Altitude Sickness and Climbing

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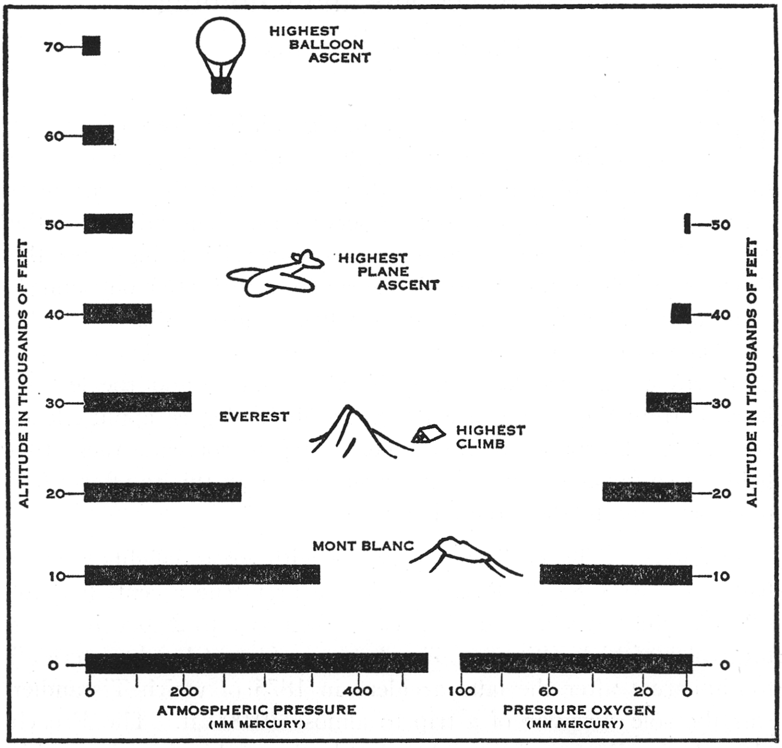
UNTIL quite recently the effects of high altitude were of interest and importance only to that small school of fanatics who make the summits of high mountains their goals, and there was little scientific work to confirm their observations. The advent of the plane, the breath-taking advance of commercial flying, and the threat of modern war have all enormously increased our understanding of what happens to a man when he goes high.

Plane ascents and pressure chamber studies are short-term experiences of the problems faced by the climber, and the lessons learned from the former are to only a slight degree applicable to the latter. I propose in this paper to try to correlate these two fields in so far as they are comparable, and from this to offer a few practical hints to the mountaineer.

Historical. The earliest experience with great heights was in balloons. In 1783 de Rozier made the first true ascent, but not till 1862 did Glaisher and Coxwell in their rise to 29,000 ft. enter the realm of high altitude. The dangers of great heights were all too apparent after the fatal accident in 1875 of which Tissandier was the sole survivor of a trip to almost 30,000 ft. The French physiologist Bert, saddened by the deaths of his friends in this tragedy, made the first scientific studies of altitude, and much of his work is still valid today. Berson, using oxygen, survived a trip to 36,000 ft. in 1894, and since that time man's "ceiling" has been steadily rising. In 1934 Donati took an open-cockpit plane to 47,358 ft., using oxygen of course, and the following year Stevens ascended to the phenomenal height of 72,395 ft. in the sealed gondola of the balloon "Explorer II." In the last ten years a great deal of work has been done in pressure chambers, where the total air pressure is reduced by pumps to levels corresponding to different heights, and in tents where nitrogen is used to dilute the air and give percentages of oxygen which are found at great heights.

All of these studies, and all of our experience confirm the theory suggested by Bert: that the low pressures of high altitude are unimportant to the body; it is the *percentage* of oxygen in the air breathed which is so important.

Altitude Sickness. Again may I emphasize that there is little comparison between brief and rapid flights to high altitudes and the



longer, slower climbs to the same levels made by mountaineers. Certain lessons learned in one may, however, be of use in the other.

The dreadful nausea and its results which many of us have experienced early in a climbing season, and the uneasy sensation we hate to admit during a rough plane trip are not true altitude sickness. In the first our poor stomachs are rebelling against cold, exposure, too violent exercise without training, change of food and water, and a little fear of high places. In the latter, motor noise and vibration, vertigo from stimulation of our balancing apparatus, excitement and apprehension are the precipitating causes of our distress. It may safely be said that altitude is not important until above 9000 ft. or higher.

Acute altitude sickness is a very modern and rather uncommon disease, because only recently and with a few planes have we been able to climb at the rate of more than 5000 ft. per minute which causes the illness. At this literally breath-taking rate of climb a man is unaware of any difficulty until suddenly, at from 15,000 to

18,000 ft., the lights go out. Usually there is little or no warning before the sudden unconsciousness, and none of the symptoms to be described below are present. It is due solely to lack of oxygen in the blood, which of course cannot provide more oxygen than it can pick up from the air in the lungs. Obviously this is of no importance to the climber, and of little danger to the average flier, for he can prevent coma by using any of the many oxygen apparatuses to increase the oxygen he breathes. Another interesting factor enters, however, when the speed of climb is greatly increased.

Nitrogen which makes up almost 80% of the atmosphere is dissolved in the blood and tissues just as is any other gas. When a deep-sea diver comes to the surface from, say 150 ft., where he has experienced a pressure five times as great as on the surface, then bubbles of nitrogen appear in his blood and tissues just like bubbles in a freshly opened bottle of soda water, and the well-known "bends" is the result. Parallel to this is the case of the flier who climbs rapidly to over 20,000 ft., but in the air he must go much higher before the bends appear. In the pressure chamber 26 men have gone as high as 16,000 ft. in six seconds, at the unbelievable rate of 160,000 ft. per minute, yet no ill effects have been suffered. But at 18,000 ft., climbing at the rate of 5000 to 10,000 ft. per minute produces bubbles in the spinal fluid with headaches and brief paralysis as the result. Not until 28,000 to 30,000 ft., at this rate of climb, do bubbles appear in the blood. Although the bends depends on the rapid decrease of pressure entirely, it is possible to wash nitrogen out of the blood by breathing oxygen for a period before the rapid ascent, and oxygen, being used by the body, will not produce bends. This problem is more complicated in practice and may be insuperable in extremely high military maneuvers.

At rates of climb between the very fast and the very slow opinion differs as to the effect of altitude. In general it may be said that the nervous system is the first to be affected when the speed of ascent is from 3000 to 10,000 ft. per minute, resulting in fainting and convulsions, whereas at slower speeds the circulation shows the first effects. It has been found, for example, that a man can go to an altitude of, say 16,000 ft., with *fewer* symptoms if he goes at the rate of 8000 ft. per minute than if he goes at 2000 ft. per minute. This is quite the opposite of what we would expect from experience in climbing where the speed is of the magnitude of 10-15 ft. per minute. Individual variation is very noticeable in this particular.

Chronic altitude sickness is probably the better name for mountain sickness and for altitude deterioration. It too is entirely due to oxygen lack, though, as pointed out above, mountain sickness as we know it is due to a combination of factors in which oxygen lack may or may not be important. The disease is seen in subjects who have an inadequate oxygen supply over a long period of time, and may be due to a block between the circulation and the tissues that use the oxygen, to damage to the enzymes which are active in metabolism, or to the change in certain glands of internal secretion. Some aspects of this illness resemble Addison's disease, due to lack of adrenal hormone, but whether or not prolonged oxygen lack does actually damage the adrenal tissue remains a fertile field for future work. A small percentage of persons who spend months or years above 15,000 ft. suffer from chronic altitude sickness, although others of the same bodily and racial characteristics remain unaffected at the same altitudes for years. Aviators who fly at high altitudes frequently during a long period of time, and other fliers, or test subjects in pressure chambers who go high very often in a shorter period, all these groups are subject to the illness. Probably chronic oxygen lack is responsible for the deterioration which has been noticed on the great Himalayan peaks after a long stay at the higher camps.

The symptoms are subtle and severe, increasing in degree as the disease persists. Sleeplessness, nightmares, indigestion, loss of appetite, loss of initiative, mental and physical apathy, irritability, and loss of strength are noted early. Weight loss, diarrhea, hallucinations appear later. Fortunately the critical faculty suffers also, and the individual rarely appreciates how markedly he is affected. This is a striking feature of the disease, commented on over and over again by observers who have had the chance to study subjects suffering from oxygen want while they themselves were adequately supplied. Judgment is greatly changed as is initiative, and it is the highest faculties which are impaired first. For example a normally sweet dispositioned man may be irritable, pugnacious and unreasonable at heights, he will lose all interest in his diary, in his photography, in any studies he may undertake. His memory becomes very uneven, his enthusiasm wanes. Reaction times have been shown to lengthen with increasing altitude as has perseveration time. In short the man is completely changed and may not know it.

Later, if the crying need of the body for oxygen is not answered, the heart and circulation fail. The pulse, which has become more rapid with altitude, may become thin, irregular, the blood-pressure falls, the color of the skin darkens to purple, and chronic congestive heart failure results. A few actual cases of this late stage have been seen, but needless to say, most men do not stay at great heights long enough to reach this stage.

It is important to note that this disease may affect men who go to considerable altitude frequently and return to sea level, to those who remain high for a long time, or to those who are unable to tolerate moderate altitudes. In other words, frequent ascents to high altitudes with return to sea level between ascents after only a short stay will not increase the power to adapt to the heights. We cannot say for certain whether a climber who has been high on several occasions is better able to go high again as a result; what evidence we have suggests that the experienced climber goes through the same processes of acclimatization every season, but having once been able to acclimatize makes him able (though not more able) to do it again. Nor is there convincing proof that a man acclimatized to moderate altitudes is much more capable at, say a mile higher, than the man who is acclimatizing with sea level as a starting point. The Tibetan porters on the Himalayan peaks have not been outstandingly better than the Europeans in their reaction to the great heights.

It is also important to note that different individuals are affected at different levels and after different lengths of time. Many methods have been suggested to predict a man's ability to adjust to altitude, but no clear-cut formula has been found. Studies of natives who live at 18,000 ft. and are so well acclimatized that they play soccer there have not given the whole picture. Good physical health is essential, obviously. A lung which is normal in structure and in function is also a *sine qua non.* Normal blood and blood-forming organs are necessary if the body is to adjust, and a strong heart and circulation must also be present. Age by itself cannot be said to play a constant rôle, and a man whose heart and blood vessels are younger than his chronological years will do as well as his younger companions. But in general there are few men over fifty who are capable of performing hard physical work at altitudes above 20,000 ft.

ACCLIMATIZATION. Adaptation of man to high altitudes is an outstanding example of the flexibility of the body's precise physiology.

If an unacclimatized man be taken quickly to 27,000 ft. he is certain to die within a few hours without oxygen; yet acclimatized men have lived and done hard physical work at this height for several days. A man coming to 17,000 ft. from sea level in a few hours is almost incapacitated for many days, but natives in the Andes live most of their lives at 18,000 ft. and are able to play soccer for recreation.

How acclimatization is accomplished is far from clear, but many factors are involved, among them some of the most delicate chemical balances in the body. One of the better known changes is the increase in the red blood cells or oxygen carriers which takes place as acclimatization proceeds. It is not uncommon to find the normal level doubled in men habituated to life at 15,000 ft. or higher, and this increased number of carriers is able to transport more oxygen from lungs to tissues. Recently it has been shown that the increase in red cells may begin after only an hour in the low-pressure chamber, and from the scanty data at hand it may be supposed that this increase continues. Yet even this straightforward change is not uniform: a fair number of acclimatized natives in Peru have normal levels, and on the Everest trips it has been found that some of the well-acclimatized Tibetans have much lower red cell counts than the poorly acclimatized Europeans. It may be that this particular change is but one of many, and the increased efficiency of one of the other changes may make the red cell change unnecessary.

There is a shift in acidity of the blood by loss of certain radicals which enables the hemoglobin in the red cells to be more efficient in carrying oxygen. There is a change in metabolism so that the tissues burn less oxygen, as if the flame were turned lower in a lamp. The pulse rate is increased at rest and shows a greater increase with work than does the pulse at sea level, thereby bringing a little more blood to the tissues. Muscle hemoglobin may be increased; the adrenal glands may also be involved. The percentages of the different gases in the lungs are slightly altered in the direction to make hemoglobin more efficient. These are a few of the changes we have measured; others more delicate doubtlessly exist.

I should mention here that increasing the rate of breathing not only does not bring more oxygen to the blood, but also washes out important carbon dioxide from the lungs and causes a serious change in blood chemistry.

TREATMENT. There is a specific cure for simple altitude sickness—oxygen. Low pressure *per se* is not harmful, and oxygen lack is the major problem except under the exceptional circumstances of very rapid ascents as in fighting planes. Air sickness, due as is sea sickness to mechanical factors, is treated with sedatives; some of the airlines provide a light meal during flight and this may be of considerable help. Mountain sickness below 9000 ft. is due to other factors than oxygen lack; above this level oxygen is of but little help until the more critical level of 12,000 ft. is reached and oxygen need is more marked. Acclimatization cannot be hastened by any means we now know. Some have suggested iron and liver to increase the production of red cells, but the body is already producing increased numbers of these oxygen carriers under the strongest possible stimulus: oxygen need, and if the diet intake of iron is normal, addition of other stimulants to the intake will not help. Repeated ascents in planes or in the pressure chamber not only do not help but may actually hinder the process as shown above. The German aviators have been kept in residence in the Alps in preparation for high altitude flights, but the value of this is not certain.

For practical purposes for climbers a slow steady ascent without descents of any height is the best method of obtaining acclimatization to high altitude, *i.e.,* above 12,000-15,000 ft. Experience indicates that moderately heavy work decreasing as height is gained makes acclimatization more complete and rapid, but too heavy work may exhaust without helping. The two American expeditions to the Himalaya have done heavier work at the lower altitudes and have had less altitude difficulty than have the Everest parties; granted however, that the latter have gone higher. For high altitude deterioration some expeditions have used rest periods at base camp after a stay at high camp; the value of this is uncertain. It is my opinion that slow steady ascent with gradually decreasing pack is more valuable than a climb interrupted with "vacations" at base camp. Theoretically, oxygen might be used for a short period each day while in high camp in order to delay deterioration. Unless it were practical to carry enough oxygen to give a continuous supply during work, which seems more than unlikely, I believe it is neither desirable nor necessary to use it on the great peaks, except as mentioned above, it might be employed prophylactically in camp. Given a strong capable party and good conditions I believe Everest will be climbed—without oxygen.