulation at altitudes above 19,000 feet. Three of the members experienced giddiness. One noticed that it was immediately relieved by taking a deep breath. Once the extremities become cold at these high altitudes there is a great difficulty in regaining warmth even in the interior of a sleeping-bag. The pulse is not markedly accelerated while at rest, but increases rapidly on the slightest exertion. Norton's normal pulse is 40, and it was only 60 when he was resting at 27,600 feet. An intermittent pulse may develop at high altitudes. In one instance, after crossing a pass of only 14,000 feet the pulse missed four beats every minute without causing any particular symptoms or distress. This irregularity of the pulse seems to be a common feature. Mosso states that, when on Monte Rosa, he noticed that nearly all the members of his party showed some signs of irregularity of the heart. Hæmorrhages at high altitudes have often been described, from the gums, the lips, the conjunctivæ, the nose. Nothing of the kind occurred amongst the members of our expedition.

The following table shows the changes in the pulse of one individual at successive altitudes above sea-level. The first column gives the pulse-rate when the person is at rest. There is no change except at the highest altitude, 21,000 feet. The second column shows the change that occurs when the person is made to stand up. There is an increase in the pulse-rate somewhat in proportion to the altitude of the experiment. Column 3 shows the change after regulated exercise. The exercise consisted in standing alternately on a chair and on the ground five times in 15 seconds. Again there is a marked increase in the pulse-rate, and this increase is greater the greater the altitude. The last column gives the time in seconds that the pulse takes to return to normal.

Pulse-rate of one individual.

Altitude in feet.	Pulse-rate per minute sitting.	Pulse-rate per minute standing.	Pulse-rate per minute after regulated exercise.	Time in secs. of return of pulse to normal.
Sea-level...	72	72	84	20
7,000 ...	72	84	96	15
14,300 ...	72	84	108	40
16,500 ...	72	96	120	20
21,000 ...	108	120	144	20

The blood-pressure was taken with a sphygmomanometer in the manner adopted by the Royal Air Force. The following is a table of results. There seems to be no change in the blood-pressure definitely associated with increase in height.

Blood-pressure at successive altitudes.

Altitude in feet.	R.W.H.		E.O.S.		B.B.		G.B.		E.F.N.		J.V.H.		G.L.M.		A.C.I.		T.H.S.		N.E.O.	
	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.
Sea-level	120	80	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7,000 .	130	90	125	90	150	110	130	90	140	80	120	100	120	85	130	100	110	85	100	80
14,300 .	135	95	115	80	145	85	130	90	135	90	—	—	120	90	130	100	130	90	—	—
16,500 .	146	104	128	90	140	102	128	93	136	96	126	94	122	78	140	110	120	82	125	95
21,000 .	138	118	100	80	—	—	110	90	—	—	100	80	—	—	—	—	—	—	—	—

A well-known change that takes place during an ascent to high altitudes is the increase in the number of red corpuscles per unit volume of blood. The conditions on Everest were too rough for these delicate determinations. But further west, on the Pamir plateau, I had previously made a series of blood counts up to 18,203 feet. The following table shows the results :—

Date.	Altitude.	Corpuscles per mm.
April 10	700 feet	4,480,000
May 12	4,390 ,,	5,240,000
May 21	8,000 ,,	6,040,000
May 28	10,000 ,,	6,624,000
May 30	11,960 ,,	6,760,000
June 1	12,400 ,,	6,800,000
June 21	13,300 ,,	7,525,000
June 23	15,600 ,,	7,840,000
June 26	16,900 ,,	7,640,000
July 27	18,200 ,,	8,320,000

There has been an increase in the number of red corpuscles from 4,480,000 at 700 feet to 8,320,000 at 18,200 feet. Another point of interest is that the people who live on the Central Asian plateau have a higher blood count than those at sea-level. The average blood count of the Sarikoli is 7,596,000, of the Kirghiz 7,920,000. The blood count of the European is about 5,000,000, but, on making an ascent to the Tibetan plateau, the corpuscles in his blood rapidly increase until they

reach the number normal to the people who live permanently at those heights.

Muscular Power.—Airmen describe great muscular weakness when flying at considerable altitudes. Even working a camera-shutter calls for enormous effort. We did not notice such pronounced effects, probably because our ascent was slow. But if inhalation is inadequate the legs soon become tired. It is not the tiredness of a prolonged walk, but more a heaviness and a lassitude which quickly disappears with a short rest.

The endurance test employed by the Royal Air Force is said to indicate the stability of the medullary centres and the capacity of the individual to resist fatigue. The test consists in blowing a column of mercury to a height of 40 mm. and noting how long the person is able to sustain it at that height. The pulse is counted in periods of five seconds during the performance of the test. The following table gives the result of this test. Every column shows a diminution in the powers of endurance at each successive height. Take, for example, the first column. At sea-level the subject could sustain the mercury for 45 seconds ; at 21,000 feet for only 15 seconds.

Endurance test.

Altitude in feet.	Time in secs. Hg maintained at 40 mm.									
	R.W.H.	E.O.S.	B.B.	G.B.	E.F.N.	G.L.M.	J.V.H.	A.C.I.	T.H.S.	N.E.O.
Sea-level	45	—	—	—	—	—	—	—	—	—
7,000 ...	35	30	60	50	20	60	35	45	50	50
14,300 ...	30	30	25	40	25	35	—	45	25	—
16,500 ...	23	23	23	15	23	—	17	25	22	20
21,000 ...	15	15	—	15	—	—	10	—	—	—

The pulse-rate was taken during the above test. Some of the results are given below. The first figure in each series shows the normal rate of the pulse during the five seconds before the test begins. This figure is separated from the following figures by a stroke. These following figures give the pulse-rate during each successive period of five seconds throughout the performance of the test. Take, for example, the first line of figures in the first column—6/7.8.9.9.8.7. The 6 is the pulse-rate during the five seconds immediately before the test. The 7 is the pulse-rate during the first five seconds of the test. The remaining figures, 8.9.9.8.7, are the pulse-rates during the successive periods of five seconds until the test ends. In this way we obtain the character of the pulse while the person is undergoing continuous strain.

Pulse-rate in secs. during Endurance test.

Altitude in feet.	E.O.S.	B.B.	G.B.	A.C.I.
7,000	6/7.8.9.9.8.7	6/6.7.9.9.9.7.6.6.6.5	5/6.6.8.6.5.4.5.5.5	8/9.11.10.8.7.6.6.6.6
14,300	6/6.7.7.7.7.7	6/7.8.8.6.5	5/7.7.7.6.8.6.5.5	8/9.9.11.10.9.9.9.9.8
16,500	6/7.7.8.7	6/9.9.9.3	6/7.8.9	8/11.10.9.7.6
21,000	8/10.8.6	—	9/10.10.6	—

The chief point of interest in this experiment is the marked slowing of the pulse that takes place when the capacity of endurance is beginning to tell. At the commencement of the test the pulse first increases, but after a lapse of 15 to 20 seconds it begins definitely to slow up. This slowing of the pulse is more marked at the higher altitudes. There is an extreme case in the lowest line of figures of column two. The 6/9.9.9.3 indicates that on the commencement of the experiment the pulse immediately rushed up from 6 to 9 beats in the first 5 seconds, and after a lapse of 15 seconds suddenly fell back from 9 to 3. This occurred at 16,500 feet.

Nevertheless, in spite of these vagaries of the pulse, it is remarkable how well the strength is maintained at altitudes over 20,000 feet. This specially strikes us when we observe how animals can move so freely at such great heights. Ravens and crows used to come to our camp at 21,000 feet. We saw lammergeyers circling round the mountain at 23,000 feet, and choughs followed the climbers to their highest bivouac at 27,000 feet. They moved through the air with perfect ease, though it must have required much greater effort to sustain them than when flying in the denser atmosphere of the plains.

Special Senses.—Changes in the function of the special senses have occasionally been noticed by mountaineers. They describe an impairment of vision, a diminution in hearing, alterations in the taste and smell. Most of our party noticed nothing in this respect, but two members were particularly emphatic in their loss of the sense of taste. One said that 'taste was distinctly affected,' that 'things seemed to have less taste, though there was no change in the character of the flavour.' He was unable to taste onions at 19,000 feet. Another found food 'distinctly tasteless.' At 19,000 feet he could eat a slab of peppermint without strongly appreciating the flavour. Their sense of taste returned on descending to the base camp at 16,500 feet.

Pain.—The only kind of pain which we could attribute to high altitude was the occasional occurrence of a slight headache. Most of the members never experienced it, but some of us noticed it on first reaching the plateau, though, after

a few days' acclimatization, it completely disappeared. It usually commenced at the back of the neck, spread into a general mild headache, and disappeared after an hour's rest. Exercise, and particularly stooping, increased it. Lying down quickly brought relief. Our porters also suffered from headache. Many of them asked for headache tablets the first time we passed over into Tibet. Even the inhabitants of the plateau are not immune. It is common to see patches of plaster on their temples and black pigment smeared on their cheeks. These are remedies which they use to alleviate the headache caused by the altitude and wind.

Gastro-intestinal Symptoms.—Loss of appetite is a serious consequence of residence at great heights. Probably it is the cause of much of the wasting that occurs. There is much individual variation in this respect. Some of the climbers maintained that there was no loss of appetite. I found some dislike for food even at the base camp, though this disappeared on acclimatization. Bruce thought that his appetite was unimpaired up to 21,000 feet. At 23,000 feet he found a disinclination for meat, though he still had an appetite for cereals and sweets. At 25,000 feet he lost all appetite for solid food, but could still take coffee and to a less degree soup. Somervell at 27,000 feet found an absolute distaste for solids, though he enjoyed liquids and sweets and fruit. The general opinion seemed to be that sweet things were the most palatable and meat the least palatable above 19,000 feet. There was no suggestion of nausea or vomiting even at the highest altitudes reached.

Diarrhœa is not uncommon. It is usually of a transient nature, and may be associated with much bile. Occasionally it may be more persistent, and refuse to yield to any treatment until a descent is made to moderate heights. Thirst is a far more important factor. It may be excessive at the end of a hard day, and, owing to the practical difficulties in obtaining water, may cause exhaustion of the climbers and failure of the climb. How best to relieve thirst at the high camps is a most important practical point. The craving for drink is not the result of perspiration, but of the loss of moisture in the respiratory passages from the excessive inhalation of cold dry air. This desiccation of the body at extreme altitudes may result in a great scantiness of urine. One of the climbers at 21,000 feet did not micturate for 16 to 18 hours; another on his descent from 28,000 feet did not do so for 24 hours.

Mental Effects.—High altitudes affect the operations of the

mind. One member was confident of a dulling of the will-power, a diminution in the strength of purpose, with less and less desire to reach the summit the further he made the ascent. Somervell describes a lack of observance at and above 25,000 feet. Bruce records an enfeeblement of memory. He found an effort in recalling previous events. Above 23,000 feet his ideas became increasingly inaccurate. It was necessary for him to record them immediately, as otherwise they would become forgotten or distorted. I think every one experienced some mental lassitude. Though the mind was clear, yet there was a disinclination for effort. It was far more pleasant to sit about than to do a job of work that required thought. We did not notice any peevishness or petulance, though I suspect that high altitudes would cause unsociability in a party less perfectly harmonious than ours. Though mental work is a burden at high altitudes, yet with an effort it can be done. One physiologist has said that sustained mental work is out of the question at anything over 10,000 feet. We certainly could not agree with this. Those who have read Norton's despatches to the *Times*, especially one dictated at Camp III, when he was burdened with anxiety and partially blind, will admit that this effort from 21,000 feet was not a bad intellectual performance. The main effect of altitude is a mental laziness which determination can overcome.

I made some mental tests on the members of the party. These tests were very simple. The first was a multiplication test. It consisted in multiplying the figures 123456789 by 7. The second was a division test, and consisted in dividing the same series of figures by 9. A record was made at successive altitudes of the time taken to do these sums. Probably these tests were far too simple. By an effort of concentration they could be easily done, and thus the effect of altitude was not properly shown. I give the results for what they are worth. They show no definite deterioration of mental activity. It will not please the members of the next expedition to hear that more complicated and worrying tests are required.

Multiplication test, showing time in secs. for completion of sum.

Altitude in feet.	R.W.H.	B.B.	E.F.N.	G.L.M.	T.H.S.	E.O.S.	G.B.	J.V.H.	A.C.I.	N.E.O.
0 ...	20	—	—	—	—	—	—	—	—	—
7,000 ...	25	25	27	13	40	43	40	35	25	80
14,300 ...	25	24	19	15	28	43	25	—	28	—
16,500 ...	18	23	28	17	40	35	35	55	35	30
21,000 ...	17	—	—	—	—	35	27	40	—	—

Division test, showing time in secs. for completion of sum.

Altitude in feet.	R.W.H.	B.B.	E.F.N.	G.L.M.	T.H.S.	E.O.S.	G.B.	J.V.H.	A.C.I.	N.E.O.
0 ...	30	—	—	—	—	—	—	—	—	—
7,000 ...	20	20	30	10	25	55	15	35	15	45
14,300 ...	28	20	13	23	20	45	17	—	17	—
16,500 ...	13	27	23	17	40	38	23	43	20	50
21,000 ...	15	—	—	—	—	40	13	59	—	—

The knee-jerks were examined at successive altitudes. In no case did they seem in any way affected by the height. Three of the party developed mild tremors: one a tremor of the eyelids at 14,000 feet, two a fine tremor of the fingers at 21,000 feet. This was an indication of nervous strain. It was a common sign of exhaustion and anxiety amongst those serving in the Great War.

Sleep.—To my mind insomnia was an unpleasant feature. But there were others who suffered from no lack of sleep except when they happened to be cold. Bruce on two nights slept for more than ten hours at 21,000 feet. He had a fair, but somewhat broken, night at 23,000 feet. He had about two hours' sleep at the beginning of the night, then a long period of sleeplessness, then a few more hours' sleep in the morning, when at 25,000 feet. He always slept with his head raised, having learned the trick on the previous expedition. Somervell slept well at 25,000 feet, and had two good spells of sleep at 27,000 feet. Norton, however, takes the record. He slept well and had an excellent night at 27,000 feet. A point about high-altitude sleeplessness is the fact that it is not associated with restlessness, nor does it cause weariness the next day. One lies awake, but does not toss about; nor is the sleep accompanied with irritable dreams.

Glacier Lassitude.—A distinct feature in the Mount Everest region is the very pronounced glacier lassitude which develops over tracts of ice. This was most marked on the Rongbuk glacier, especially when passing through a trough in the ice at an altitude of about 20,000 feet. The trough was a remarkable feature, being girt on either side with walls of ice, in many places hewn into fantastic pinnacles and ornamented with pyramidal spires. In this trough there was a peculiar sapping of energy, a weakness of the legs, and a disinclination to move. It was not a breathlessness due to exertion, but a loss of muscular power. There was a feeling of prostration. One seemed to drag oneself along, instead of going with the usual strength. A profuse sweating was not uncommon. It was something

like the oppression experienced when marching through a hot, moist jungle in the rains. The lassitude appeared immediately after stepping on to the glacier ; it was as quickly relieved on again reaching rock or moraine. It was most noticeable in the absence of wind and in the middle of the day when the sun was strong. It was absent late at evening and in the early morning, and was less marked on cloudy days.

The cause of this lassitude is easily explained. The conditions for its development are a sheet of ice, a hot sun, and a still air. The sun melts the superficial layer of the ice. The lowest stratum of the atmosphere becomes saturated with moisture, but does not rise owing to its being chilled by contact with the ice. Thus, when on the glacier, one is in a saturated atmosphere, and this, in conjunction with the high altitude, is sufficient to cause the unpleasant effects.

We did not notice that other atmospheric conditions had any special influence on these high-altitude symptoms. This was different from my experiences in the western Himalaya. There, on two occasions, our party climbed the same peak to a height of 18,203 feet. During the first ascent the sky was clear, the air was free from moisture, and our disability was slight. On the second occasion the conditions were different. The sky was dark, stormy weather was imminent, and the atmosphere felt heavy and damp. Our distress on this second occasion was acute. Every few paces found us gasping for breath, and we had repeatedly to make short halts. The same explanation applies to this as in the case of the glacier lassitude. On the second ascent the atmosphere was laden with moisture. The free evaporation of perspiration was checked, and, as a consequence, the high-altitude symptoms were increased.

Individual Variation.—The experiences of the party, as already detailed, indicate considerable individual variation with respect to oxygen want. It was obvious that some of us breathed more laboriously than others. One suffered from headache, another did not ; one lost the sense of taste, another observed no such change ; one was sleepless at comparatively low altitudes, another slept well at the highest camps. One member seemed particularly resistant to the lassitude that occurs over snow and ice. All were agreed that the Sherpa porters suffered, on an average, less than Europeans. Their power of carrying loads was extraordinary. They went with loads as fast as did the climbers without loads. It was not that they were muscularly more powerful than we. Probably their actual strength was less. It was their capacity to carry that

was so much greater. This must be due to their permanent habitations being at altitudes of 12,000 to 14,000 feet, and to the fact that they habitually carry loads over passes of 16,000 and 18,000 feet.

Oxygen.—To what extent does the breathing of oxygen alleviate the symptoms already described? Theoretically we should expect an enormous benefit. We know of its great value in balloon ascents, which could not be made to extreme altitudes unless oxygen was breathed. But our evidence on the subject is most unsatisfactory. The two climbers who could have told us most about it have perished on the mountain. Bruce used oxygen on his ascent to the North Col—that is, between 21,000 and 23,000 feet. He noticed scarcely any benefit. Odell used it at the same altitude and considered that it gave no relief. Later he used it between 25,000 and 27,000 feet. There the oxygen seemed to relieve the breathing and diminish the tiredness of the legs. He thinks it may have helped to keep up the temperature. Its use produced an uncomfortable drying of the throat which necessitated frequent swallowing and expectoration. He abandoned the oxygen at 27,000 feet and descended easily without it. It is remarkable how little benefit was obtained from the oxygen compared with the experiences of the previous expedition.

Acclimatization.—I pass to the problem of acclimatization. When we compare a rapid with a gradual ascent we see how powerful is this factor of adaptation to increasing heights. Haldane describes the condition of visitors after a rapid ascent of Pike's Peak to a height of only 14,100 feet. 'Many persons walked or rode up during the night to see the sun rise, especially on Sunday morning, and the scene in the restaurant and on the platform outside can only be likened to that on the deck or in the cabin of a cross-channel steamer during rough weather.' Now the altitude at which this scene took place was about the same as that of the Tibetan plateau. But our ascent to the plateau was gradual, and therefore accompanied by acclimatization. As a consequence we felt scarcely any distress. We were quite comfortable at a height where, if our ascent had been rapidly made, we should have been like the nauseated visitors on Pike's Peak.

But the contrast is more marked if we compare our progress with an air ascent. In the year 1875 Tissandier and his two companions made their famous ascent in a balloon from Paris. They were provided with oxygen but were unable to make use of it. Tissandier fainted at 26,500 feet, and when he recovered

consciousness the balloon was descending and his companions were dead. The balloon had reached an altitude of 27,950 feet. This was a rapid ascent with no acclimatization. The result was death between 26,000 and 28,000 feet even when sitting quietly in a balloon. Compare this with a gradual attack on Mount Everest. Climbers without oxygen have ascended the mountain to 28,000 feet, somewhere about the same height where death occurred in the balloon. Yet at that altitude they were capable of strenuous effort; they showed no indication of fainting; they could sleep well at a slightly lower elevation, and were comparatively comfortable so long as they were at rest. The difference in the two ascents is due to acclimatization, without which any attempt to reach the summit of Mount Everest would be altogether out of the question. The fact is that balloon ascents and experiments in air-chambers are not at all comparable to the conditions of a prolonged climb.

A special point which the expedition of this year taught us is that persons who have once experienced high altitudes will acclimatize very much more rapidly than those entering them for the first time. Those of our party who had been on two expeditions were unanimous in the view that they suffered less on the second than on the first occasion. One said that his mind was much more active than it was in 1922, another that he reached Camp III. with much less difficulty, another that he had not to breathe deeply at night as he had found necessary on the previous expedition. Also it was obvious that the new members of the party were distinctly more affected than the old. This is a point of practical importance. It means that, other things being equal, old hands will acclimatize more rapidly and be in a fitter state to climb the mountain than will be a party of fresh recruits. Even aviators have noticed the same thing. Although their ascents are so quick and short, yet they say that they get accustomed to the height. The body seems, as it were, to become trained by one experience, and therefore to make the necessary adjustments more easily on reaching high altitudes a second time.

To what height can acclimatization continue? There seems to be no doubt of a steady improvement at 19,000 feet. Shebbeare spent over a month at that altitude in Camp II. At first he found the ascent to Camp III. very laborious, but at the end of a month could do it with ease, and on the last day did it in the record time of 1 hour 55 minutes. Odell remained for ten days at 23,000 feet, and said that he certainly felt better

as a result of this. Somervell believed that acclimatization took place at 24,000 feet. But we must remember that while acclimatization is in progress there may be physical deterioration at the same time. Though the body is becoming more accustomed to the altitude, yet simultaneously it is losing both in weight and strength. Dr. Kellas puts the important question: 'Is it possible to become sufficiently acclimatized to altitudes of 24,000 feet to 26,000 feet to enable one to climb to over 29,000 feet?' I think that most of our party would reply in the affirmative. Two of them have already reached 28,000 feet aided by no other power beyond their own natural capacities for acclimatization.

After-Effects.—A note as to the after-effects consequent on residence at the high camps. The climbers were examined before we left the mountain. All of them showed signs of dilatation of the heart; in two it was decidedly marked. All were debilitated. All had wasted considerably—probably as much as 1½ to 2 stone. The porters too had lost much weight. Barcroft observed the same effect on his expedition to Peru. Loss of weight occurred in all the members of his party, the most marked being a decline from 155 to 131 lbs. in twenty-seven days.

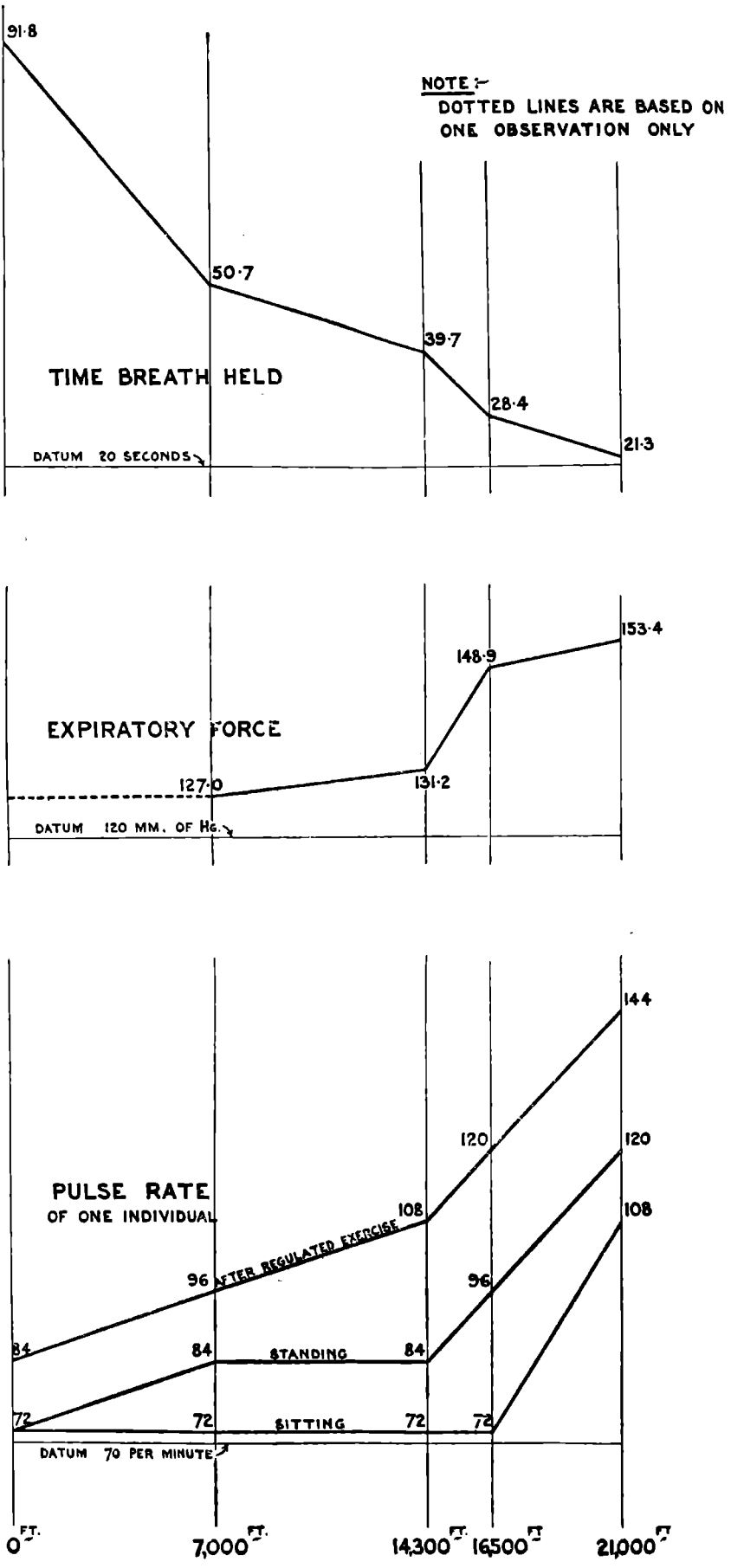
Those of the expedition who had been badly frostbitten required treatment for weeks after we had left the mountain. Frostbite showed itself in two varieties: the moist form with large blisters full of fluid and the dry gangrenous type. Snow-blindness also may need after-treatment. A point of interest was that Norton developed a severe attack of blindness when at high altitudes though in the absence of snow. At 28,000 feet he was on bare rock. He thought it unnecessary to use his snow-glasses, and on the next day he was completely blind. The sun's rays in this thin air can cause a most acute attack of conjunctivitis even when reflected from bare dark rock.

Thus life on the mountain causes physical deterioration. Improvement followed on our return to the base camp, with increase in appetite and better sleep. Finally we descended into the Rongshar valley, where, at the pleasant altitude of 10,000 feet, all were quickly restored to health.

Conclusion.—A last word on the possibility of reaching the summit. In the year 1916, at an afternoon meeting of this society, Dr. Kellas showed an interesting dissociation curve of Oxy-Hæmoglobin in blood. On this curve he plotted the heights of some well-known mountains. From it he drew the following deductions. 'The curve,' he said, 'is very

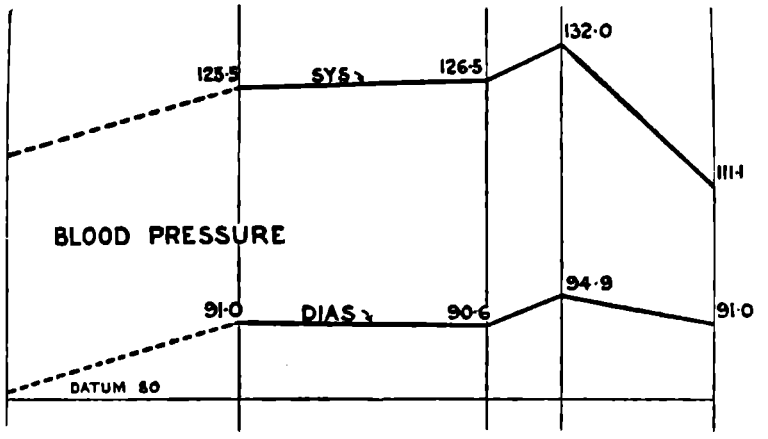
MOUNT EVEREST

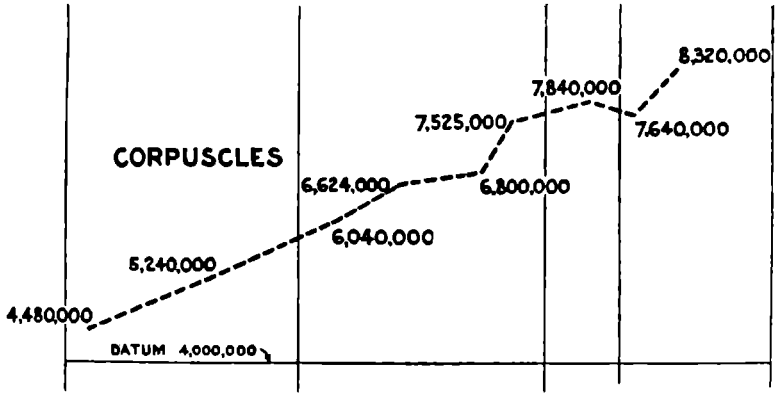
PHYSIOLOGICAL DIAGRAMS BASED UPON

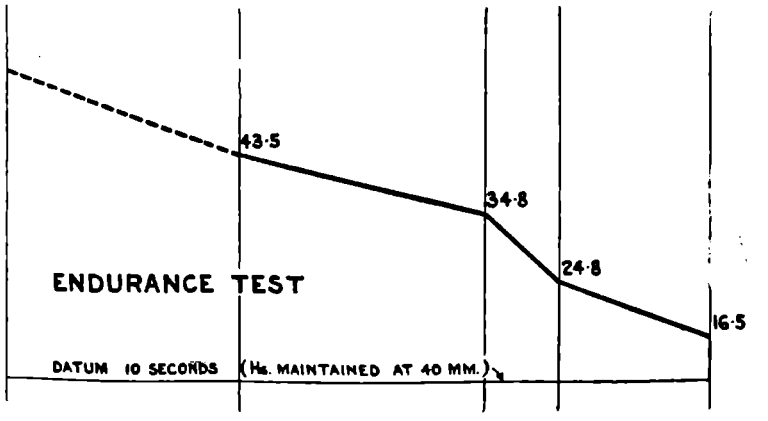


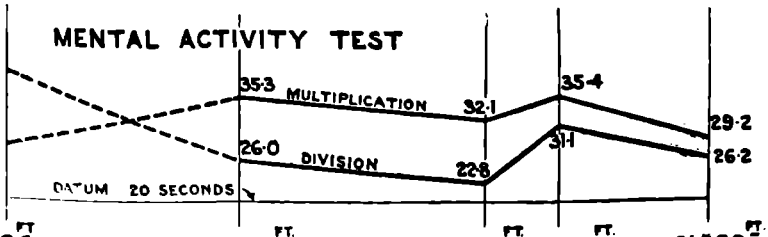
EXPEDITION 1924.

MEDICAL OFFICER'S OBSERVATIONS.









ALTITUDE 0 FT. 7,000 FT. 14,300 FT. 16,500 FT. 21,000 FT.

suggestive. It shows that the strain on the climber is nearly negligible up to 10,000 feet, and at about 15,000 feet becomes appreciable; but one must pass above 20,000 feet before the steepening of the curve indicates that the mountaineer will have to adapt himself carefully to his aerial environment. At 23,000 feet the curve is getting much steeper, and the climber will obviously be put on his mettle above 25,000 feet, for the curve then attains its steepest. Every 1000 feet still higher must mean considerably increased difficulty, and the climber near the summit of Mount Everest will probably be on his last reserves in the way of acclimatization and strength.' This deduction was made before the first assault on Everest, and I think that we can now safely say that our practical experiences bear it out.

I think that climbers will reach the summit of Mount Everest even without the help of oxygen. Though the physiological difficulties are undoubtedly severe, yet they can be overcome. But the condition of the weather must be more favourable than this year. The climbers must be in perfect health and in first-rate training; they must be men of exceptional powers of endurance, and their capacity for acclimatization must be complete.

The diagrams on pp. 36 and 37 show the average effect of all the figures in the tables.

Some Climbs in New Zealand and Notes on Tasmania in 1921.[1]

By Major H. D. MINCHINTON, M.C.

IN 1920, through Mr. Mannering's kind offices, I arranged to join Mr. H. C. Chambers (A.C.) at the Hermitage early in January 1921.

After many contretemps I eventually found myself at Christchurch on January 27. Mr. Mannering was kindness itself, and I know how ardently he desires visits from climbers outside New Zealand. On January 28 I took the train to Timaru, and on 29th went up to the Hermitage, a wonderful 150-mile

[1] See the map in *A.J.* xxix., and Mr. Harper's valuable note, xxxiv. 295, on the maps presented by the Surveyor-General of N.Z.