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29,000 Feet

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UNTIL a man actually stands on the summit and returns to tell about it, no one will know for certain that Everest can be climbed. But ignoring the technical climbing problems, one can speculate on the physiology involved and perhaps reach certain conclusions.

The war has made high altitude flight a commonplace. Ten or fifteen years ago 30,000 ft. was a remote and seldom attained height; today tens of thousands of military plane crews have flown even higher. Before the war there were perhaps a dozen steel altitude chambers in the entire country, while today hundreds of them are in constant use. All military flying personnel are trained for altitude flight by at least one simulated "flight" in these chambers to altitudes of 30,000 ft. and higher.

It is not surprising, in view of this extensive altitude experience, to find that our knowledge of the body's response to altitude has increased enormously. Not that we have discovered many new facts which Paul Bert, Barcroft and others did not know thirty or fifty years ago—we have merely polished up, refined, and learned to understand them better. Having spent the past four years in altitude training and research, I should like to try to apply some of these facts to climbing.

When the military pilot takes his altitude training "flight" in an altitude chamber, he may be allowed to remove his oxygen mask at 30,000 ft. or thereabouts. Within a few seconds he begins to fumble over simple tasks, becomes ludicrously and pathetically "drunk" and in less than two minutes loses consciousness. After two or three breaths of oxygen he has recovered completely, none the worse but much the wiser. The higher the altitude, of course, the quicker his collapse, but even as low as 18,000 ft. his condition is far worse than at sea level. His nails are blue from lack of oxygen, and he feels sleepy, dizzy, perhaps hilarious. Even simple problems baffle and irritate him, and his judgment is poor, his emotions unstable. He is certainly far different from the acclimatized mountaineer who feels little effect as high as 23,000 ft.

The difference is, of course, due to acclimatization—that delicate adjustment of the body to oxygen lack. Most climbers who reach altitude slowly, working as they climb, are eventually able to spend weeks above 20,000 ft. and perform strenuous physical work. On the other hand, the unacclimatized man taken in a few minutes or hours to high altitude from sea level, has only minutes of rapidly failing consciousness as is dramatically shown in the following table:

DURATION OF CONSCIOUSNESS AT ALTITUDES

Altitude	*Acclimatized Man*	*Unacclimatized Man*
20,000 feet	weeks*	30 minutes
23,000 feet	weeks	15 minutes
25,000 feet	at least 10 days	8 minutes
26,000 feet	at least 5 days	7 minutes
27,000 feet	at least 3 days	5 minutes
28,000 feet	several hours	3 minutes
30,000 feet	?	1½ minutes

* Remember that these figures represent the time that climbers have actually spent at these altitudes *without* losing consciousness.

A complete discussion of the intricate processes of acclimatization is obviously beyond the scope of this paper, but among the many changes which occur, three may be mentioned briefly: The red blood cells increase in number, thereby providing more transportation to carry oxygen from lung to tissues. The volume of breathing is increased in an effort to bring more oxygen deep into the lungs and thence into the blood. And finally, the increased breathing, by "blowing off" carbon dioxide (carbonic acid gas), makes the blood more alkaline, which in turn increases the amount of oxygen which the blood can hold.

At present we have practical means to control only the second and third of these processes. Years ago physiologists knew that over-breathing would decrease the effects of oxygen lack. But if the over-breathing were too great and too much carbon dioxide were lost, the blood became so alkaline that dizziness, pins and needles, and later muscle cramps resulted. Too much over-breathing might thus be worse than lack of oxygen.

Many recent studies have shown, however, that if the breathing is increased only slightly above what the body dictates, it is possible to stand safely between the Scylla of oxygen lack and the Charybdis of carbon dioxide lack. One of the truly dramatic demonstrations developed by aviation medicine is the difference between a man breathing normally and a man over-breathing slightly, at 25,000 ft. The former is incapacitated in five minutes and unconscious in less than ten, whereas the latter can move freely about the plane, perform his work, and remain in good condition for 45 minutes or longer.

It remains for some one to show us whether or not over-breathing will help the acclimatized mountaineer as much as it helps the unacclimatized pilot. In the case of the climber, acclimatization has already increased his breathing somewhat (though individuals differ considerably in this) and how much good he can obtain from further increase is speculative at best. But we do know that the pattern of breathing may be as important as the depth. Smooth rhythmic breathing, with inspiration about equal to expiration, at the rate of twelve to fifteen a minute probably gives the optimum oxygen supply to lungs and blood. Thus the scientists confirm what climbers and distance runners have known for years: smooth rhythmic breathing is of great benefit for optimum efforts.

Are there any methods for predicting or for improving the ability of a man to acclimatize? Aviation medicine has not helped us much in this respect, for acclimatization is really not practical for high altitude flying, in which the pilot ascends in a matter of minutes to heights which climbers reach in days or weeks. No tests have been developed recently which are better than that by which Harrop, in 1922, predicted which members of a Peruvian expedition would suffer from mountain sickness* and which would not. His method is a bit cumbersome and complicated, however, to apply to any man who is interested in learning his altitude potential. The ability to withstand lack of oxygen in an altitude chamber is no indication of acclimatizing ability, because this process requires weeks rather than minutes. And finally, none of the physical fitness

* It might be well to emphasize once again that *mountain sickness* occurs only at altitudes above 10,000 feet and is due to lack of oxygen. *Air sickness,* like sea sickness or car sickness, is due to rough motion and occurs at any altitude.

tests can be used with confidence, because fitness and ability to acclimatize are not necessarily linked. However, many small pieces of information, plus the Himalayan experiences of the past ten or fifteen years, indicate strongly that acclimatization is not much better in youth than it is in middle age. In fact many men under 21 withstand altitude less successfully than others over 28. There is good reason to believe that 22 to 35 is the optimum age for acclimatization, but that even up to 40 or 45, age *per se* does not decrease acclimatization ability.

The ability to tolerate altitude can, however, be improved by several means, and this may be of considerable help to Everest climbers. The controversy over the best foods for climbers which has raged for years and almost disrupted several expeditions seems to have been fairly conclusively settled recently. It has been shown experimentally that carbohydrates (sugars and starches) increase altitude tolerance by 1000 to 5000 ft.—in unacclimatized men. Theoretically the explanation for this effect should also apply to acclimatized men, though the demonstration remains to be made. The reasoning behind this effect is sound though too complex for this paper. Of course it is well known that carbohydrates are an excellent source of rapid energy. On the other hand it cannot be denied that men need proteins and fats to replenish constantly breaking down tissues, particularly during hard work.

An ideal arrangement would therefore appear to be a diet which is almost exclusively carbohydrate during the working day, when energy is needed and when any protection will be of help. In the evening, when the day's work is done and the need for oxygen less acute, proteins and fats can be the main part of the meal, to rebuild the body. Finally, quite apart from altitude, other considerations indicate that frequent small feedings (every two hours or so) are far more effective than fewer but larger meals. This is particularly helpful at altitude where the stomach, laboring under difficulties anyway, should not be over-burdened by large meals.

Vitamins on the whole have been oversold to the public. Though these mysterious compounds work wonders in certain specific deficiency diseases, they definitely do not "increase resistance" or "prevent colds" in the average man. For the climber, on a long expedition, they may, however, be of value, since his dietary is by necessity somewhat limited. Furthermore we do know that the vitamins B and C are indispensable catalysts in the use of oxygen by the tissues, and bits of evidence, as yet fragmentary, indicate that altitude tolerance may be improved by adding these vitamins to the diet. This means that the high altitude mountaineer, in addition to a normal quota of vitamins added to his diet, will probably benefit by larger doses of vitamin B complex and vitamin C.

What about other drugs? Years ago ammonium chloride was proposed, and used, to improve altitude tolerance. The rationale behind its use was logical, but the effects were disappointing in most cases. Bicarbonate of soda, suggested for entirely different reasons, is probably no better. No new "secret" drugs studied during the war have been revealed nor is it likely that any will be found which significantly raise man's ceiling.

In any discussion of the 28,000 and 29,000 ft. peaks the use of oxygen is inevitably brought up. In aviation, the pilot knows that life above 20,000 ft. is impossible for more than a few minutes unless he breathes oxygen. To the flight surgeon dealing with aviation problems, it seems incredible that oxygen should not be a *sine qua non* on any major peak. Even in acclimatized men, he argues, oxygen should give an added lift, an extra source of energy which might get the climber to the top. Why then have several who used oxygen on Everest claimed that they obtained little if any benefit from it? Were their statements biased by the bulk and discomfort of the apparatus then available? Or did the oxygen, in fact, fail to relieve their worst difficulty—the dreadful shortness of breath which resulted from the slightest exertion?

Lack of oxygen itself exerts a relatively weak influence on breathing. A man may lose consciousness and even die without being anywhere near as short of breath as a distance runner. Breathing is largely controlled by the balance between carbon dioxide and base in the blood. During exercise, large amounts of carbon dioxide, and other acids, are formed which must be neutralized by the blood or blown off through the lungs by deeper faster breathing. After hard work, therefore, we pant to blow off carbon dioxide rather than to obtain more oxygen. As mentioned above, one of the changes which takes place in acclimatization is a loss of carbon dioxide which, over a period of days and weeks, is balanced by a loss of base from the blood in order to maintain the proper reaction, though at a lower level. The net result is that there is a smaller reservoir of base available to neutralize the acids formed during exercise; these acids (particularly carbon dioxide) change the reaction of the blood and cause far more panting than they would were the normal amount of base present in the blood.

Acclimatization, therefore, actually is responsible for our breathlessness at altitude. In fact if the blood contained as little base at sea level as it does at, say 20,000 ft., in acclimatized man, the slightest exertion would cause severe breathlessness just as it does at altitude. However, this very breathlessness may keep the climber from "committing suicide" by exerting himself too far beyond the supply of oxygen available to him.

This is probably the best available explanation of the failure of oxygen to benefit the acclimatized man, at least to any great extent. Differences from individual to individual may explain why some men did notice some help from oxygen, though most did not. We have the anomalous situation, therefore, in which an unacclimatized man fresh from sea level and provided with a full supply of oxygen will far outclass a well acclimatized climber *with or without oxygen.*

In this air age one cannot resist speculating about the possibility of dropping a climber at base camp with a full oxygen supply. This man could climb at least at the Alpine rate of 1000 ft. per hour and descend at least twice as fast. Allowing seven days to reach 29,000 ft. and return, he would require 168 hours of *continuous* oxygen supply. He would be forced to breathe oxygen for every minute of the nights and days, otherwise he would lose consciousness like the pilots in the altitude chamber. Using any of a number of excellent military oxygen assemblies, his supply of oxygen, plus equipment, would weigh between 400 and 600 pounds, depending on the type used, the man's size, and his physical condition. Yes, it could be done, with elaborate preparations, detailed supply and transport arrangements—and extraordinary luck. The risk would be tremendous, for failure of his oxygen supply for an hour or less at higher altitudes would cost our climber his life.

Can men reach 29,000 ft. (or higher) without oxygen? Until it is actually done the answer will be doubtful at best. But by the best calculations which we know how to make at the present time, we can say that 29,000 ft. is only imperceptibly worse than 28,000 ft. On paper at any rate man can climb to 29,000 ft. and perhaps higher. He will need magnificent physical condition and climbing ability. He must have sound judgment and great perseverance and courage. His food, his creature comforts and his climbing stages must be elaborately planned. He will probably be as well off without oxygen as with it.

One day a man will do it.