CHAPTER I

MOUNTAIN SICKNESS AND ITS CAUSE

WITHIN the span of life of the middle aged a wonderful change has come over our knowledge of the causation of disease. Indeed to say that nothing was known about the matter in the early seventies of last century is not very far from the fact.

Since that date the whole science of bacteriology has arisen, the micro-organisms which are responsible for innumerable complaints have been isolated. By analogy we argue that certain other diseases are communicated by similar agents, and in some of the most remarkable researches of our time the insects by which these micro-organisms are disseminated have been sought out. Nowadays there is before us a complete panorama of the ætiology of epidemics, no single component of which was vouchsafed to those who died about the time of my own birth. I well remember being rebuked for sleeping with the window open not on the ground that by such action I courted the mosquito, but for such reasons as that "the night air was injurious" or that "to sleep in a draught was certain to give me a cold which might lead to inflammation of the lungs or even consumption."

In those days therefore any disorder which had a definite cause loomed large for the student of medical science—among such was mountain sickness. Most persons as they approached the snow line in the Alps were inclined to vomit. Sometimes the inclination overcame them. In other cases severe headache ensued and so forth, but the cause seemed clear, it was the ascent into the rarer levels of the atmosphere.

Indeed according to Longstaff[1] (1), these scientific investigators were the fathers of mountaineering. "During the latter part of the eighteenth and the beginning of the nineteenth century, that great period of awakening interest and research into physical science, mountain ascents were encouraged and performed only by scientific men. Such men, practised observers and expecting to be severely affected by what we consider to be only moderate diminutions in atmospheric pressure noted even the smallest abnormal symptoms

[1] Dr Longstaff's paper was published in 1906 when much less was known about anoxæmia than at present. Probably being a doctor, his point of view has shifted, but it represents that of many climbers who are not medical men.

in themselves....On the other hand during the last fifty years mountaineering has become a sport and is practised by a much larger and very different class, although it is true that many men of scientific attainments are to be found in the ranks of modern mountaineers."

Whether or no these early scientists were inclined to exaggerate their symptoms, as Longstaff suggests, their modern brothers will endorse the view that the cause of their complaint was the diminished partial pressure of oxygen in the lung. This view which seemed to be established by the researches of Paul Bert (2) has been challenged seriously on two occasions, once by Dr Longstaff himself, and once by the Italian physiologist Mosso. Longstaff considered[1] that mountain sickness was due to a combination of physical exertion, "want of condition," and poverty of diet. The general trend of his argument may be gleaned from the following quotation. "In support of this view I would mention the ascents of the Peak of Teneriffe (12,200 feet) and of Fujiyama (12,425 feet). These are both easy walks. They are frequently climbed by tourists who have no experience of mountaineering and generally, owing to their geographical position, at the end of a sea voyage. The ascents take two days from the sea-level and have to be done on foot so that there is no rapid change in pressure. Yet on both these mountains reports of mountain sickness, often of a severe type, are of very frequent occurrence. I maintain that there are no sufficient grounds for attributing these cases primarily to insufficient oxygen. If these people were placed in a pneumatic chamber and the pressure reduced to an equivalent extent it is almost certain that they would remain unaffected by so slight a diminution in O_2 supply. But these individuals have performed an enormous physical task, such a task as they have probably never previously attempted and for which they are not in proper training. It would be surprising if great physiological disturbances did not arise under conditions which must produce an extreme degree of fatigue."

Much confusion seems to have arisen from the basing of argument on individual cases, and therefore it is with a good deal of diffidence that I cite my own experiences in criticism of a statement made by so great an authority on mountaineering as Dr Longstaff. It does happen that I have been the witness, and in one case the victim, of experiments which appear to be the obvious "controls" to Dr Longstaff's statement.

[1] In 1906.

Firstly, I have seen the summit of Teneriffe climbed by persons who started only 1500 feet below it, perfectly fresh and in good condition, and secondly, I have lived in "chambers" in diminished partial pressure of oxygen.

About Fujiyama I can say nothing, but about Teneriffe I can testify that our party had avoided all the causes to which Longstaff attributes mountain sickness. They had lived and walked a good deal and been excellently fed at an altitude of 7000 feet for

FIG. 1. The summit of Teneriffe as seen from the Cañadas. The white patch just below the summit is pumice above which is sand.

a fortnight, so that they only had 5000 feet to ascend. Of these they climbed all but 1500 feet on mules and even then two slept the night in the hut at 10,800 feet before the crater was climbed. Prof. Zuntz's expedition had not performed any fatiguing feat before their ascent. The actual climbing of the last five 500 can only be described as "an easy walk," in the sense (and that no doubt is what Longstaff means) of being quite devoid of mountaineering difficulties.

Considered in the light of the amount of energy which must be expended per foot of ascent accomplished the climbing is far from

easy. The surface of the ground at the summit of the peak consists of sand which lies at the critical angle; as the tourist endeavours to climb, the ground beneath him sinks immediately his weight is placed upon it. For every foot he goes up he comes down nine inches. The party of which Douglas and I formed two members, arrived at the Alta Vista Hut perfectly fresh and in good condition, but the 1500 feet which remained to be climbed, entailed a greater expenditure of energy than is usually required for so trivial an ascent. Of the party of seven one was so mountain sick as to turn back, the rest all reached the summit. I think all felt a degree of breathlessness and at least two a nausea which they could not possibly have experienced on such a climb within 1500 feet of the sea level.

Of the second "control" I have an even more intimate knowledge, having lived in a chamber (4) in which the partial pressure of oxygen was gradually reduced until on the morning of the sixth day I awoke with three of the typical symptoms of mountain sickness, vomiting, intense headache and difficulty of vision. I have recollections of very acute headache accompanied by vomiting as a child, but never in adult life or even in my boyhood can I think of any such attack as occurred in the chamber, there seems to be no reason to regard it as an attack of megrain which "just happened" to occur that day. In the chamber I had lived an easy though normal life, reading, writing, making observations, doing gas analysis, cleaning the chamber, seeing to the air scrubbers, taking exercise on the bicycle ergometer and so forth. Moreover I had been thoroughly well fed—a rather light breakfast, tea, eggs, bread and butter cooked by the attendant and lunch and dinner sent from the College kitchens. There was no cause other than oxygen want to which my sickness could be attributed. It is true, of course, that the partial pressure of oxygen corresponded to about 18,000 feet and therefore a much higher altitude than that of the Peak of Teneriffe but, on the other hand, I had not precipitated matters by the performance of any such exacting feat as the ascent of a sandhill 1500 feet in height. There is every reason to suppose that my friend who was sick on Teneriffe would have been sick doing the same amount of work in a chamber in which the oxygen pressure was that to which he was subjected on the Peak and would not have been sick under similar circumstances in atmospheric air. And this brings me to the undoubted element of truth which runs through the whole of Longstaff's—as it seems to me—vicious argument. Fatigue, of course, is an element in mountain

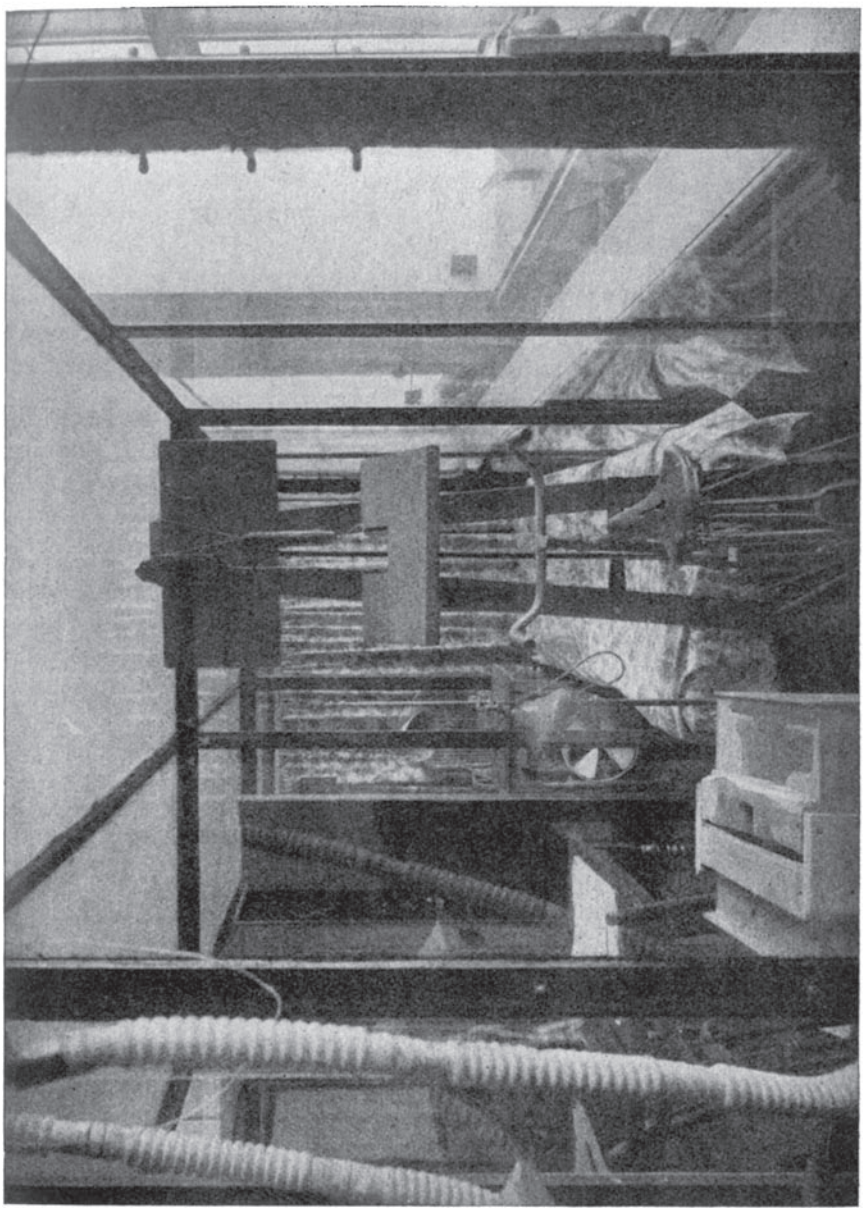

FIG. 2. Glass respiration chamber in the Physiological Laboratory, Cambridge, England.

sickness, for mountain sickness is due to *oxygen want* and oxygen want is the discrepancy between oxygen supply and oxygen demand. It depends upon the balance between the two. The mountain sickness complex may be brought on at almost any given altitude at which the demand of the body for oxygen can be made to exceed the supply to a sufficient degree and for a sufficient time. The vice of Longstaff's argument consists in his presenting as antithetic two factors which are in reality complementary. There could be no more convincing proof that mountain sickness is not due to fatigue than is furnished by the passengers who daily reach altitudes of about 15,000 feet by train. A vivid account (5) has been given by Haldane and his colleagues of the condition of the tourists who were conveyed to the summit of Pike's Peak during the stay there of the party. Even more convincing, if possible, is the exhibition which daily takes place at Ticlio the highest point of the Central Railway of Peru. It would seem that here the effect of the rare atmosphere is more immediate than at Pike's Peak, for this there may be several reasons. In the first place, the altitude is somewhat higher being just short of 16,000 feet at the highest point (15,885 feet to be exact), in the second place, the train conveys not merely tourists whose object is to ascend the mountain, but all and sundry—men, women and children who are crossing the Andes in the course of their business, and in the third place, the train when on its journey east comes up the whole way from the sea level in less than twelve hours. Unlike ascents on the Alps, the element of cold may be ruled out as constituting a possible cause of the sickness of the passengers who reach Ticlio for the trains are warmed to a very comfortable temperature. It must be admitted that when first I passed over this summit I was occupied in keeping very quiet lest I should be sick myself—an effort which

FIG. 3. Ticlio near the summit of the Central Railway of Peru.

proved to be abortive, for while I was not actually sick in the train, the crisis came two or three hours later when I left the train at an altitude of 12,000 feet. On the occasion of my second crossing I was in a better position to observe my neighbours, looking out at Ticlio I saw the most astonishing spectacle; all along the train from the windows of the carriages occupied by *οἱ πολλοί*, a row of heads protruded from the windows—the outward and visible sign of a single purpose, that of regurgitation.

Of course there are more subtle factors involved in mountain sickness than diminished pressure of oxygen in the lungs and the degree of muscular exercise which is involved. An instance is the sight of food. I remember having a bad quarter of an hour at the Capanna Margherita on the most accessible summit of Monte Rosa. I had been there twenty hours without any tendency to mountain sickness and I had slept reasonably well, but lunch was almost too much. I struggled through without the nausea turning into anything worse, but I ate little and just sipped at a glass of wine. In the last resort the symptoms of mountain sickness are less due to deficient oxygen supply to the body as a whole, than to deficient oxygen supply to the brain; if therefore the amount of oxygen which is reaching the brain at any moment be only just sufficient, a diversion of blood from the brain to other regions whether the cause be physical or psychological may precipitate mountain sickness.

Another point made by Longstaff has perhaps received too little attention, namely, the factor of cold. He quotes the work of Zuntz, Schumberg and Loewy (6) who found a 40 per cent. increase of oxygen consumption by the human body when at rest on Monte Rosa. At Cerro de Pasco, in Peru, at an altitude of 14,200 feet we recorded no such experience. Out of five cases studied the change in oxygen consumption was as follows (7):

Meakins's oxygen intake at rest rose			25	per cent.
Harrop's	,,	,,	,, 15	,,
Binger's	,,	,,	,, 4	,,
Redfield's	,,	,,	fell 2	,,
Barcroft's	,,	,,	,, 15	,,
Bock's	,,	,,	,, 12	,,

When I enquire as to what may be the caus of the discrepancy between Zuntz's results and our own my mind g es back to the night which I spent shivering on Monte Rosa and to he contrast between the conditions there and those of the beautifu little cottage where

we were housed at Cerro and in which there was a large fire-place and as hot a bath as you please. The mere fact of living at an altitude of 14,000 feet does not send up my oxygen consumption, but in Cambridge by going from my own laboratory to that of the cold storage research department and sitting at 0° till I feel inclined to shiver, I can put up my oxygen consumption by one-sixth and I have seen that of my colleague, E. K. Marshall, rise from 269 to 410 c.c. per minute (66 per cent.) by the same procedure (8). Cold then, in so far as it raises the oxygen consumption is equivalent to work, and does so by increasing the muscular contraction. To that extent it is a predisposing cause of oxygen want.

The second theory of mountain sickness which has had some vogue is that of Mosso (3) who was impressed by the fact that there was less carbonic acid in the expired air at high altitudes than is normally the case.

Further reference to this theory will be made in the chapter on the hydrogen-ion concentration of the blood. Here it need only be said that, so far as I know, the theory is dead. For me it died when I was on the Peak of Teneriffe when first at the Alta Vista Hut (10,500 feet) without actually vomiting I was a good deal affected by the altitude, Douglas who was with me was quite unaffected. Yet the carbonic acid in my alveolar air was practically normal, in his it was reduced (9).

	CO_2 pressure in England	Alveolar air mm. Alta Vista
Barcroft	40	38
Douglas	39–42	31·9

Douglas was well though acapnic, I was not acapnic yet ailing. Granting one's CO_2 production to be the same at the Alta Vista Hut as normal it follows that the fall in Douglas's CO_2 was due to increased total ventilation, which in my case, unfortunately, did not take place. It may be deduced that because my alveolar CO_2 was six millimetres higher than that of Douglas my alveolar oxygen was seven or eight millimetres lower and this no doubt was the cause of my trouble.

Whilst there can be no doubt that oxygen want is the prime cause of mountain sickness there remain some rather interesting points which have never been quite cleared up, one of these is the persistent statements that as between localities situated at the same altitude mountain sickness is more prevalent at some than at others. In

general, for instance, persons are said to be affected at lower altitudes in the Andes than in the Himalayas. Of course it is not a foregone conclusion that at equal altitudes the barometric pressure is the same in Thibet as in Peru, any more than the level of the sea is the same in the Atlantic and in the Pacific. In point of fact the sea level at one end of the Panama Canal is appreciably different from that at the other. I put the question to Sir Napier Shaw who very kindly supplied me with such statistics as there are on the subject. They went to show that there was a slight difference in the mean barometric readings at say 15,000 feet as between the Andes and the Himalayas, but as the barometer is on the whole higher in the Andes the trifling difference of atmospheric pressure renders alleged proneness to mountain sickness in the Cordilleras of Peru the more remarkable.

The late Dr Kellas in an unpublished manuscript, from which the secretary of the Alpine Club has kindly given me permission to quote, makes the following remarks on this subject: "Zuntz has also pointed out that Mountain Sickness seems to vary greatly in incidence with locality. He observes that it is met with at 3000 metres in the Alps and Caucasus, at 4000 metres in the Andes and at 5000 metres in the Himalayas.

"This statement would be very difficult of explanation if true, since the composition of the atmosphere is practically uniform, except with regard to relative humidity, but it can only be considered a vague generalisation, expressing the chances of acclimatisation. As indicated later, if untrained individuals can rapidly alter their altitude mountain sickness may be produced, but if the alteration is slow acclimatisation prevents incidence. Hooker (10) for example states that they never suffered when riding at 18,000 feet in the Himalaya (where the traveller by road generally takes at least a week to reach 15,000 feet) but he suffered when climbing on foot.

"More important because more difficult of explanation is the statement, that mountain sickness varies within certain narrow areas. Two general statements have been made in this connection.

"(1) It has been repeatedly affirmed by travellers and natives of the Himalaya and Andes that passes of about the same height in the same region differ greatly as regards incidence of mountain sickness. For example v. Tschudi (11) states that it is incident with great severity in some districts in Peru, whilst in others of higher altitude it is scarcely perceptible.

"(2) It has also been generally assumed that one is more liable

to be attacked when climbing in gullies and on snow, than on open ridges and rock.

"Many quotations might be given regarding this latter statement. De Saussure (12) in describing the early unsuccessful attempts on Mont Blanc says that in 1783 two chamois hunters ascended by a series of rock arêtes to within 2500 feet of the summit, and that 'the air on those slopes was so easy and light that there was no fear of that kind of suffocation felt in the valley of snow, which extended from the mountain of La Coté at a lower elevation, which had defeated another attempt during the same year.

"In 1831 Boussingault (13) wrote in connection with his attempt on Chimborazo "A hauteur égale, je crois avoir remarqué, que l'on respire plus difficilement sur la neige, que lorsque l'on se trouve sur un rocher." Conway in connection with the ascent of Pioneer Peak remarks that they felt much worse on snow than on the arête, in fact they had difficulty in restraining themselves from taking to the cornice[1].

"Thomas on the contrary found climbing on rocks more difficult than on snow, suggesting that the heated rocks caused rarefaction of the air, agreeing with Zurbiggen, a guide of quite exceptional ability and experience, who told Professor Mosso that he suffered more on bare mountains than on snow or ice.

"Probably all these vague statements are capable of simple explanation. It seems unnecessary to invoke ionisation of the air due to radio-activity of the minerals present in certain mountain regions, a theory due to Zuntz. Intense electrical disturbances which would produce ionisation seem to have little effect on the incidence of mountain sickness, but Mosso cites examples of an apparent influence, perhaps psychic in origin.

"The true explanation of the above contradictory statements regarding incidence of mountain sickness is probably much simpler, but may depend upon several factors, all of which would require to be considered in any particular case:

"(*a*) Nature of the ground, e.g. whether snow or rock, and whether easy or difficult.

"(*b*) Presence or absence of wind.

[1] Major R. W. G. Hingston, I.M.S., medical officer to the 1924 Everest expedition draws especial attention to this point, under the heading of Glacier Lassitude. The discomfort felt on snow and glaciers especially when in enclosed places is attributed to a high degree of saturation of the atmosphere with aqueous vapour. [*Proceedings of the Royal Geographical Society*, 10 Nov. 1924.]