The PRESIDENT: I am sure that you will be grateful if I now wind up the discussion. My remarks will be very brief. I listened with respect to Prof. Garwood's very luminous summary of the natural forces which have helped to make the Alps. He spoke of the work of the sub-glacial torrents. We have an excellent opportunity of observing that in the glacier that comes down below the Eiger close to the inn on the Little Scheideck. The glacier has retreated about half a mile, and we see in the ground it has abandoned smooth rocks, and in their middle a deep cleft, cut as if with a knife. The Lower Grindelwald glacier affords another excellent example of similar action, where the contrast between the work of ice and water is forcibly shown.

My friend Sir Martin Conway has been pleased to make sundry genial gibes; but I noticed that while he was talking of Hannibal and the Saracens the real point of his remarks was revealed by one word. He talked of the *low* passes I had been describing. Sir Martin Conway is, as we all know, a great mountaineer, and he naturally despises a pass that has not a glacier on the top of it.

Sir Henry Howorth has addressed a challenge to me to which I am thankful to say that I can give an amply sufficient reply. The task of writing the history of the Alpine Passes has been undertaken by the man in Europe who is most competent to do it, and that is Mr. Coolidge. He has begun with an article in the *English Historical Review* on the first Pass, the Col di Tenda. I understand he is going right through the Alps, and if he does the rest with the same marvellous industry and almost profligate detail he has bestowed on his first article, there will be nothing left for future writers to do. I think it would be a grave impertinence for anybody to try to rival him, and it is certainly far from my intention to make the attempt.

There is only one remark made by Sir Henry Howorth which I should like to qualify. There is no doubt that the passes which were used in early times were both the western and the eastern passes. I am quite ready to give precedence, in the number of peoples who went over them, to the eastern, but I believe that most of the Gauls came over the western. If Sir Henry Howorth refers to Livy he will find a very decisive statement that the Gauls came over the western passes. They were able to show Hannibal the way through the Alps, and they would not have been able to do so if they had not been in the habit of traversing them. I thank those who have taken part in this debate for so kindly enlivening our meeting.

A CONSIDERATION OF THE POSSIBILITY OF ASCENDING THE LOFTIER HIMALAYA

A. M. Kellas

Read at the Afternoon Meeting of the Society, 18 *May* 1916.

UNDER certain conditions mountaineering can be regarded as a branch of geographical exploration. Any one doubting this statement has merely to read a recent publication of the Indian Survey, describing the completion of the "Link connecting the Triangulations of India and Russia," to be convinced of its truth.

Surveys involving the triangulation of the great ranges of Asia and America, still far from complete, will require mountaineers to carry them out, using the term "mountaineer" in its truest and widest signification, namely, that mountaineers are those who can ascend and find their way among mountains. If this fact had been grasped when the survey of the Himalaya was begun about seventy years ago, and surveyors specially trained as mountaineers, the maps of the mountain regions would have been more accurate and complete. Amateur geographers will probably, however, find the correction of the present maps of great interest, and the above statement is not intended either as complaint or protest.

Although, fortunately for our surveyors, it is not absolutely necessary to ascend mountains above 25,000 feet in triangulating the Himalaya, still, such ascents would be of scientific importance, and therefore a consideration of the difficulties involved in climbing the loftier summits comes within the purview of this Society. Geodetic problems, such as the exact determination of the effects of refraction on altitude calculations, might be solved, triangles with immense length of side directly measured, physiological problems of considerable interest worked out experimentally, and Science as a whole would undoubtedly benefit. If these reasons were deemed insufficient, one might bring forward the primeval axiom which subconsciously at least is in the soul of every geographical explorer: Man must conquer and investigate every spot on the Earth's surface. If the difficulties are carefully considered the conquest should be peaceful; but Nature in some of her aspects is adamantine, and even the most cautious explorer may suffer.

From the general point of view, the chief difficulties of Himalayan exploration might be summarized as due, firstly, to transport, and, secondly, to intrinsic difficulties of the mountain region.

Transport cannot be discussed in a paper of this type, but a few notes might prove useful. The actual difficulties vary with the region to be explored. As all tents, equipment, foodstuffs, etc., have generally to be carried 100 to 200 miles, the arrangement of carriage, or "bandobast" as it is termed, is of great importance in connection with the success of an expedition, especially if time be limited. All luggage will have to be carried by coolies, if ponies, mules, or yaks are not available, or the route too rough for animals. The experienced traveller will generally use animals for a portion of the journey, if procurable, in order to save time. After reaching the glaciers one has generally to depend upon coolie transport.

Of the different types of coolie, the writer has found the Bhutia Nepalese superior to all others he has employed. They are strong, good-natured if fairly treated, and as they are Buddhists there is no difficulty about special foodstuffs, a point strongly in their favour at high altitudes. The Lepcha and Kumaoni are of inferior physique, but the former makes an excellent coolie. The Kashmiri of the plains were not found reliable on the mountains, which was perhaps hardly to be expected; but the hillmen of North-West Kashmir can be trained, as Collie's account of mountaineering in the Nanga Parbat region shows and the author can confirm. The

Gahrwali is inferior to the Bhutia at high altitudes, because he is a Hindu, and there is far more difficulty with his food supply.

The writer has had no opportunity of travelling with the Gurkha and Balti, who are highly spoken of by those competent to form an opinion. A solitary traveller, anxious to do a little easy climbing, might find it worth his while to take a few carefully selected Bhutia Nepalese with him as personal servants to any mountain region. They can be engaged at Darjeeling.

The first difficulties in the mountain region would be among the glaciers leading to the peaks to be attempted. The Himalayan glaciers may be divided into two main types: (*a*) Great moraine-covered ice-streams, like the Zemu and Kangchenjunga Glaciers, with ice-cliffs and small tarns. The ice-cliffs have resulted from the opening out of the crevasses. The great glaciers of the Mount Everest region seem to be of this type, as the slide showing the north-east Chomo Langmo Glacier indicates. This glacier seems to be covered with limestone *débris*, which is of great geological interest. These glaciers are troublesome, but offer no serious difficulties with regard to transport. Roping is unnecessary. (*b*) The tributaries of this type, and sometimes their upper portions, are like the ordinary Alpine glaciers, and crevasses, icefalls, etc., are often difficult and dangerous for loaded coolies. Before the monsoon snows set in seriously one has to be particularly careful. Coolies often dislike roping, and may shirk it if not carefully looked after. A case in point, where a fatal accident nearly occurred, was emphasized in an earlier paper in the *Alpine Journal.*

After these preliminary notes, we now come to the consideration of the possibility of ascending the loftier peaks of the Himalaya, mountains over 25,000 feet in altitude, none of which have so far been climbed. We will consider the limiting case as a rule, and the problem might be stated as follows:—

Could a man in first-rate training ascend to the summit of Mount Everest (Tibetan Chomo Langmo), 29,141 feet above sea-level, without adventitious aids?

Colonel Burrard's corrected values are used for the loftier peaks, as 140 feet might require at very high altitudes an hour's climbing, which could easily mean the difference between success and failure.

The difficulties of ascending the higher Himalaya must be considered from two points of view: I. Physiological; II. Physical.

I. Physiological Difficulties.

The physiological difficulties are indubitably of a very high order, and depend upon deficiency of oxygen. The supply of oxygen varies directly with the barometric pressure. At sea-level the pressure of the atmosphere is balanced by a column of mercury 760 millimetres high, but at the top of Mount Everest the barometric pressure would be about 250 mm., and the oxygen supply would therefore be only one-third of that at sea-level.

KANGCHENJUNGA FROM A DISTANCE OF 9 MILES AT A HEIGHT OF 18,000 FEET ON A SOUTHERN SPUR OF THE JONGSONG PEAK, NEPAL

KAMET FROM NEAR THE SUMMIT OF DHANARAU MOUNTAIN, GARHWAL (18,500 FEET), EIGHT MILES TO THE NORTH-WEST

The body is kept alive by the process of respiration, during which oxygen taken up by the blood from the air in the ultimate ramifications of the lungs—the alveoli—passes with the blood to the tissues, effecting oxidation processes necessary during maintenance of life. Carbon dioxide is formed, and being transported by the blood to the lungs is exhaled.

How absolutely fundamental respiration is in maintaining life may be grasped when it is stated that unconsciousness would ensue in about three-quarters of a minute if an indifferent gas like pure nitrogen is breathed, the body being at rest. Death would follow in a few minutes unless oxygen were supplied.

One has to consider whether respiration near the summit of Mount Everest under about one-third of an atmosphere pressure will suffice to aërate the blood not only at rest, but while climbing. The problem might be attacked by the four following methods :—

I. By consideration of the physiological effects recorded during high balloon ascents.

II. By consideration of the results obtained in air-chambers at sub-atmospheric oxygen pressures.

III. By evaluation of observations and experiments of physiologists at sea-level and moderate altitudes—up to 15,000 feet.

IV. By consideration of the effects of minor Himalayan ascents up to the highest recorded, viz. 24,600 feet.

Space permits only of a consideration of the first three methods, as the fourth would involve a discussion of mountain sickness and the limits of acclimatization to high altitudes.

I. *Balloon Ascents.*—From our point of view two are of special importance, namely, that of Glaisher and Coxwell from Wolverhampton in 1862, and that of Tissandier and two companions (Crocé-Spinelli and Sivel) from Paris in 1875.

In Glaisher and Coxwell's ascent at 29,000 feet both men became paralyzed, and then Glaisher became insensible. Coxwell, unable to raise his hands, seized the valve-rope in his teeth, managing to open the valve before he in turn lost consciousness. Fortunately Coxwell's action gradually stopped the ascent of the balloon, thus undoubtedly saving their lives. Glaisher claimed that the balloon rose to 37,000 feet before beginning to descend. If so this would constitute a record ascent; but the estimation of height seems of doubtful accuracy.

Tissandier's ascent to 27,950 feet was not so fortunate. Although provided with oxygen the three men were paralyzed before they could raise the tubes of the oxygen reservoirs to their lips. Tissandier fainted at an altitude of 26,500 feet (approx.), and when he recovered consciousness his two companions were dead and the balloon was rapidly descending.

The conclusion from these balloon ascents must inevitably be that an ascent of Mount Everest without adventitious aids would be quite impossible if the physiological conditions of mountaineers and balloonists are comparable. They are not comparable, however, as the balloonist has no opportunity of becoming acclimatized to high altitudes. As will be shown later, this fact is of fundamental importance.

In many more recent balloon ascents oxygen has been used with success. In 1898 Berson and Spencer ascended from London to 27,500 feet, and in 1901 Berson and Süring ascended from Berlin to about 35,500 feet, an actual barometric reading corresponding to 34,500 feet being made before both men, notwithstanding oxygen inhalations, became unconscious.

These ascents showed that oxygen was an immense help at high altitudes, and might suggest that the ascent of Mount Everest would be possible if air enriched with oxygen were breathed during the latter portion of the climb.

II. *Experiments in Air Chambers.*—Considering pressure alone it might at the outset be stated that considerable variations of pressure, *e.g.* increase up to four atmospheres pressure or diminution to a pressure of a fourth of an atmosphere hardly affect the body. Provided decompression is slow, one might say that moderate variations of pressure are innocuous. It is alteration of the available amount of oxygen which affects the body, and this alone need be considered. Two types of experiments are worth studying.

1. Experiments in which the oxygen percentage in the air breathed was *slowly* reduced. Rapid variations need not be discussed as they are inapplicable.

2. Experiments in which the pressure of the air breathed was diminished.

Both yield similar results.

1. *Slow Alteration of Percentage of Oxygen in the Air breathed.*—When the percentage of oxygen in the inspired air is slowly reduced below 20·96 per cent., the proportion present in air at sea-level, no effect is produced until the percentage is 12 to 14, and then the breathing becomes deeper (*i.e.* more air is taken into the lungs than normal), and at 10 per cent. cyanosis is evident, the lips, ears, etc., being blue. Haldane states that "marked symptoms of mental incapacity are also present. Simple observations or calculations become impossible." Consciousness is generally lost without a struggle when the percentage of oxygen in the air breathed falls to between 10 and 7 per cent.

2. Experiments in air-chambers where the atmospheric pressure was diminished gave exactly similar results. Mosso, for example, lowered the pressure in an air-chamber to 310 mm., corresponding to 24,500 feet at 15° C. "His mental faculties became blunted, he experienced difficulty in reading his watch, was twice unable to count his pulse, his handwriting altered and his memory weakened."

In considering the results of experiments in air-chambers Starling states that the lowest limit at which life is possible corresponds to an oxygen tension in the alveoli of 27 to 30 mm., which is distinctly above that calculated for Mount Everest.

It follows, therefore, from experiments in air-chambers that the ascent of Mount Everest should be quite impossible without adventitious aids, agreeing with the observations of balloonists. Again however the conditions are not comparable, since the subject in an air chamber cannot become acclimatized to low oxygen pressures, whereas the mountaineer can.

Mixing oxygen with the air in the chamber gives significantly a different result. In air enriched with oxygen Paul Bert withstood successfully a pressure of 240 mm., which corresponds to nearly 32,000 feet. The best results were obtained with a mixture of oxygen and carbon dioxide. Aggazotti actually breathed such a mixture at a pressure of 120 mm. for some time. This pressure corresponds to approximately 50,000 feet above sea-level.

These experiments prove conclusively that air enriched with oxygen would easily maintain life during rest or moderate work at the summit of Mount Everest, where the pressure is, approximately, one-third of an atmosphere.

III. *Consideration of Observations and Experiments of Physiologists at Sea-level and Moderate Altitudes up to* 15,000 *feet.*—The work done by Haldane and by Barcroft and their respective coadjutors is of special importance. A very interesting series of observations on the incidence of mountain sickness was made by Haldane and his co-workers on the summit of Pike's Peak, Colorado, in 1911. Pike's Peak is one of the eastern Rocky Mountains near Denver, which has a cogwheel railway to its summit (14,109 feet), upon which there is a small hotel. The following notes on the effect of change of altitude on the visitors to the summit show that mountain sickness was of very frequent occurrence.

"Among the numerous visitors who came up by train and stayed only about three-quarters of an hour, the most marked and almost universal symptom was blueness of the lips, cheeks, etc., accompanied by great hyperpnœa (*i.e.* deep breathing) on exertion. As a rule there was no marked discomfort, but some persons became very miserable and faint, and actual fainting was observed occasionally, as well as vomiting. One press representative who came to 'interview' us became so alarmingly blue and faint that we gave him oxygen, which revived him at once, and immediately restored his colour and spirits. He continued all right for a few minutes, and then again became blue and faint, and was again revived by oxygen, after which he hurried into a descending train.

"Among those who walked up or came on donkeys, the symptoms were much more general and severe. The blueness was more marked, and nausea, vomiting, headache, and fainting were extremely common. Many persons walked or rode up during the night to see the sunrise, 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." And this occurred at 14,100 feet!

The description suggests that if any of the Himalayan giants in the far future are desecrated by a cogwheel railway, oxygen will have to be breathed continuously by the patrons when near the summit, otherwise none will get down alive. This may be a consolatory thought to some minds.

Haldane's party suffered somewhat on first arrival, but after a few days on the summit, blueness, headache, nausea, and lack of appetite vanished, and in about a week all felt quite well physically and mentally. With regard to the mental effect, it must be noted, however, that the brain seems particularly sensitive to a deficiency of oxygen. Many visitors were inclined to be unreasonable, the symptoms being similar to those of alcoholic poisoning, and a deputy-sheriff is therefore stationed at Summit House during the summer.

This psychic effect is apparently not confined to those unacclimatized to altitude. Miss Fitzgerald, one of Haldane's collaborators, who independently carried out observations at many high mining camps in Colorado, states that the nervousness of the people, both men and women, was very apparent, especially above 7000 feet, and adds: "The miners and others were fully conscious of the nervous tension, and attributed to this impulsive actions mentioned as common in mining communities at these altitudes." It might follow that some of the regrettable incidents with revolvers in the old days might belong to this category, but statistics and more extended observations are required. The Tibetans do not seem to be affected with nervousness.

The above account shows that mountain sickness is apparently something very real in the case of people unacclimatized to high altitudes when pressure is rapidly varied. In the Alps one rarely notices serious cases because of adaptation, and in the Himalaya, where as a rule the ascent to 15,000 feet is gradual and requires at least a week's travel, mountain sickness is exceptional even at high altitudes.

Paul Bert indicated, in 1878, that the cause of such mountain sickness was simply want of oxygen. He carried out numerous experiments with men and animals under different pressures, and using various mixtures of oxygen, nitrogen, and other gases. He showed that symptoms similar to mountain sickness were produced when the oxygen partial pressure of the mixture fell below a certain value. Bert's explanation has been challenged. Mosso maintained that many symptoms of mountain sickness depended on deficiency of carbon dioxide, which he termed "acapnia," and Kronecker suggested mechanical reasons. Recent experiments of Zuntz, Haldane, Barcroft, and their co-workers have clearly indicated that Bert was correct, and one might therefore state that *mountain sickness depends primarily upon deficient oxygen supply*. There may be many accessory factors, but the fundamental cause underlying all is *want of oxygen*.

As already stated, Haldane's party on Pike's Peak (14,109 feet) became completely acclimatized after about a week's residence on the summit, and the problem which really has to be solved in connection with Mount Everest might now be stated as follows: Is it possible to become sufficiently acclimatized to altitudes of 24,000 feet to 25,000 feet to enable one to climb to over 29,000 feet? This question can only be answered after a careful study of the scientific explanation of acclimatization to moderate altitudes which has been worked out by Barcroft and Haldane and their respective co-workers.

In order to be able to understand this explanation, one must, as a preliminary, study more closely what takes place during respiration. The process of respiration includes the formation of a compound of oxygen and hæmoglobin called oxy-hæmoglobin, which, being carried to the tissues, gives up its oxygen, thus maintaining life, which as previously mentioned depends on the continuity of a series of slow oxidation reactions. The two processes mentioned might be represented as a reversible chemical equation—

$$Hb + O_2 \rightleftarrows HbO_2$$

In the lungs, under an oxygen pressure which varies with the altitude, oxy-hæmoglobin is formed, and in the tissues, where the oxygen pressure is less, oxygen is given up to oxidizable substances.

It is obvious that a study of the pressure conditions under which hæmoglobin respectively takes up and gives off oxygen, might help one to understand the physiological difficulties of respiration at high altitudes.

Experiments were carried out by Hüfner with *hæmoglobin dissolved in water* at blood temperature (37° C.) and a varying pressure of oxygen, with the following result:—

TABLE I.

Pressure of oxygen in millimetres of mercury.	Percentage saturation of the hæmoglobin with oxygen.
10	50
20	71
30	81
40	87
50	90
60	92
70	93
80	94-5
90	95
100	96

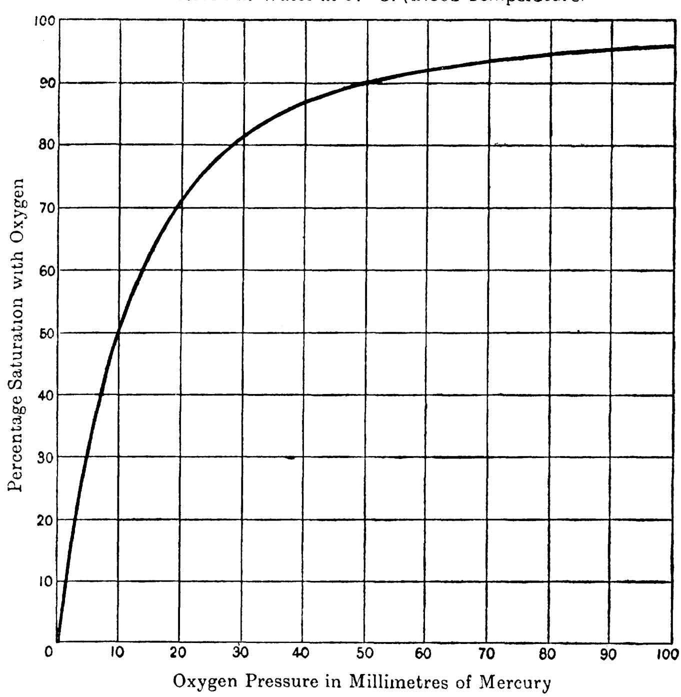
To enable these values to be thoroughly understood, consider one pressure, *e.g.* 50 mm. If a large quantity of air containing oxygen of partial pressure 50 mm. is shaken with a small quantity of hæmoglobin dissolved in water, the hæmoglobin rapidly takes up oxygen until 90 per cent.

is saturated, *i.e.* there must be in the water 90 per cent. oxy-hæmoglobin and 10 per cent. hæmoglobin. If the oxygen pressure is increased, more oxygen will be taken up; but if diminished, oxygen is given up, *e.g.* if the pressure of the oxygen were diminished to 10 mm., oxygen would be given up until 50 per cent. of the hæmoglobin remained as oxy-hæmoglobin.

The connection between the hæmoglobin in water and the oxygen pressure is best represented, not by the above set of figures, but by a curve which shows graphically the relationship between the two inter-related qualities.

Plotting the pressure of oxygen in millimetres of mercury horizontally (along the abscissa) and the percentage saturation of hæmoglobin in water vertically (along the ordinate), one obtains what is termed the ***dissociation curve of oxy-hæmoglobin in water.***

CURVE No. 1.
Dissociation Curve of Oxy-Hæmoglobin dissolved in Water at 37° C. (Blood Temperature)



This dissociation curve, worked out by Hüfner, somewhat puzzled physiologists, because even at comparatively low pressures the hæmoglobin is nearly saturated with oxygen. For example, the alveolar oxygen pressure in the lungs at the top of Mont Blanc (15,780 feet) should be nearly 50 mm., corresponding to 90 per cent. saturation, and at sea-level the oxygen pressure is about 100 mm., corresponding to a saturation of 96.

The trifling difference of 6 per cent. in saturation for an alteration of altitude of nearly 16,000 feet should not cause serious effects, and Bert's explanation that oxygen deficiency was the exciting cause of mountain sickness seemed unintelligible.

The difference was explained when it was discovered that the dissociation curve of hæmoglobin in blood is quite different from that of hæmoglobin in water. Many factors affect the action of oxygen on hæmoglobin, notably, (1) temperature, (2) presence of carbon dioxide (an acidic body), (3) presence of other acidic bodies like lactic acid, (4) presence of salts.

With regard to temperature, it is obviously only profitable to consider one temperature, viz. 37° C. (99° F.), the normal blood temperature.

The substances mentioned, carbon dioxide, other acidic substances, and salts are present in blood, and tend to flatten the dissociation curve of hæmoglobin. The normal dissociation curve of hæmoglobin in blood can be drawn from the following experimental data, the pressure of CO_2 being taken as 40 mm., the normal pressure at sea-level.

TABLE II.

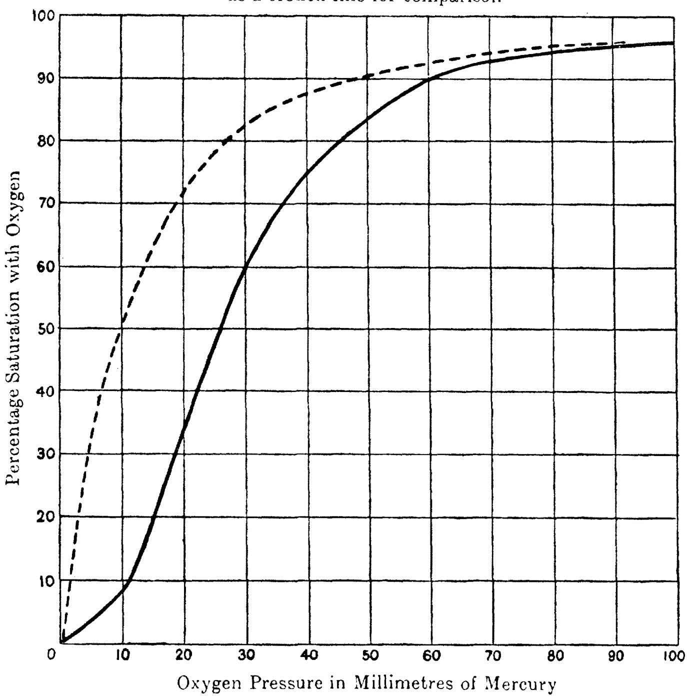
Oxygen pressure in millimetres of mercury.	Percentage saturation of hæmoglobin in blood with oxygen.
10	10
20	32
30	57
40	74
50	84
60	90
70	92
80	93·5
90	95
100	96

These results can be expressed by a curve, the *dissociation curve of hæmoglobin in blood.* (See next page.)

This normal dissociation curve for hæmoglobin in blood is, as already remarked, flatter than that for hæmoglobin in water, with the result that the hæmoglobin is less saturated for any given pressure of oxygen. For example, the saturation of hæmoglobin in water with oxygen at 24 mm. oxygen pressure—the calculated approximate alveolar pressure for the top of Mount Everest—would be 74 per cent., whereas the saturation of hæmoglobin in blood with oxygen at the same pressure would be only about 40 per cent.

One of the main factors causing flattening of the dissociation curve is carbon dioxide, and as the quantity of this substance in blood considerably diminishes with altitude, one might suppose that the curve would steepen, and that the blood hæmoglobin would therefore be more easily saturated with oxygen. Barcroft, however, proved by experiments carried out on the peak of Teneriffe, that although the carbon dioxide in the blood diminishes with altitude, yet the resting dissociation curve for any individual was identical with his curve at sea-level.

CURVE No. 2.
Dissociation Curve of Oxy-Hæmoglobin in Blood at 37° C. (Blood Temperature)
The Dissociation Curve of Oxy-Hæmoglobin in Water is given as a broken line for comparison



This surprising fact was confirmed by Haldane on Pike's Peak, and the explanation was found by Barcroft to depend upon an increased acidity (or rather diminished alkalinity) of the blood in such quantity as to exactly compensate for the loss of carbon dioxide, which itself is acidic in character.

This relationship between carbon dioxide and blood acidity (or diminished alkalinity) is of far more vital importance than might at first sight appear. *The automatic regulation of the process of respiration* at sea-level depends upon the quantity of carbon dioxide in the blood, the pressure of which is the same as that in the alveoli of the lungs. The carbon dioxide in the blood effects the regulation by acting directly on a nerve-tract called the "respiratory centre" in the medulla oblongata, nerves from which control the muscles of respiration. Normally, about eighteen respirations occur in a minute with the body quiescent. If work is done, more carbon dioxide is produced, the respiratory centre is more powerfully stimulated, and one breathes more deeply and rapidly, thus supplying that necessary extra oxygen to the tissues.

If, while at rest, one breathes rapidly for about a minute—forced breathing—so as to wash the carbon dioxide out of the blood, the respiratory centre ceases to be stimulated, and breathing stops until sufficient carbon dioxide is formed to act as excitant.

At high altitudes, as mentioned, the quantity of carbon dioxide in the blood diminishes, but the acidity increases correspondingly. This acidity acts on the respiratory centre in the same way as carbon dioxide.

It follows from above that there seems to be less danger than might have been expected of a cessation of respiration on breathing rapidly for some time at high altitudes. Even if all the carbon dioxide were washed out of the blood, the respiratory centre might still be sufficiently stimulated by the increased acidity of the blood circulating through it. This is of primary importance, as the following example will show.

If a subject in an air-chamber were decompressed to 370 mm., correspondlng to 20,000 feet, his oxygen supply would be diminished to less than half. Suppose he then carried out forced breathing so as to try to get a larger quantity of oxygen through his lungs per minute than at sea-level, he would quickly wash the carbon dioxide out of his blood, the respiratory centre would cease to be excited, he would stop breathing, and would probably faint because of deficient oxygen supply to the brain.

Were it not for the increased acidosis of the blood after acclimatization to high altitudes, the danger of fainting after rapid breathing during climbing might be a most serious one for the mountaineer. A climber fainting above 25,000 feet would obviously be in grave danger.

We are now in a position to grasp the significance of the different factors conditioning true acclimatization to moderate altitudes.

These factors are four in number, and might be briefly discussed in the following order. The third factor is at present debateable :—

1. The oxygen pressure in the alveolar air rises.
2. The number of red blood-corpuscles and the quantity of hæmoglobin in the blood increase in due proportion to each other.
3. There may be actual secretion of oxygen by the lung epithelium, so that the arterial oxygen pressure can be raised above that in the alveoli.
4. The blood stream may circulate more rapidly during exercise at high altitudes than at sea-level.

1. *Increase of Oxygen Pressure in the Alveolar Air.*—The increase of pressure of oxygen is brought about by a diminution of the alkalinity of the blood, which means that its carrying power for carbon dioxide diminishes. On staying for a few days at a moderate elevation the pressure of the alveolar carbon dioxide diminishes in accord with this

diminished carrying capacity, and as the partial pressure of carbon dioxide sinks that of oxygen rises. The respiratory centre remains adequately stimulated because of the increased acidity of the blood, The gain of alveolar oxygen pressure is considerable, as shown by the following table:—

TABLE III.

	Alveolar pressure of oxygen.	
	Calculated for 40 mm. CO_2 as at sea-level.	Observed.
Sea-level	102 (approx.)	102
10,000 feet	59	65
15,000 feet	38	52

Considering the calculated and observed pressures at 15,000 feet, one notes the great advantage of the extra 14 mm. pressure of oxygen. On referring to the dissociation curve of hæmoglobin in blood one sees that at 52 mm. oxygen pressure the blood would be about 80 per cent. saturated with oxygen, whereas at 38 mm. pressure it would only be about 65 per cent. saturated.

As stated, this adaptation to altitude may take a few days to develop, so that any one ascending quickly from sea-level to 15,000 feet is physiologically at a great disadvantage, as his carbon dioxide alveolar pressure will be nearly the same as at sea-level (40 mm.), and his oxygen pressure about 38 mm. This factor is obviously of considerable importance in connection with adaptation on the higher Himalaya, and a table will be given later to show the relationship between altitude and calculated alveolar oxygen pressure after acclimatization.

2. *Increase of Red Corpuscles and Hæmoglobin.*—It is generally stated that an increase in the number of red corpuscles and hæmoglobin occurs at high altitudes, but the exact value of this multiplication is not so simply gauged as has been supposed, and much more work must be carried out before its exact significance is understood. The normal number of red corpuscles for man is about 5,000,000 per cubic millimetre at sea-level, and values up to over 8,000,000 have been recorded at different altitudes. A few typical determinations might be quoted:—

TABLE IV.

	Metres.	Feet.	Red corpuscles.
Sea-level	0	0	5,000,000 (approx.)
Zurich	412	1,352	5,752,000
Davos Platz ...	1560	5,118	6,551,000
Pike's Peak	4300	14,109	7,000,000 (approx.)
Andes	4392	14,410	8,000,000
Taghdumbash Pamir	5548	18,203	8,320,000

These values seem easy of interpretation. To use a simile of Barcroft's, the number of " ships " available for carrying their precious cargo of oxygen to the tissues is increased, more oxygen cargoes will therefore be despatched in a given time from the lungs, and this may compensate for a diminution in weight of each freight carried.

If, however, the number of corpuscles increases quickly simultaneously with a rapid alteration in altitude, it is almost certain that the blood merely concentrates itself by transudation of part of its plasma (in which the corpuscles float) through the capillaries; this would of course mean an increase in the number of corpuscles per cubic millimetre.

In 1908 the writer carried out a series of experiments in London and Silvaplana which seemed suggestive. His average corpuscular value in London was approx. 5,400,000. During the journey of about thirty hours' duration (which meant rail to St. Moritz and then drive of 4 miles) his red corpuscular value rose to approx. 6,200,000, *i.e.* there was an increase of about 800,000 corpuscles per cubic mm. during a rise of about 6000 feet. One would imagine that it would be difficult to devise anything less stimulating to the corpuscle-manufacturing mechanism than a long railway journey, so that most probably concentration of the blood occurred. The same phenomenon has been observed by other observers and balloonists.

In the case of Haldane's party on Pike's Peak the results for different individuals varied greatly, but there was a distinct gradual increase in each case. The variation was from 115 to 154, taking 100 as normal hæmoglobin value for sea-level.

It is assumed that this slow increase probably represents abnormal production of new corpuscles, or slower destruction of old corpuscles than usual.

Some observers regard this alteration of corpuscular and hæmoglobin value as the chief adaptation to high altitudes, and it is undoubtedly important. Hingston, who was engaged in survey work on the Pamir ranges, states that a carrier of his who seemed inadaptable to high altitudes had a blood count of only 5,760,000 at 13,300 feet, whereas the rest of the party had a value of about 7,000,000. It is worth noting in this connection, however, that two of Haldane's party during nearly a month on Pike's Peak (14,109 feet) had lower average values than that which Hingston considered inadequate, namely, 5,530,000 and 5,240,000 respectively, although both were in excellent health. It is just worth mentioning also that the author at a camp at 20,000 feet had a blood count of only 6,500,000, and on ascending Pawhunri (23,180 feet) and again taking his blood count a few hours after return to this camp it was only 7,200,000. Probably diet and exercise may affect matters, and more work must be carried out.

Some physiologists have asserted that it would be impossible to carry out accurate blood-corpuscle estimations at high altitudes, and this is of interest in connection with the psychic adaptation to the loftier Himalaya. One physiologist put the matter as follows :—

"During two successive years, Mr. Dent, Dr. Slater, and myself studied this question of polycythæmia in the Alps. We are of opinion that the counting of blood-corpuscles at high levels requires an amount of attention which no one can give when at a level of anything over 10,000 feet. Sustained mental work is out of the question at this level, and is performed with difficulty in Europe at a level of even 6000 feet. This statement we are certain would be confirmed by those who have experienced the cold and discomfort, together with the nausea and other slight symptoms of 'mal de montagne' which affects most people in some degree."

This is merely quoted to show that even first-rate observers may be misled by want of acclimatization. Probably blood counts could be made at upwards of 23,000 feet by one acclimatized to high altitudes. There was certainly no serious physiological difficulty involved in carrying out determinations at 20,000 feet, with the exception of overcoming the very distinct disinclination for serious mental work which attacks all above 18,000 feet, due to the mountain lassitude of high altitudes. This agrees with the report of Haldane's party, which states that after a few days at 14,100 feet "mental work seemed quite as easy as at sea-level."

3. *Secretion of Oxygen by the Alveolar Epithelium.*—Two theories have been proposed to explain the passage of oxygen from the alveoli of the lungs to the blood through the epithelium and capillary walls. One theory supposes that the physical process of diffusion is sufficient to explain the transference, but the other postulates that under certain conditions, *e.g.* high altitudes, the cells of the lung epithelium secrete oxygen from the alveoli and pass it on to the blood in the capillaries. According to the first theory the oxygen pressure in the alveoli would always be greater than the arterial oxygen pressures; but according to the second the arterial oxygen pressure might be higher or lower than the alveolar.

Haldane's party on Pike's Peak found that the arterial oxygen pressure in acclimatized subjects was invariably far greater than the alveolar pressure (35 mm. above or more), whereas in new-comers it was about the same, and they regard the secretory action of the lung epithelium to be one of the most important means of adaptation to high altitudes. If secretion actually occurs, then the value of the process to the climber might be very great; but Krogh and other physiologists oppose the theory, so that further confirmation is required.

This problem of oxygen diffusion and secretion is intimately bound up with the quantity of oxygen required by the body per minute at rest and during exercise. The results of different observers vary somewhat, but one may assume that the body requires during rest a volume of 230 to 270 c.c. measured at 0° C. and 760 mm. pressure, during moderate work 1200 to 2000 c.c., and during hard work 2500 to 3500 c.c. of oxygen per minute.

The following results of experiments made by Zuntz indicates the relationship between the oxygen required at sea-level and on Monte Rosa during rest and doing easy work on a glacier.

TABLE V.

	Oxygen required per minute.
Sea-level at rest, fasting	233 cub. c.
Monte Rosa do.	260 ,,
Ascending glacier on Monte Rosa ...	1329 ,,

Assuming that the quantity of oxygen required per minute during slow climbing near the top of Mount Everest was from about 1200 to 1500 c.c. per minute (a moderate computation), the question arises as to whether this quantity of oxygen could diffuse at the low alveolar pressure of 24 mm. Haldane and Barcroft seem to consider it impossible, but Krogh would say that it could diffuse. As the volume of a gas varies inversely with its pressure, the actual volume of oxygen measured at the barometric pressure of the top of Mount Everest which would have to diffuse would be about $1500 \times 3 = 4500$ c.c.

If only 1000 c.c. (measured 0° C. and 760 mm.) could pass the dividing septum, then the rate of climbing would be very slow; and if only 750 c.c. were available the rate of climbing might be less than 300 feet per hour.

In this connection one must point out that the actual quantity of oxygen used in doing efficient work depends on the training of the individual. The trained man requires far less oxygen than the untrained during an ascent because his muscular co-ordinations are arranged for maximum economy. Hueppe worked out a series of determinations, using town dwellers and an Alpine porter as subjects, with the result that the efficiency of the porter as regards work performed was about 100 per cent. above that of the untrained man.

4. *More Rapid Circulation of the Blood at High Altitudes during Moderate Exercise.*—After acclimatization on Pike's Peak the pulse rate at rest was only slightly raised in the case of three observers, and was actually diminished in the fourth case. On moderate exercise the pulse rate rose to a much greater extent than at sea-level. This would be beneficial.

General Conclusions from Physiological Data.—There is no doubt that (*a*) the rise of alveolar oxygen pressure, (*b*) the diminution in the alveolar carbon dioxide pressure, and corresponding increase in acidity of the blood, and (*c*) the increase in the quantity of hæmoglobin and red corpuscles are of great value in promoting acclimatization. If confirmed the secretion of oxygen by the lung epithelium will doubtless be further studied and might yield useful information.

As indicated above, however, much more work must be done at high altitudes before exact evaluation of the different factors conditioning acclimatization can be made.

One might, however, work out the essentials of the problem under consideration in another way. If one could determine the relative strain under which the body has to undergo adaptation at different altitudes, the approximate difficulties in connection with an advance above 25,000 feet can be computed. The strain can be gauged by considering the relative capacities for saturation of the blood at different heights under the respective alveolar pressures which would obtain after acclimatization. These can be probably calculated within 2 or 3 mm. from a curve for the variation of carbon dioxide with altitude worked out by Miss Fitzgerald, and are given in the following table for a few well-known mountains:—

TABLE VI.

	Height.		Barometric pressure. 0° C.	15° C.	Alveolar Oxygen press.
	Feet.	Metres.	Mm.	Mm.	Mm.
Mount Everest	29,141	8882	251·0	266·9	23·6
Kangchenjunga	28,225	8603	259·9	275·8	25·0
Nanga Parbat	26,620	8114	276·3	292·2	27·8
Kamet	25,447	7756	288·9	304·7	29·4
Aconcagua	23,080	7035	316·1	331·8	33·5
Mount McKinley and Jonsong La	20,300	6187	351·3	366·6	39·2
Kilimanjaro	19,321	5889	364·7	379·7	41·2
Mount Elbruz	18,465	5628	376·4	391·2	43·3
Mont Blanc	15,785	4811	417·2	431·0	49·5
Aorangi (Mount Cook) ...	12,349	3764	475·3	487·8	58·9
Gorner Grat	10,290	3136	514·0	524·0	65·0
Mount Kosciusco ...	7,328	2236	575·0	584·0	73·5
Rigi	5,905	1800	606·0	613·0	78·4
Ben Nevis	4,406	1343	642·0	649·0	83·6
Scafell Pike	3,210	978·4	673·0	677·0	88·7
Sea-level	0	0	760·0	760·0	102·5

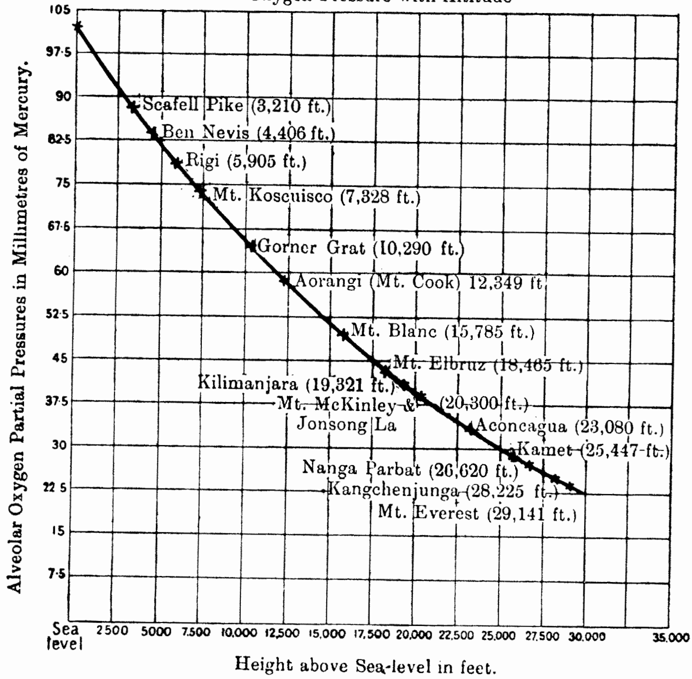
This table shows that while the oxygen in the atmosphere diminishes to one-third at the top of Mount Everest, the available oxygen, as indicated by the alveolar oxygen pressure (23·6 mm.), diminishes to less than a fourth of that at sea-level (102·5 mm. approx.). This, of course, tells heavily against the climber. The relationship of altitude to alveolar oxygen pressure is clearly seen in curve No. 3.

The relative capabilities of the different alveolar oxygen pressures at the heights mentioned to saturate the blood is well indicated by plotting the heights of the mountains on the dissociation curve of oxy-hæmoglobin in blood already given. (Curve 4.)

This curve is very 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 indicated that the mountaineer will have to adapt himself carefully to his aërial environment. At 23,000 feet the curve is getting much steeper,

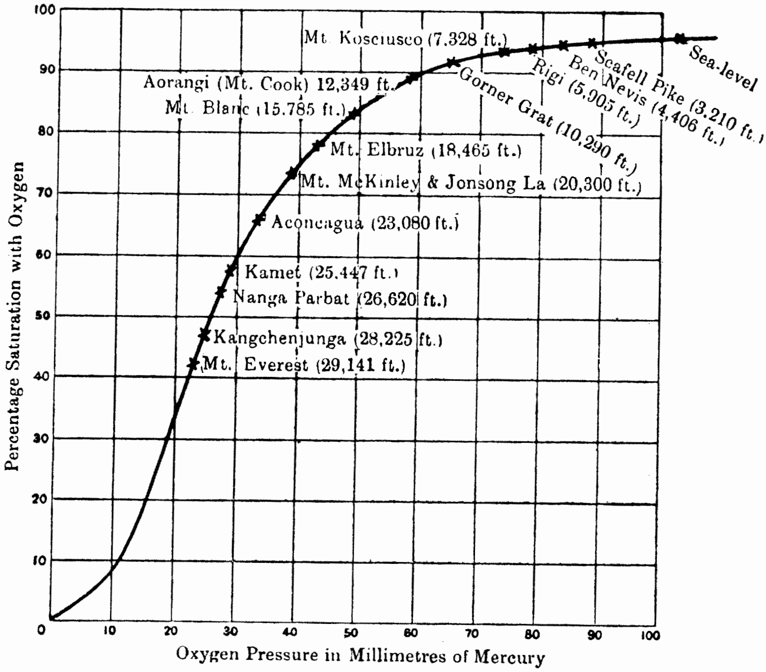
CURVE No. 3.

Curve showing the variation of Alveolar Oxygen Pressure with Altitude



CURVE No. 4.

Dissociation Curve of Oxy-Hæmoglobin in Blood with the heights of a few notable mountains plotted so as to show the saturation of the Blood with Oxygen corresponding to the alveolar oxygen pressures at their summits.



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.

Before drawing final conclusions from all the data summarized above the physical difficulties must be discussed. The mountaineering obstacles are usually of considerable magnitude, and in a few cases seem insuperable, but there are notable exceptions.

II. Physical Difficulties.

The physical obstructions might be classed as those due first of all to weather conditions, and secondly to the intrinsic rock and snow difficulties of the mountains.

Himalayan Weather.—The weather among the southern Himalayan ranges is notoriously bad during the monsoon, which may extend from the middle of June to the middle of September, that is to say, during practically the whole summer, but further north towards the Tibetan border may be much ameliorated owing to the intervening ranges precipitating the aqueous vapour. Above 20,000 feet on the southern ranges there is usually a fall of snow every day.

Mount Everest (29,141 feet) and Kangchenjunga (28,295 feet) would hardly be accessible during the monsoon, but could probably be attempted during the latter half of April, May, and the first half of June. The latter half of September and the first half of October would also be a good time for ascents.

The wind is a weather factor which may be of great moment to the climber. If not too strong and of moderate temperature—not much below 0° C.—it is helpful in raising the alveolar oxygen pressure as already mentioned.

A point of considerable interest, which does not seem to have been mentioned before, is that the strength of the wind for any given velocity is greatly diminished above 20,000 feet, as one might expect from the general equation for kinetic energy of moving bodies, $f = \frac{1}{2} mv^2$, that is, the force or kinetic energy of the moving body is equal to half its mass multiplied by the square of its velocity. It follows from this that the lifting or striking power of a tornado of 100 miles an hour would be reduced by 66·7 per cent. at the top of Mount Everest.

The writer has repeatedly had occasion to observe this difference of wind pressures. On the Grampians, when the wind roars past one's ears at a velocity of about 70 or 80 miles an hour, one finds great difficulty in pushing against it. Above 20,000 feet one has frequently found it comparatively easy to force one's way forward against a wind of nearly similar velocity. To gauge the velocity is difficult, but the general statement is certainly correct.

There is, however, one serious difficulty in connection with wind, namely, the low temperature sometimes met with. An intensely cold north or north-east wind might drive one down to avoid frostbite of hands and feet.

The snow and rock difficulties vary greatly, and might be best illustrated by consideration of the possibility of ascent of a few of the chief peaks, but space unfortunately only allows of a few brief notes.

Many of the most magnificent mountains of all present such physical difficulties that climbers will probably await attacking them until the effects of altitude are better understood. K_2 (28,253 feet), Makalu (27,790 feet), the Gasherbrum Peaks (I. 26,470 feet, II. 26,360 feet, III. 26,090 feet, IV. 26,000 feet), the Masherbrum Mountains (E. 25,660 feet, W. 25,610 feet), Nanda Devi (25,645 feet), Rakaposhi (25,550 feet), Boiohagurdoanasur or Hurza Kunzi (I. 25,370 feet, II. 25,118 feet, III. 25,050 feet), and Jannu or Jano (25,294 feet) are all difficult.

Many of these peaks seem impervious to direct assault, and if on close investigation that were found to be the case, they may be attacked in some future decade by aeroplane or airship. They will certainly be ascended. At present climbing by airship would probably be regarded as an unwarranted innovation by all true mountaineers.

Of the peaks which look possible of ascent Kāmet, Nanga Parbat, Kangchenjunga, and Mount Everest are of special interest.

Kamet (25,447 feet) is at present the most interesting of the peaks between 25,000 and 26,000 feet, because it is the most accessible of all, and is admirably adapted for carrying out acclimatization experiments. Lying back on the Tibetan border behind the main chain in the Zaskar Range, it is not so much affected in the rainy season as peaks like Mount Everest or Kangchenjunga, which bear the full brunt of the monsoon. It could therefore be attacked with distinct hope of success between May and October inclusive.

Nanga Parbat (26,620 feet) is one of the most fascinating summits of the main range. Mummery, in 1894, carried out the only difficult climb yet effected in the Himalaya, ascending rock ridges of the north face to about 21,000 feet. After examination from a spur of the adjacent Ganals Peak in 1913, the writer came to the conclusion that the north arête is practicable.

Kangchenjunga (28,295 feet) is in some ways the grandest mountain mass on the surface of the planet. Mr. Freshfield made the first near circuit of the mountain in 1900, and examined the eastern and western faces with regard to the possibility of climbing them. Regarding the magnificent eastern face, the finest ridge I have ever seen, he describes it as "a broad line of cliffs of terrific steepness which appeared hopelessly inaccessible to any direct attack." The only chance would be along the north-eastern arête, of which he writes as follows: "The right-hand buttress is a marvel of mountain architecture; it springs from a low mass as pedestal of splintered granite, and flies up in an ice arête of a length and steepness which defy Alpine comparison." The western face is also difficult.

The south face presents a practicable but dangerous route of ascent. During an attempt from this direction in 1905 four men lost their lives, being swept away by an avalanche. The height attained was about 21,000 feet.

Mount Everest or Chomo Langmo (29,141 feet).—As the latter name was obtained by Colonel Bruce and the writer from quite different sources, its claims may be worth consideration at a later date. A pass to the north-east of the mountain, about 18,500 feet high, leading to Kharta near the Arun River, is called Langma La. The mountain may be assailable from the north-east or north.

While the limited scope of this paper hardly allows of the deduction of categorical conclusions, yet it is highly probable from the data cited that a man in first-rate training, acclimatized to maximum possible altitude, could make the ascent of Mount Everest without adventitious aids, provided that the physical difficulties above 25,000 feet are not prohibitive. A supply of sodium peroxide (Na_2O_2) to provide oxygen as an occasional refreshment would be of great value. It is intended to discuss the incidence and causes of mountain sickness, as well as the limits of acclimatization, and the possible rate of ascent above 25,000 feet, in an extended paper.

The author would be grateful for any practical unpublished information directly bearing upon the physiological effects of high altitudes, and in particular abnormal mental or physical effects observed by airmen above 20,000 feet.

The author has pleasure in expressing his obligations to Dr. Carl Browning, Director of the Bland Sutton Institute of Pathology, for kindly reading and criticizing the manuscript.

Before the paper the PRESIDENT said : The Poles having both been reached it is obvious that the next object of importance on the Earth's surface to be attacked by adventurers is the highest mountain in the world. There are, perhaps I should not say unfortunately, a good many difficulties in the way of reaching it. In the first place you have to deal with a Government which has up to the present time forbidden you to approach within 100 miles of the mountain's base. In the next place the mountain itself is probably—though of this we have no sufficient evidence—of considerable difficulty; and there is thirdly the main obstacle, the effect of the rarity of the air at great heights on the human frame. As you know, the greatest heights reached at present are 24,600 feet by the Duke of the Abruzzi's party and 24,000 feet by some young Norwegians on Kabru, one of the mountains nearest Darjeeling.

Dr. Kellas, who is going to lecture to us this afternoon, will deal with this question of the effect on the human frame of high altitudes, and there is no one in Europe who can deal with it with greater authority or greater practical knowledge. He is a mountaineer himself; he has gone to the Himalaya several times, always to the Sikkim frontier. There, without Alpine guides, himself the only European in the party, Dr. Kellas, with a few hillmen whom he has trained to climb on snow and ice, has reached several summits of between 22,000 and 23,000 feet. He therefore adds practical experience to the scientific knowledge of an eminent chemist competent to deal with the medical side of the problem.

(*Dr. Kellas then read the paper printed above and a discussion followed.*)

Lieut. C. MEADE : In travelling in the Garwhal Himalaya at high altitudes, I have always found the sun peculiarly formidable. My coolies were all accustomed to living above 11,000 feet, but at heights above 20,000 feet I used to forbid them taking siestas in the open. I believe that exposure to the sun's rays at such a height is an important factor in causing mountain sickness.

The PRESIDENT : I should like to ask Dr. Kellas one or two questions. He told us about the unfortunate experience of the people who went up Pike's Peak by train. There is a similar ascent made by railroad in Switzerland up to the Jungfrau Plateau—11,300 feet. I do not know whether he has any statistics of what the effect on passengers in those trains has been. I recollect when there was a serious project, happily brought to naught, of making a railroad or lift up through the middle of the Matterhorn. It was proposed that caves should be excavated on the summit, and one of the caves was to be for a resident doctor who was to attend on distressed or collapsed tourists when they arrived on the top ! It is not usual for healthy people to suffer at the height of 11,000 feet unless they are brought up suddenly from sea-level or from relatively low altitudes. On the top of Mont Blanc (15,700 feet) many climbers suffer little or no inconvenience.

On one occasion when a hut was being built on the summit the workmen who lodged in a lower hut at a height of 14,300 feet used to run up the last ridge at as good a pace as you or I might run up Primrose Hill. I found it hard work, but still possible to keep up with them. One of the puzzling things in mountain sickness is the way in which the symptoms vary, not only with different individuals—some people, as in the case of sea-sickness, suffering far more than others—but vary on different mountains and on the same mountain on different days. For example, the first ascent to the top of Elbruz, 18,500 feet, in the Caucasus, was made by an English party in very good training ; none of us suffered at all. The summit being a crater with a rim to it, we ran about on the rim ; while the next party, who were equally good mountaineers and in equally good training, suffered severely. The only explanation I can offer is the difference between the weather on the two days ; on the first day there was a very high wind. That may possibly have increased the supply of oxygen.

Dr. Kellas has indicated the right line of research and practical experiment. He has also enforced a lesson that may be useful, and possibly even save lives: that is that climbing in the Himalaya is not to be lightly undertaken in the spirit of certain travellers who have boasted of running up them in their shoes, but is a task which requires careful preparation beforehand and a readiness to profit by previous experiences. I believe—I do not suppose I shall live to see it—that the highest mountains will be climbed, and I hope climbers will not lose time about it, else they may find themselves anticipated by airmen.

I do not know that I can add anything to the very careful deductions we have had from the chemistry of the human frame, but would ask Dr. Kellas if there is anything he would like to add now, and I am sure you will wish me particularly to thank him for the very fine set of photographs he has shown us, which will give you some idea of the great variety, the enormous majesty, and of course the very great difficulty, in many cases, of the Himalayan Mountains.

But among so many there must be a few easy ones on which experiments may be made by those who are testing the rarity-of-the-air problem.

Dr. KELLAS: First with regard to the effect of the sun mentioned by Lieut. Meade: there is no question that above 20,000 feet the sun's glare is terrific, and it is most inadvisable to think of sleeping in the exposed open. The effect must depend upon certain specific rays, probably ultra-violet rays, but perhaps also others which are filtered off lower down. I could not give any more definite reason, but I have noticed, when camping with thin tents on snow above 20,000 feet, that one has to cover the tents with opaque material to keep the sun's rays out, otherwise they are almost uninhabitable, especially if the air is stagnant.

With regard to the President's remarks about the apparently different effects of altitude on the first and second parties which ascended Mount Elbruz, the point he mentioned as being different on the two days was certainly one cause. Wind has a considerable effect on the breathing when climbing at altitudes over 20,000 feet, and is also important at lower elevations. I have noticed repeatedly that a high wind helps one greatly. There are various reasons which might be adduced: In the first place, when there is a breeze the exhaled air is carried away and none of it is re-inhaled. Secondly, air is packed into one's lungs by the breeze. This aids in the pressure, driving oxygen into the tissue between the capillaries and the alveoli of the lungs.

The PRESIDENT: In the early ascents of Mont Blanc in the eighteenth century, when they went up the great valley they always complained of the aridity and the stagnation of the air up at 12,000 or 13,000 feet in this hollow in the mountain; it seemed to cease when they got on to the ridges.

Dr KELLAS: One reason usually given as an explanation is that snow takes up more oxygen than nitrogen. One would not expect much effect unless the air were very stagnant, but there might be other reasons, such as reverberation of the sun's rays from the snow. Both could be investigated experimentally.

HAKLUYT AND MULCASTER

Prof. Foster Watson

HAKLUYT, it has been asserted, cannot be included in the highest rank of the great men of literature. Judged by his literary style no doubt this is true, as it would be true of Roger Ascham, of Thomas Fuller, or of Samuel Pepys. Still, such writers as these belong to a class which has a greatness of its own, not always reached by those who surpass them in the dignity of the highest literary style. They are men who draw towards them the affections of their readers on account of their personality, which finds expression in their work. Style and matter become united, for the concrete subject-matter is of high human interest, and the style is determined by the mode of expression which the personality finds inevitable for spontaneity and completeness of utterance.

Hakluyt's absorbing passion is that of patriotism—devotion to England. England, for him, is identified with the old Viking spirit, adventure on the sea, which in itself is sufficient to absorb all a man's thoughts. But Hakluyt, with the love of romance at sea as deep-set as that of Cervantes on land,