be extremely difficult, and frequently entirely barred by the ice cliffs of the hanging glacier which dominates it.

It would, therefore, appear that the presence of ice below in the couloir, and its absence at the same time on the slopes above, are the most favourable conditions for an ascent, apart from possible risk from avalanches, though whether such will ever be found to co-exist only the future can show. It should be borne in mind that the expedition is one for which fine settled weather is absolutely essential, and one where the endurance of every member of a party may be put to a severe test. In spite, therefore, of the risk of prophesying, I venture to predict that some time will elapse before an easy route is discovered up the N.W. side of the Aiguille du Plan.

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## Mountain Sickness.

By C. G. MONRO, M.B.

IT may seem unnecessary to begin this paper with a description of mountain sickness, especially in a publication like the 'Alpine Journal'; but the fact is that even quite recently doubts have been thrown on the very existence of mountain sickness as a distinct affection. To begin with, the name is not altogether a good one, for it implies that the presence on a mountain of the individual so attacked is a necessary feature of the affection. This is by no means the case, for aeronauts have been known to suffer from similar, if not identical, symptoms; and M. Paul Bert has shown that the malady may be produced in individuals who are subjected to artificial exhaustion of the atmosphere by means of an air-pump. As, however, the train of symptoms caused by these various conditions is best known as mountain sickness, I shall adhere to this name in default of a better. The symptoms of mountain sickness are somewhat variable; but the chief and all-important one is an 'indescribable feeling of illness,' associated with great muscular weakness, especially in the lower limbs, and a consequent inability to proceed with the ascent. To this may or may not be added breathlessness, headache, loss of appetite, nausea and vomiting, giddiness, thirst, and, at least in one case, rise of body temperature. Mountain sickness has been known for centuries. Accounts of it are given by Father de Acosta in 1590, Bouguer in 1737, and by de Saussure. In our own

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times the best account of it has been given by Mr. Whymper, which is so well known that I need only briefly allude to it. It is sufficient to say that the attack was very sudden, coming on very soon after a meal, and that it was characterised by severe headache, great breathlessness, increased pulse-rate, and rise of temperature. The acute symptoms passed off gradually, and did not recur during Mr. Whymper's protracted stay in Ecuador. In another passage he says:—'In reviewing the whole of our experiences, two different sets of effects could be distinguished—namely, those which were transitory and those which were permanent—that is to say, permanent so long as we remained at low pressures. The transitory effects were acceleration of the circulation of the blood, increase in the temperature of the body, and pressure on the blood-vessels. The permanent ones were augmentation of the rate of breathing and disturbance of the habitual manner of respiration, indisposition to take food, and lessening of muscular power.'

In the 'Jahrbuch' of the Swiss Alpine Club for 1891–92 is a paper by Dr. Egli-Sinclair on 'Bergkrankheit.' He, with two companions, started for an ascent of Mont Blanc in a condition of scepticism as to the existence of mountain sickness. They returned from their expedition sadder, wiser, and thinner men, for they suffered severely from mountain sickness. They reached, by easy stages, the Cabane des Bosses, situated at a height of about 14,500 ft. Here they remained about ten days, suffering more or less all the time, and the symptoms noted by them are briefly as follows: Quickening of pulse-rate and of respiration, great loss of appetite, with consequent loss of weight. Certain experiments regarding hæmoglobin I shall refer to later on. The most recent observations on the subject are those of Mr. Conway, and he has very kindly furnished the following information. In his journey the rise in altitude was gradual, but the work was most laborious. When first a height of 16,000 ft. was reached, the party suffered, especially at night, from headache, but no serious symptoms, referable to altitude, were noted until they attained a height of about 17,000 ft. Here, without exception, everyone was affected, and it is especially noteworthy that the native porters, some seventy in number, who live habitually at a height of about 10,000 ft., were affected at the same time as the other members of the expedition. The symptoms were chiefly difficulty in breathing, and weakness in the lower limbs. Appetite throughout was good, but during the ascent of Pioneer Peak,



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the highest point reached, none of the party, except the Goorkhas, ate anything but kola biscuits. The rate of respiration was not apparently much, if at all, increased, except on exertion. By gradual stages they reached a height of about 20,000 ft., at which they camped, and from this camp they ascended a mountain about 3,000 ft. higher. During this ascent one of the Goorkhas suffered from an attack of mountain sickness, including vomiting; but none of the Europeans, during the whole time, was attacked by mountain sickness in the acute form. They by no means escaped, however, from what I venture to call chronic mountain sickness, the chief symptom of which was difficulty of respiration. Anything, such as an obstacle in climbing, a tug at the rope, the necessity of taking observations, which produced an obstruction to respiration or an involuntary holding of the breath, caused a feeling of giddiness which was only dissipated by taking several deep breaths. This tendency to dyspnœa was greatly increased by the heat of the sun, which was intense. Mr. Conway also says that during the time that they were above 16,000 to 17,000 ft., he, as well as the others, was aware of the presence of his heart, a sure sign that it was not acting normally. And though they were, on the whole, able to sleep well, they could not sleep if they lay on their left sides, also an indication that the heart was affected injuriously. Owing to the feeble action of his heart, Mr. Conway was obliged to give up smoking after reaching a height of about 17,000 ft. Pulse-rate does not seem to have been increased, except, of course, on exertion. No rise of temperature was noted except in the case of one of the party who suffered from malarial fever. On the summit of Pioneer Peak (about 23,000 ft.), the party were quite comfortable, and the guide smoked a cigar and enjoyed it. Mr. Conway took tracings of his own pulse on about a dozen occasions, and states that they showed that his heart was acting badly.

Having thus mentioned a number of accounts of actual mountain sickness, I shall briefly allude to the symptoms which affect aeronauts and persons placed in an atmosphere which has been artificially exhausted. The conditions in these two classes are practically the same, inasmuch as those who thus experience the effects produced do so rapidly and without bodily exertion.

In M. Paul Bert's work, 'La Pression Barométrique,' will be found detailed accounts of a series of experiments on animals and men; and the facts noted were as follows:

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Under the influence of exhaustion of the atmosphere, the pulse-rate rose rapidly, malaise and nausea were present, sight became dimmed, and flatus was passed in considerable quantity. The inhalation of oxygen removed these unpleasant effects to a large extent. Very similar symptoms have been recorded by aeronauts.

It must, however, be noted that the persons experimented on remained but a short time at very low pressures. And the bearing of this is shown by the fact that two aeronauts, who had been thus experimented on, and who subsequently ascended in a balloon to a height of 28,000 ft., were found dead with their mouths full of blood, in spite of the fact that they had oxygen with them, the supply of which was not exhausted. I think it may now be fairly considered certain that a definite malady exists, similar to, if not actually identical with, affections noted as occurring in aeronauts, and in persons placed in an artificially exhausted atmosphere.

Turning now to the question of its causation, I have been astonished, since I have gone more deeply into the subject, at the complexity of the physical and physiological problems involved. This is sufficiently indicated by the number and variety of the views which have been expressed on this point. It seems to me that those who have hitherto endeavoured to solve the question have almost invariably attempted to reduce the cause of mountain sickness to a single factor; but it seems to me that mountain sickness is due to a number of factors, modifiable by circumstances, which, as it were, form a resultant. This resultant has to act on a very complicated mechanism, the human body, and may be modified again by the individual peculiarities of this mechanism.

It has been suggested that mountain sickness should be divided into two classes, according as it occurs at high or low altitudes; but I do not consider that there is any fundamental difference; even though dilatation of the heart has been described by Professor Clifford Allbutt as occurring—a result presumably due to overstrain—it by no means follows that mountain sickness is caused by dilated heart; and I prefer to look at that, and any other result of overstrain, not as the true cause of the attack, but rather as the proverbial 'last straw' which would render the body incapable of further resistance to the forces which tend to produce mountain sickness.

The most important kind of mountain sickness, however, is that which is produced by the circumstances which attend ascents to very great elevations, in which conditions, such as

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want of training, may be practically eliminated. Suggestions, such as that put forward by the late Dr. Emil Zsigmondy, that it is due to 'Magenkatarrh,' or entirely to fatigue, are utterly disproved by the experiments of M. Paul Bert and the experience of aeronauts. Moreover, these experiments show that mountain sickness must be due, in a great measure at any rate, to conditions which equally exist on lofty summits, and in a cylinder at the level of the sea from which the air has been artificially exhausted. The two obvious conditions which so co-exist are, first, diminution in the quantity of oxygen per cubic unit, and, second, reduction of atmospheric pressure. It would therefore seem probable, *prima facie*, that these two conditions are important factors in the resultant which is the cause of mountain sickness.

Let us, then, first consider the facts and views concerning the diminution of oxygen.

M. Paul Bert, as the result of his experiments, regards the want of oxygen as the great cause of mountain sickness, because his unpleasant symptoms were relieved by the inhalation of oxygen; and suggests as a remedy that large quantities of oxygen should be taken by mountaineers during high ascents for purposes of inhalation. The enormous weight which it would be thus necessary to carry would absolutely prevent the attainment of the highest summits of the world. But is this really necessary? Mr. Conway's party reached a height of 23,000 ft., with labour it is true, but without suffering from the acute form of mountain sickness, and they certainly took no oxygen with them. Besides, two aeronauts, experimented on by M. Bert (who afterwards perished in a balloon ascent), in spite of draughts of oxygen, suffered, from rise in pulse rate, a sort of drunken sensation, inability to see or hear clearly, and loss of appetite. It must be remembered that respiration is a purely muscular act, and, besides, is practically automatic. Now, it can readily be understood that, if the automatic mechanism be suddenly thrown out of gear, evil results may follow. But if time be given for a compensatory equilibrium to be established, the respiratory function may, and can, be carried out very fairly well. M. Vallot has shown that after a time the quantity of air introduced at each inspiration is increased with only a slight increase in the rate of respiration. Mr. Conway's experience shows, however, that though very fairly complete respiratory compensation is established, a very slight strain on the respiratory mechanism is sufficient to throw it out of gear.

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Mr. Bosanquet, in the 'Philosophical Magazine' for January 1893, puts forward another view. He compares the body to a steam engine and boiler—a comparison which I do not feel altogether disposed to consider permissible—and suggests 'that in cases of great-altitude mountain-sickness, such as Mr. Whymper relates, the diminution of the air supply reaches a point at which there is not enough oxygen for the consumption of the fuel continually brought forward by the internal feed. Of course, so long as this is the case, disturbance of the system is to be expected from the accumulation of the reducing (oxygen-devouring) substances furnished by the internal feed to the blood. Under these circumstances food would probably not be taken for a time; the internal feed would after a time be reduced; and an equilibrium of the system set up again, founded on a reduced food consumption. And this is precisely what happened according to Mr. Whymper's account.' But I learn from Mr. Conway that their appetites continued good, and that they ate heartily, which was shown by the rate at which their stores diminished. During the ascent of Pioneer Peak, it is true, they ate nothing but kola biscuits; but this, I imagine, was more for convenience than because they had no appetite. According to Mr. Bosanquet's view, they ought to have had acute attacks of mountain sickness, which they did not; and I do not see how this theory accounts for the symptoms of the individuals experimented on by M. Bert.

Dr. Egli-Sinclair, in the article previously referred to, states, as his belief, that the essence of mountain sickness is 'anoxæmia,' *i.e.*, that the blood is poor in oxygen, and he finds that the quantity of hæmoglobin is considerably diminished, but that after a time it increases; and to this increase is due, he says, the recovery from mountain sickness. If I have rightly translated his remarks, he accounts for the increase as follows:—'The diminution in tissue-change which is connected with mountain sickness' (presumably owing to loss of appetite, inability to move, &c.), 'leads of itself to a diminished consumption of oxygen, and this allows a restitution of hæmoglobin.' But this by no means allows of a permanent restitution of hæmoglobin, and, therefore, as soon as there is necessity for an increased consumption of oxygen, there should be a diminution again in the quantity of hæmoglobin, and so on in a circle. That this decrease in hæmoglobin does exist I am quite willing to believe, but I cannot agree with him in thinking that in this consists the essence of mountain sickness.

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It is therefore impossible to deny that the diminution of oxygen per cubic unit of atmosphere is a factor, and a very important one, in the production of mountain sickness; at the same time, I consider that it is only a factor and not *per se* the cause of it.

I shall now turn to the second of the two co-existent conditions to which I referred, namely, diminution of atmospheric pressure. Mr. Whymper considers this to be the cause, *par excellence*, of mountain sickness, although he admits diminution in oxygen as a factor. He thinks that it acts 'by causing the air or gas within the body to expand and to press upon the internal organs.' That he is right in considering these two conditions to be factors in the production of mountain sickness I have no doubt; but I do not think that his view, of the way in which diminution of pressure acts, is a physiological one. For there is no doubt that vast quantities of gas may be generated within the body, without producing any unpleasant results; and I do not think that he takes into consideration the power which the human body possesses of absorbing gases so generated. But I think that, under *rapidly* diminished atmospheric pressure, the gases which are loosely combined with the elements of the blood may be set free in the blood so quickly as to produce a mechanical obstruction to the circulation, comparable to that which is caused by entry of air into a vein. And I think it possible that the deaths of MM. Crocé-Spinelli and Sivel, the aeronauts I have referred to, were due to this cause, and not to want of oxygen, inasmuch as the supply of that gas, which they took with them, was found subsequently to be not exhausted. Owing to the comparatively gradual reduction of pressure which is experienced during a mountain ascent, I do not think that this cause is largely operative in the production of true mountain sickness.

What, then, are the results of diminished pressure which tend to produce mountain sickness? In the Croonian Lectures for 1881, delivered by Dr. Moxon, I think we may find a clue. In these lectures, on 'The Influence of the Circulation on the Nervous System,' he describes a malady which he terms 'caisson disease.' This arises in men who work under greatly-increased pressure during the construction of bridge-piers, &c., and attacks them when they return to ordinary pressure—that is to say, on undergoing a rapid diminution of atmospheric pressure. He shows that the tip of the spinal cord, a part which under ordinary circumstances

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is poorly and with difficulty supplied with blood, is the first part to be affected by diminution of atmospheric pressure. Now, this part of the spinal cord corresponds to the lower limbs, and defective blood supply to the former would produce a loss of power in the latter. He shows also that under increased pressure there is mechanical congestion of the brain productive of nothing but good results; and, therefore, I think it probable that under diminished pressure a condition of cerebral, as well as spinal, anæmia would be produced. In the same lectures Dr. Moxon demonstrates, pretty clearly I think, that many symptoms, such as giddiness and vomiting, are not due to cerebral congestion but to cerebral anæmia.

I think we are now in a position to apply these facts to mountain sickness. For if diminished pressure produce spinal anæmia, may not the great weakness of the lower limbs, which is so prominent a feature in mountain sickness, be due to this cause? And, again, if diminished pressure produce a tendency to cerebral anæmia, may not the giddiness, the headache, the vomiting, which may characterise acute attacks of this malady, be due to such anæmia? In support of this I shall quote a case. A gentleman, while suffering from mountain sickness, fell, and in his fall turned slowly heels over head; on rising again, his unpleasant symptoms had disappeared. Whether his recovery were due to cerebral congestion as a result of his temporarily inverted position, or merely to the shock of the fall, in any case the fact goes to show that the cause was of nervous origin. And I may compare with this the recovery from attacks of faintness, especially that produced by purely nervous causes, which, as is well known, results from holding the head down.

And now let us apply this theory to Mr. Whymper's careful account of his attack. The first point to note is that it commenced immediately after a meal. Now, the taking of food and the process of digestion tend to produce anæmia of other parts of the body, as is well shown in persons whose hands become 'dead' after a heavy meal. And Mr. Conway's account leaves no doubt that in high mountain ascents an injurious amount of strain may be put upon the heart. And if we recall the fact that when the heart is even functionally affected, a very small quantity of food will produce very violent dyspnœa by placing an additional strain on an already feeble heart; and if we also take into consideration the tendency of diminished pressure to produce cerebro-spinal

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anæmia, I do not think that we can be accused of formulating a very improbable theory if we say that Mr. Whymper's attack was produced by a resultant, the factors of which were, first, and perhaps most important, cerebro-spinal anæmia; second, the diminished quantity of oxygen; third, the probably enfeebled condition of his heart; and, fourth, as the last straw, the taking of a meal. Even the rise of temperature and the violent dyspnœa may be accounted for by supposing some irritation of the heat and respiratory centres due to the cerebral anæmia. And this idea is supported by the fact that in Dr. Egli-Sinclair's account of his symptoms, I find that he notes something much resembling Cheyne-Stokes' breathing. If we accept the theory of cerebro-spinal anæmia, we can, I think, account for all the symptoms; and I have been struck with the resemblance of mountain sickness to sea sickness, which is undoubtedly of cerebral origin, as shown by the very similar symptoms and the rapid recovery which may result when a lower elevation in the one case, and *terra firma* in the other, is attained.

I have now discussed, at some length, the various views on the causation of mountain sickness. It has been my endeavour to show, or rather to suggest, that the cause is probably made up of two main factors, and I have stated my opinion as to how these factors may act. It now remains to consider very briefly how these factors may be modified by circumstances.

Firstly, climate. There is no doubt that this has a great effect. The climate of the Andes, for example, is of the very worst description. In the Himalayas and in the Caucasus, on the other hand, the climate is far better, though in the former the enormous daily range of temperature is very trying. It must be noted, too, that Mr. Whymper passed through a malarious district before attempting Chimborazo.

Secondly, the nature of the ground traversed. If the work is such as to require constant efforts which produce constant cessations of respiration, the tendency to giddiness, &c., will be increased. Moreover, the shape of a mountain has much to do with the production of mountain sickness, which is much rarer, for instance, on Monte Rosa than on Mont Blanc, though there is not much difference in height. Mr. Conway says that in hollows, where the air stagnated, their symptoms were much increased, while on the crest of a ridge they were much diminished, so much so that the party with difficulty restrained themselves from walking on a

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cornice; and this admission, coming from a skilled mountaineer like Mr. Conway, shows how great the difference is between a spot where the air is still and one where it can circulate freely. Again, if the nature of the ground traversed be such that too great a strain is thrown on a heart already somewhat enfeebled, the resulting dilatation would, by tending to produce cerebro-spinal anæmia, tend to produce mountain sickness.

I have previously stated in this paper that the cause or causes which produce mountain sickness have to act on a very complicated mechanism; and this must be constantly borne in mind. For the functions of the various organs which make up the human body are so interlocked that it is scarcely possible to affect the function of one organ without at the same time affecting the functions of all the other organs. It is, therefore, all the more difficult to ascertain which particular organ is most at fault in a particular malady. I have endeavoured in this paper to abstain as far as possible from dogmatic statements, for I do not think we are yet in possession of sufficient facts on which to base a really sound theory. If I have shown that the cause of mountain sickness is far more complicated than has been frequently supposed, my object will have been attained. I cannot close without placing on record my warmest thanks to Mr. Dent for much valuable information on the subject of mountain sickness.

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## IN MEMORIAM.

### KASPAR BLATTER.

On May 18 Kaspar Blatter died suddenly at his house near Meiringen. Though suffering much from rheumatism, and feeling his sixty-four years of hard life, his health was good, and he had on that same morning been about his usual work at home and walked into Meiringen. On his return he refused dinner, and, after lying for an hour on his sofa, he died without consciousness that it was death.

To the older members of the Club and to all readers of Dr. Roth's book on the Blümlisalp range Blatter's name will be familiar. It was in 1862 that he was one of the guides with whom were made the first ascents of the Weisze Frau and Doldenhorn. I knew him first in 1861, between which year and 1877 we made thirteen long mountaineering journeys together, from the Napf to the mountains of Cogne, from the Ortler to Chamonix and Sixt.

He was in all respects worthy of his worthy profession—brave, cautious, judicious, unsparing of himself; honourable, true-hearted,

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