St. Maurice, where we ate some of the excellent trout from the Lac de Tignes, and then over the little St. Bernard to Courmayeur, reaching our hotel at 11 P.M. This ended the fourth and last stage of our journey proper. Next morning we wandered about in the little street, getting our boots nailed and revelling in ripe fruit. The Dauphiné guides were somewhat disappointed at the view. Approaching the range from the direction we had come, we had day by day admired the magnificent snowy mass in front of us, and after that the restricted view from Courmayeur itself was somewhat surprising. That afternoon we went up to the Mont Fréty, rested an hour or so, and, crossing the Col du Géant, climbed the Aiguille du Géant, and reached Montanvert and our baggage after dark. Next morning we awoke to see the view which after all nothing can spoil, and knew we were on our way home.

I wish we could have spent more time about Pralognan, but I hope some day to fill up the gaps. We met in the two years only two Englishmen between La Bérarde and Courmayeur, so I recommend the district to the jaded centrist. The journey in itself is very interesting, passing, as photographs show, from the barren and desolate rocks of Dauphiné over the rolling pastures of the Tarentaise to the wooded scenery of the Swiss Alps. It should certainly be taken in the direction we took it, for the beauties grow as one comes N.

Moreover, such a journey enables one to visit places such as the Pelvoux and the Aiguilles d'Arve, which will be ever memorable in the history of Alpine exploration. And this brings me to the one advantage which we younger men have over our older brethren. The stirring tales which we have read in our boyhood have invested the scenes of their early adventures with a glorious romance. They had 'the first fine careless rapture'; but the pleasure of visiting those places of heroic deeds, which we have known so long, was not for them. We have it, and prize it, as our one superior possession.

Some Reasons why the Science of Altitude-Illness is still in its Infancy.

By M. L. HEPBURN, M.D., F.R.C.S.

At a meeting of the Alpine Club on April 2, 1901, Mr. Bryce made the following suggestive statement in connection with mountain-sickness: 'The fact that we are still in

the infancy of the inquiry is strange, seeing that the phenomenon has been noticed three hundred years ago.' This remark almost carries with it an unintentional rebuke to those scientific men who have attempted from time to time to deal with the bulk of subject-matter committed into their hands. The difficulties, no doubt, are great, but whether unintentional or not, the rebuke is well merited; and in view of the complications which at the present time surround the study of altitude-illness, I have thought it advisable to indicate some of the possible errors arising out of what I shall call excess of observation, so that, by clearing our minds and by narrowing down our investigations to one or two definite objects, we may place ourselves in a better position for experimental research and within reasonable distance of conquering the highest peaks of the world.

At the outset it must be noticed that I have avoided the term 'mountain-sickness' in my title, and I do so now for a special purpose. The name suggests, and has been used to denote in its broadest sense, illness connected with the mountains and mountain-climbing, together with the symptoms complained of by aeronauts and laboratory experimentalists, yet there are but few conditions met with on the mountains or in balloon ascents, apart from diminished pressure caused by altitude, which may not be observed and studied at sea-level, producing the same symptoms all the world over; and on the other hand diminished pressure may be artificially produced at sea-level, in some cases giving rise to symptoms similar to but at the same time distinguishable from those of so-called mountain-sickness, while at least one class of case possesses no similarity whatever. These artificially produced cases of illness should only be used as a means of elucidating the difficulties which must necessarily characterise the investigation of the subject of illness connected with mountain-climbing.

To begin with, the expression 'mountain altitude illness' is only justified when we have proved that there is a definite disorder which may accompany muscular exertion at high altitudes, and which cannot occur under other conditions.

I propose to deal with some of the commonest errors from four different points of view; which indeed are more or less intimately connected, as the mistaken conclusions in one often lead to those in another.

1. Errors in connection with the symptoms.

2. Errors in connection with the pathology or physiological cause.

3. Errors in connection with acclimatisation.
4. Errors in connection with treatment.

1. *Errors in connection with the symptoms.*—The earliest writers, of whom there are about sixty up to the time of Jourdannet, the great pioneer in the science of the subject, appear to have aimed exclusively at the collective and elaborate classification of all the symptoms ever noticed on the mountains by climbers and explorers as far back as the year 1519. In 1875 Jourdannet issued his exhaustive work on 'The Influence of the Pressure of the Air on the Life of Man,' followed in 1878 by that of M. Paul Bert on 'La Pression Barométrique,' containing a large amount of experimental work. On these men rests the responsibility of the present unsatisfactory position in relation to our subject. In spite of much admirable work, and in spite of arriving, as I think, at the only right solution of the problem, they succeeded in handing down to all subsequent observers some of their mistaken ideas which, as time goes on and as fresh light is gained, only serve to magnify our difficulties and render more hopeless any definite conclusions.

It will be as well here to give the usual classification of the various symptoms which have hitherto been accepted as indicating mountain-sickness, or *mal de montagne*.

(1) General malaise.
(2) Tired feeling in the legs, or paralysed sensation in the lower limbs. (N.B.—We are told that if these symptoms have not gone too far, and the sufferer lies down, they improve!)

(3) Respiratory symptoms	Accelerated respiration, sometimes deep and full, at other times shallow. Oppression at the chest. Breathlessness on the slightest movement. (Lortet, Whymper, Freshfield, Conway, &c.)
(4) Circulatory symptoms	Accelerated heart's action, 80 to 100 pulsations per minute. If illness intense, 120–140 pulsations per minute. Throbbing of vessels of the neck. Sometimes rise of blood pressure. Sometimes fall of blood pressure. Sometimes bleeding from eyes and nose. In rare cases hæmaturia (Luzzato).
(5) Gastro-intestinal symptoms	Want of appetite. White tongue. Salivation. Nausea and vomiting. Colic and diarrhœa.

(6)	Symptoms connected with the nervous system	Giddiness. Intense headache. Intellectual faculties diminished. Indifference to personal appearance. Stupefied, having no ideas. Somnolence. Hallucinations.
(7)	Symptoms connected with body temperature	Rise of temperature (Whymper). Fall of temperature (Marcet, Lortet).

This classification is adopted by most scientific writers on the subject, and the list either in whole or in part is considered applicable alike to aeronauts, laboratory experimentalists, and mountain explorers.

It is admitted that these symptoms are not constant, do not appear in every individual, vary according to energy expended, age, &c., are not often all present at the same time, and the height at which they make their appearance is also extremely variable, generally about 10,000 ft., but often considerably lower. These are important admissions, and it is surprising that at least one obvious explanation of this inconsistency did not occur to the writers.

Putting aside the effects generally acknowledged to be rare, such as diarrhœa, hæmorrhages, hallucinations, &c., the symptoms thus grouped together are seen to be of a very usual type and common to many diseases and physiological states at sea-level, so that it is only in their relation to the special condition of altitude and diminished pressure that they call for any comment.

For instance, if we group together—

Accelerated respiration, deep and full;

Accelerated heart's action, 80 to 100 pulsations per minute;

Oppression of chest;

Aching of limbs which at the moment are doing most work;

Rise of blood pressure,

we have the ordinary symptoms of dyspnœa often following any form of severe muscular exercise.

If we group together—

General malaise;

Headache, varying in intensity;

Dulness of intellectual faculties--somnolence;

Accelerated respiration, generally shallow;

Accelerated heart's action, often 130 to 140 per minute;

Lowering of blood pressure;

Aching of limbs, especially those principally engaged in the work at the moment;

Nausea and vomiting,

we have the symptoms of fatigue after prolonged muscular work without adequate compensation in rest and food. These are the same all the world over, on the highest mountains as well as at sea-level.

If we group together—

Nausea and vomiting;

Colic and diarrhœa;

General malaise;

Perhaps some acceleration of pulse,

we have the ordinary symptoms of indigestion.

If we group together—

Shallow breathing, but not much accelerated;

Small, feeble, rapid pulse;

Dulness of the intellectual faculties;

Indifference to personal appearance;

Somnolence,

we have the symptoms due to cold and exposure.

Added to all this, the actual symptoms which are commonly present and acknowledged to be due to altitude are seen also in sufferers from anæmia, neurasthenia, commencing vascular degeneration, dilatation of the heart, &c., and as no line is apparently drawn by some writers between pathological (*i.e.* diseased) and physiological states on the mountains our difficulties are still further increased. The pathological state, however, known as anæmia is of immense value to us indirectly in the study of altitude-illness, though of course easily recognisable from it. The symptoms are precisely the same, and the analogy I hope to point out more fully on another occasion.

The earlier observers, and indeed many of those of the present day, take no account of any pathological weakness, difference in powers of endurance, want of training, age, &c., as affecting the results of laborious muscular work, but the fact that dyspnœa and its attendant discomforts are the most prominent and distressing effects produced in mountain-climbing, as well as in muscular overstrain due to any cause, soon sufficed to render the problem a very abstruse and complicated one, and necessarily furnished a wide field for discussion, calling forth the greatest diversity of opinions with the most convincing proofs in favour of many of them.

The three commonest forms of illness occurring on the mountains are ordinary physiological dyspnœa, the result of

exercise; physiological dyspnœa associated with fatigue, and less commonly indigestion. The first is accompanied by a rise of blood pressure, the second by a fall, which is also responsible for the symptoms of nausea and vomiting so often described apart from indigestion. So far no distinction has been drawn between these two varieties of dyspnœa, at any rate on the mountains, and the largest amount of error has centred round the confusion of these two physiological states which can never be mistaken at sea-level.

There are a large number of direct and indirect causes in connection with muscular and mental work at sea-level likely to give rise to fatigue, which are present in an excessive degree on the mountains; and since it is almost impossible for the body to balance exactly the income and the output with regard to food, we may, without knowing it, make overdrafts, from time to time, on our reserve as a matter of necessity. Therefore, until we have, at any given altitude, eliminated symptoms due to this cause, we are not justified in diagnosing our case as one of altitude-illness at all.

The very nature of the work in which we are engaged, even on ordinary Alpine expeditions, demands a large quantity of suitable and easily digestible food, and inasmuch as we have little time for rest after each meal it is all the more important that we should do our best to meet the necessary requirements, especially because immediately we recommence to climb the splanchnic reserve of blood is drawn upon to meet the demands of the muscular system. It is easy to see how symptoms of indigestion may soon make their appearance through carelessness or thoughtlessness in the matter of diet, producing nausea, vomiting, and even diarrhœa, and this condition may be aggravated after many hours of hard work by the supervention of fatigue affecting the stomach and so curtailing the supply of digestive fluids (Salvioli).

In this connection, the following cases are instructive:—

A man, aged 61, not accustomed to climbing, goes up Mont Blanc, and after a time suffers from dyspnœa with possibly the other symptoms of fatigue; we are told he has mountain-sickness due to altitude.

Or, again, a young man with healthy organs, but untrained and inexperienced in walking, goes up a mountain and suffers after a variable time from dyspnœa, palpitation, perhaps nausea and vomiting, accompanied by signs of some temporary dilatation of the heart. We are told he has succumbed to the altitude. A cyclist trying to beat the record on a measured track at sea-level shows the same symptoms, and we say he

suffers from fatigue. The cyclist is told that with proper training he will be enabled to undergo this special strain on his powers of endurance; yet the mountaineer, especially if he has come straight out from England for his first ascent after eleven months of muscular inactivity, is told that he will get acclimatised to this effect of the altitude.

A man who has never climbed before goes up Mont Blanc and suffers from hæmaturia. This is immediately recorded as an unusual symptom due to altitude, and takes its place amongst the circulatory effects. It is not an unheard-of thing to find cases of hæmaturia without any other symptom appearing at sea-level with no apparent cause, which passes off again in a few days, leaving no trace behind it.

The fact that vessels in certain parts of the body in some individuals are prone to give way, combined with the rise of blood pressure noticed in the earlier stages of severe muscular exercise, might sufficiently account for this unexpected symptom.

One physiologist gives the following case, which is too characteristic to be omitted.

A climber described as 'a fairly robust healthy individual in good training, without any cardiac defect,' went over the Col Ferret, and suffered at an altitude of 2,500 m. from tiredness, headache, malaise, nausea with retching, violent attack of sickness on arriving at destination, and dyspnœa. We learn also that this sufferer had partaken of a very heavy meal with too much wine the night before, followed by a very late retirement, thus procuring only a few hours' sleep. The dyspnœa of course being nothing unusual in any case, can we wonder that the other symptoms described above manifested themselves under the circumstances? And yet we are informed by this physiologist that 'this is one of the most characteristic cases of mountain-sickness which I have observed,' and he proceeds to enter into the pathology, adding also that 'the sumptuous dinner, the abundance of wine drunk, and the insufficient repose were the causes of the outbreak, and aggravated the character of the sickness.'

Similar instances could be multiplied from the works of Jourdannet, Paul Bert, Regnard, Mosso, and others, who, as physiologists, have attempted to deal scientifically with the observations made by mountain-climbers, and I could even give examples where some have gone out of their way to publish as mountain-sickness well-known pathological cases of illness with as typical symptoms as we find at sea-level.

To show the fictitious value placed upon single symptoms, as well as the undue prominence given to them—a method, by the way, always disastrous to accurate diagnosis—I will allude first to the phenomenon of hæmorrhages, especially from the nose, described by a large number of the earlier explorers during their ascents of the mountains, as well as by aeronauts.

It is a well-known physiological fact that severe muscular exercise produces at first a rise of blood pressure, which will be the more marked the more work we have to perform in a given time. This again must necessarily depend upon the amount of training and preparation for this severe muscular effort. As a result of inadequate training for a climb (a common condition at the beginning of a period of mountaineering), this rise of blood pressure may reach such a pitch that the weaker vessels are unable to stand the strain, and give way, leading generally to nose bleeding, &c., the amount of which necessarily varying with the powers of resistance of each individual to this increased pressure. Hence the appearance of hæmorrhages with some and not with others, and their subsequent non-appearance as the importance of training, &c., is more carefully attended to; but this has nothing whatever to do with altitude. We must all of us have noticed some time or other this symptom present in a greater or less degree on the mountains. How often one observes on blowing one's nose after violent exercise at any level some blood-stained discharge which, having never been sufficiently severe to cause actual flow, has become mingled with the ordinary mucoid secretion. This is nothing more than the finer vessels of the nose feeling the strain of increased blood pressure.

Similar importance is attached to a fall of blood pressure and dicrotic pulse (Jourdannet, Regnard, Mosso, Guglielminetti, &c.), which, as I have said, is only the usual accompaniment of fatigue after severe exertion, and is, as a rule, of no value as a symptom of mountain-illness, especially when considered alone. The hæmorrhages, however, described by aeronauts, where there is no question of rise of blood pressure due to muscular exercise, are very likely due to the mechanical effect of such sudden reduction of external pressure.

There are differences of opinion as regards the alteration of the temperature of the body on mountaineering expeditions, Lortet and Marcet demonstrating a fall, Whymper and others a rise, and Conway and others never observing anything above or below normal. Of course the temperature may rise

on the mountains as anywhere else, representing a symptom of many pathological states which, as I have indicated, are continually being put forward as examples of mountain-sickness, and there is such a thing as the fever of fatigue; but a fall of body temperature is a fairly constant symptom of severe fatigue after prolonged muscular exertion at any height.

Again, I have observed great stress laid on the fact of the mere acceleration of the pulse from 72 to 84, and from 90 to 100, and also of the rate of breathing from 11 to 12! Considering the perceptible difference in the pulse and respiration rates caused by emotion, slight exercise, &c., this increase is hardly surprising at any altitude, and does not merit such exaggerated attention.

Another single symptom which has excited a good deal of special comment is that of headache, and Mosso writes several pages on it in his work 'Life of Man in the High Alps.' Now, bearing in mind the uncertainty of its appearance, and the various physiological and pathological states which can fairly be brought forward to account for it even at sea-level, it seems remarkable that it should be given as a distinctive symptom of mountain altitude illness.

Again, the earlier writers attempt to fix a definite height at which symptoms of mountain-illness commence to show themselves; and when variations in this level occur they ascribe it to differences in climatic conditions. Thus, they fix the height at about 10,000 ft. in the Alps, higher in the Andes, and higher still in the Himalayas. But surely the height at which some symptoms occur depends in a great measure upon the altitude from which we start our expeditions, the extent of our previous training, and amount of rest. Experience teaches us that this is the case, for we find that the 'tourist' suffers—do not some writers confuse mountain-illness here with fatigue?—where the trained guide escapes.

Finally, as the years passed on since the complaint was first noticed and the number of explorers increased, there appeared at the same time greater facilities for training and saving of labour connected with mountain-climbing, and with this a corresponding lessening in the number of symptoms complained of by mountaineers, which is especially noticeable in the writings of the later English explorers, most of whose ideas and observations are well known to us. So remarkable is this reduction that at the present day we are in the habit of describing the symptoms of altitude-illness as—

(1) Lassitude and disinclination for exertion, while at rest.
(2) On the slightest movement—

Accelerated respiration
Accelerated heart's action
Oppression at the chest
Aching of the limbs which at the moment are doing the most work

= Practically the symptoms of severe physiological dyspnœa, due to any cause.

There is nothing unusual about these symptoms nor about their occurring on the mountains, but it is the possibility of some or all of them depending upon the altered condition of the atmosphere which establishes their claim to be considered a definite complaint; and one object of this paper is to show that the only illness which may prevent our ascending the highest mountains in the world probably consists of severe physiological dyspnœa, with the usual accompanying symptoms, due to the conditions of the atmosphere at very high altitudes. It is to-day, and always has been, in the first place a pure matter of diagnosis, and until this is correctly made all the experimental investigation with regard to the cause and treatment will be of no avail, and will lead to erroneous conclusions.

2. *Errors in connection with the pathology or physiological cause.*—It became the work of physiologists to deal with these symptoms from a scientific point of view, and, having once realised the possibility of such frequent errors in diagnosis, it is not very difficult to see how the way is opened for the widest difference of opinion as to the cause.

Considering the very ordinary nature of the symptoms above described, and the uncertainty as to other conditions besides that of pressure to which experimentalists were exposed, we see that sufficient scope is given for most of the arguments brought forward by every observer in favour of his own particular theory; some come off worse than others, but on the whole all receive a very satisfactory measure of support.

It is generally agreed that the cause of mountain-illness proper, if it exist at all, is due to some alteration in the surrounding atmosphere at high altitudes. The diminution of pressure produces two principal results: one is the mechanical pressure on the surface of the body is lowered, and the other is that there is a less quantity of each gas per unit volume of the atmosphere. It is probably safe to assume that we need only consider the gases absorbable by the blood.

In discussing the cause of the various phenomena some find a difficulty in assigning one only, and suggest that the

symptoms are produced as a result of many different causes, and in order to assist them in arriving at some definite conclusions, they turn their attention to experiments in which the same diminished pressure is accompanied by very various other conditions, and after observing a few points of similarity, and noting any success or failure of some line of treatment, argue from these deductions to the cause.

Some idea of the deceptive nature of considering merely the question of lowered pressure irrespective of other conditions may be gathered from the following table :—

Mountaineering.	Aeronaut.	Laboratory.	*Caisson.
Much muscular exertion.	No muscular exertion.	No muscular exertion.	No muscular exertion at the time symptoms likely to show themselves; but often preceded by exertion.
Gradual and slow change of pressure; the shortest time being several hours, leading to :	Abrupt change of pressure; often longest period 1 to 3 hours, leading to :	Abrupt change of pressure; often in from 10 mins. to 1½ hour, leading to :	Abrupt change of pressure; generally not longer than ¾ hour, leading to :
(*a*) Gradual reduction of pressure on the surface of the body.	Abrupt reduction of pressure on the surface of the body.	Abrupt reduction of pressure on the surface of the body.	Abrupt reduction of pressure on the surface of the body.
(*b*) Gradual removal of gases from blood.	Abrupt removal of gases from blood.	Abrupt removal of gases from blood.	Abrupt removal of gases from blood, which were previously present in excess.
Diminished pressure has to be sustained often for a very long time, several days.	Diminished pressure seldom has to be sustained longer than 2 or 3 hours.	Diminished pressure seldom sustained longer than half an hour; if very low pressure often only a few minutes.	The diminished pressure is the normal atmosphere, having previously sustained many hours of increased pressure.
When living several hours, and	No such opportunity for ac-	Less opportunity for	Often time not sufficient for

* This means return to ordinary atmospheric pressure after definite period of work under high pressure in caisson.

Mountaineering.	Aeronaut.	Laboratory.	Caisson.
especially days, at high altitudes, there is an opportunity afforded of acclimatisation both to mechanical and chemical effects of reduction of pressure; the latter change being mostly the increase in red blood cells and hæmoglobin.	climatisation, either mechanical or chemical, owing to the short space of time of sustaining pressure.	mechanical or chemical acclimatisation than in case of aeronauts.	mechanical acclimatisation; no need for chemical.
Difference of pressure which has to be sustained is a fall from about 1 atmosphere to ⅓ atmosphere on the highest mountains.	Same as for mountaineers.	Generally same as for mountaineers, though can produce pressure as low as desired.	Difference of pressure which has to be sustained is a fall often from $3\frac{1}{2}$ or 4 atmospheres to 1 atmosphere, under which circumstances the symptoms are found more likely to occur.

It is not surprising if we find the leading symptoms and the results of treatment different in the several classes of cases.

Mountaineering.	Aeronaut.	Laboratory.	Caisson.
While at rest lassitude and disinclination for exertion, with dyspnœa and its accompanying symptoms on the slightest exertion, but never loss of power to perform voluntary movement.	At great altitudes dyspnœa, &c., while at rest and on exertion; and finally powerlessness to perform voluntary movement.	Same effect as in aeronauts.	Never dyspnœa, but symptoms of distinct paralysis due to pathological change.
Inhalation of oxygen not yet proved successful up to altitudes at present attained.	Inhalation of oxygen completely successful up to 34,000 feet.	Inhalation of oxygen has same result as in case of aeronauts.	As there is ample oxygen already, inhalation is of no use.

The only similarity in conditions and symptoms lies between aeronaut and laboratory cases, and deductions based on the hypothesis that these four complaints are due to a common cause or causes must prove erroneous in the light of this analysis, and yet this is the most usual form of reasoning met with in nearly all physiological works on the subject. Even Dr. Hermann von Schrötter, whose paper written in 1899 is freer than any previous one from this method of argument, falls now and then into the old errors, which makes his otherwise valuable contribution a trifle ambiguous in a few places.

Although many theories have been propounded since 1590, none of them were sufficiently comprehensive until that of anoxyhæmia was put forward by Jourdannet in papers dating from 1861, which ultimately appeared in 1875 in the form of an exhaustive work on the subject. This received strong support from M. Paul Bert by a series of remarkable experiments recorded in an equally impressive volume published in 1878.

This theory, however, was not found to account for many of the symptoms noticed on the mountains, to which I have already alluded; some physiologists argued that as Jourdannet and Paul Bert had established the fact that inhalation of oxygen relieved their symptoms in the laboratory and on balloon ascents, which they could not deny, therefore it ought also to relieve all symptoms of whatever nature attacking mountain explorers.

Most observers respect Hüfner's experiments, and also those of Setschenow, and Fränkel and Geppert, and which go to show that oxygen is not given off from the blood in any considerable or injurious quantity until the pressure equals that found at 30,000 feet; but they argue that as symptoms of *mal de montagne* show themselves at much lower altitudes which are not relieved by inhalation of oxygen, therefore lack of oxygen cannot be the only cause, and there must be other causes acting in conjunction with it.

In this way the mechanical effect of diminished pressure received a large measure of support, especially from G. von Liebig, Lœwy, Guglielminetti, and others; and even if it did not answer to every requirement it was urged that at any rate it ought to receive some consideration. This led to theories of anæmia of the brain (Lœwy), and interference with the mechanical action of respiration producing some hyperæmia of the lung (von Liebig).

Others, such as Cyon, Mosso, and Gavarret, who have

satisfied themselves that the mechanical effect need not be considered, and yet that lack of oxygen is not sufficient to account for *all* symptoms, were forced to turn their attention to other gases held in solution in the blood and which were found to vary at high altitudes. Thus Gavarret put forward his theory of excess of CO_2 in the blood, and Mosso that of 'acapnia' suggested earlier by Cyon, and Mosso claims to have proved that he was enabled to sustain a lower pressure in the presence of an increased quantity of CO_2 than by the inhalation of oxygen alone. This, we shall see, is not justified by his experiments; and, besides, bearing in mind the relation of CO_2 in the inspired air to that dissolved in the blood—viz. chiefly in solution following the ordinary law of solution of gases in liquids—we should expect to find, on the one hand, the amount of this gas diminish more at high altitudes than does oxygen, which is more intimately held in physiological combination; while, on the other hand, since CO_2 is the product of muscular work, and thus tends to accumulate in the blood, we should expect to find it vary according to the amount of work performed on the mountains. These two causes acting separately or together would produce very wide differences in actual figures obtained by experiment, and amongst those who have made observations with this gas (Lepine, Mermod, Gavarret, Lortet, Marcet, P. Bert, Mosso, &c.), this is found to be the case. Therefore we receive Mosso's results with a considerable degree of scepticism, and he himself found that this theory was not sufficient to account for all symptoms, such, for instance, as those of fatigue which he always includes in *mal de montagne*, and he was compelled to search for some other cause.

Now, in fatigue there is general nerve depression, in which amongst others the vagus takes part, leading to the very symptoms he wishes to account for; and, although he does not say how this 'partial paralysis' is produced, he qualifies his theory regarding CO_2 by inferring that another cause in operation in these cases is this effect upon the pneumogastric nerve.

When neither a mechanical nor a chemical theory was sufficient to account for many of the so-called variations in the symptoms, other conditions apart from reduction of pressure, such as 'influence of fatigue,' 'influence of cold,' 'influence of training,' were brought in in order to fill up any deficient points. Thus we find Mosso stating that 'the two best known, and I might also say popular, causes of mountain-sickness are fatigue and indigestion,' and also 'sometimes

mountain-sickness appears as the consequence of a simple emotion'!

In consequence, then, of the failure to consider the very different conditions under which the experiments were performed, and the physiological differences between the various subjects of experiment, results were obtained by the several experimentalists which appeared to support the following very different theories of mountain-illness:—

Mechanical	Anæmia of the brain (Lœwy). Interference with the mechanical action of the expansion of the lungs (von Liebig). Plea for mechanical theory of some sort (Guglielminetti). Some great circulatory disturbance (Vergara, Lope).
Chemical	Anoxyhæmia (Jourdannet, Paul Bert, Regnard, Roy, von Schrötter, &c. Increase of CO_2 in the blood (Gavarret). Decrease of CO_2 in the blood (Cyon, Mosso).
Physiological (only)	Paralysis of pneumogastric (Mosso). 'Influence of fatigue.' 'Influence of cold.' 'Want of training.' Fatigue alone (Bouguer).

3. *Errors in connection with acclimatisation.*—The misrepresentation of symptoms leads to errors in the question of acclimatisation. Thus the man who suffers from fatigue (called by some mountain-sickness) on his first expedition, owing to insufficient training and other causes, soon recovers after a night's rest either at the altitude at which he suffers or on descending to comfortable quarters. This recovery, which is entirely independent of the height, is attributed to acclimatisation, more especially if he escapes later on at the same altitude, as a result, of course, of being in better training. It generally takes from ten to twelve days to get into condition if there has been no opportunity for the necessary training previous to the commencement of mountaineering expeditions, and this is the period generally given for so-called acclimatisation. The disappearance of isolated symptoms after a definite time, which is not an uncommon occurrence at sea-level, lends more weight to the argument.

Acclimatisation has to be considered from two points of view, the mechanical and chemical, which may act separately or together; but it is a question whether the former need be recognised at all, and there is much to be said in favour of

entirely ignoring any influence from the mechanical side as applied to lower pressures than the ordinary atmosphere. It seems to be generally accepted as having much to do with the change from higher pressures to that of the ordinary atmosphere, as in caisson disease, especially when the pressure is more *rapidly* reduced than it ought to be.

Now in laboratory and aeronaut experiments very low pressures are attained in a very short space of time, more particularly in the former, where we can reduce the pressure to as low as 60,000 ft. in about fifteen minutes. Under the circumstances, so long as the subject of the experiment is inhaling oxygen, no discomfort is felt; and the fact that a much longer time is taken up in attaining a more moderate elevation on the mountains supports us in the idea that we need not fear the mechanical influence of reduction of pressure in mountain exploration. Nature anticipates the chemical changes due to altitude, and makes attempts at acclimatisation by increasing the number of red blood corpuscles and the amount of hæmoglobin (Viault, Egger, Miescher, Regnard, Oliver, Buckmaster, &c.), the change commencing at very moderate heights, and occupying comparatively little time. In the case of mountaineers in the higher ranges this process has plenty of time to act where the need for oxygen is anticipated, and thus the development of symptoms due to lack of oxygen may be postponed, and with care we may be enabled to reach the altitude we desire; but there is no time for this process to take place in cases of rapid reduction of pressure, so that in aeronauts and laboratory experimenters acclimatisation to the sudden removal of oxygen from the blood cannot occur, and the avoidance of symptoms must be purely a matter of treatment. These efforts of nature to combat the chemical changes due to difference of pressure must not be confused with the disappearance or non-appearance of symptoms at inconsiderable altitudes due to extra precautions as to training, diet, &c., so often given as examples of acclimatisation (Jourdannet, &c.). Another feature of true acclimatisation, and one which has not been sufficiently recognised, is the power of the human organism to accustom itself to a smaller quantity of oxygen than usual, thus educating the tissues to moderate their demands. And here alone, as far as I can see, is the analogy between altitude-illness and sea-sickness (Jourdannet, Conway, &c.), where one gets used to the feeling of the motion, but it more than any other leads to the error of confounding this effect with the results of training, and so another complication

finds its way into the study of the subject, for the explanation of which several suggestions are brought forward.

4. *Errors in connection with treatment.*—These must necessarily vary according to the number of theories, and according to the value set upon isolated symptoms or groups of symptoms; and hitherto it has been the custom to work out this part of the subject by noticing the relief obtained by aeronauts and laboratory experimentalists from any special line of treatment, and then by applying it to mountaineers as soon as they begin to suffer from symptoms of any sort, although the conditions under which the former suffer may be totally distinct from those of the latter. Moreover, should the original diagnosis prove incorrect, the treatment fixed upon may give disappointing results, so that erroneous opinions may be formed of its efficacy and it is condemned as a failure. On the other hand, many lines of treatment are recorded as successful, where by carefully examining the details of the experiment there is no justification for any positive statement.

An example or two will best indicate what I mean. After a rapid ascent a man shows symptoms of severe dyspnœa, &c., as a result of excessive exertion; he is supposed to be suffering from 'mountain-sickness,' and is at once treated by oxygen inhalation, which fails to relieve the distress. The treatment is thereupon declared to be useless, when in reality the fault lies in the diagnosis.

Again, a subject sustains a pressure of 336 mm. when he suffered, and subsequently one of 246 mm. without much discomfort. On the first occasion the analysis of the air he was inspiring showed 19·9 per cent. of oxygen and 0·9 per cent. of CO_2; on the second occasion the inspired air consists of 17 per cent. of oxygen and 2·2 per cent. of CO_2. The supporter of the theory that deficiency of CO_2 in the blood is the cause of 'mountain-sickness' concludes that the presence of 2·2 per cent. of CO_2 enables the experimenter to withstand the lower pressure without discomfort, although there is less oxygen; whereas another explanation is that the experiment merely proves that with a liberal supply of oxygen we are capable of sustaining a pressure of 246 mm. for a short time while at rest, even in the presence of 2·2 per cent. of CO_2, a fact well known to be possible! Added to this, we know that we are capable of enduring for a short time very low pressures without any treatment at all and without suffering much discomfort so long as we are at rest; and on this account the results of many experiments where some definite line of treatment is

being carried out appear more successful than they really are. Again, it is said that training, attention to food, avoidance of cold, &c., all combine to ward off the symptoms of 'mountain-sickness,' whereas the attention to these details merely places the symptoms due to fatigue and exposure as remote as possible.

No wonder, then, the impression produced in the minds of many people is that the subject is very complicated and requires a complicated explanation; but the time has surely come when, by carefully using the ordinary means of diagnosis, we may simplify our work immensely.

In conclusion, I regard the mistaken ideas in connection with the science of altitude-illness as arising from the failure to recognise the following facts:—

1. That there is ample evidence to show that the functions of the body are not interfered with up to a very considerable altitude (certainly as high as 16,500 ft.), and that its physiology, especially in relation to fatigue after prolonged exertion, ought to be studied and treated under precisely the same conditions as in the plain.

2. That all forms of illness produced by reduction of pressure, whether at sea-level, on the mountains, or in a balloon, must not be discussed from one common standpoint, regardless of any difference in external or internal conditions.

3. That up to the present no systematic attempt has been made to distinguish between the different forms of illness occurring on the mountains which show a series of similar symptoms, though the idea has been suggested by Lortet, Lœwy, and von Schrötter, and that it is primarily a question of diagnosis, the incompleteness of which has given rise to the present complications and difficulties.

4. That, owing to this imperfect diagnosis, the symptoms of fatigue, those produced by diminished pressure under all conditions, and those due to climbing at very high altitudes, have all been taken as indicating one and the same complaint —viz. mountain-illness (Jourdannet, P. Bert, Regnard, Mosso, &c.).

5. That this same imperfect diagnosis leads to wrong conclusions regarding the cause and treatment of altitude-illness.

6. That by careful investigation of symptoms and the conditions under which they occur, altitude-illness as it appears on the mountains can be isolated as a complaint distinct from any other, with its own pathology and treatment.

My own provisional views are as follows:—

I. That, after eliminating the symptoms of both direct and indirect fatigue, the illness consists of severe physiological dyspnœa, with its usual accompanying symptoms, occurring under special circumstances.

II. That, in all probability, this dyspnœa is concerned with some chemical relation between the oxygen of the air and the interchange of gases in the lungs.

In support of II. it may be remarked:—

(*a*) That the balance of evidence is against the influence of any mechanical effect whatever from the change of pressure as applied to mountaineering alone.

(*b*) That the symptoms show a striking resemblance to those of anæmia at sea-level. Now, in the case of anæmia, the cause is most certainly the poorness of hæmoglobin in the presence of an adequate supply of oxygen; whereas in climbing at high altitudes we find richness of hæmoglobin in the presence of a poor supply of oxygen.

It may be that, granted time for acclimatisation by the increase of red blood corpuscles and hæmoglobin, and by the power of the tissues to accustom themselves to smaller quantities of oxygen than normal, we have only to deal with ordinary dyspnœa on the least exertion (and later fatigue after prolonged exertion) coming on sooner than usual owing to the inadequate supply of oxygen, but even so we have yet to prove that dyspnœa and fatigue are dependent on lack of oxygen at any level either directly or indirectly, though the probabilities are in favour of such a theory.

These are some of the points for experimental research, about which I hope to be able to furnish some communications on a future occasion; but, in the meantime, those interested in the subject will find a good foundation laid for any further opinions by studying the speeches of Dr. Norman Collie and Dr. Buckmaster at the meeting referred to at the beginning of this paper (see 'A. J.,' May 1901).