This article should be read in conjunction with 'The Exploration of the Nepalese Side of Everest' by Michael Ward, which appeared in AJ97, 213–221, 1992/93. The two articles, taken together, cover a progression of significant events, both scientific and topographical, which took place between 1945 and the first ascent of Everest in 1953. The linkage is set out in Appendix 3 on pages 50–51.

The opening of Nepal in 1949, and the confirmation of a possible new route up Everest by the 1951 Reconnaissance expedition, gave a powerful impetus to high-altitude studies; for despite the best efforts of medical scientists and mountaineers in the 1920s and 1930s, the final thousand feet of the mountain remained unclimbed. Between 1921 and 1938 about 25 people had reached a height of 27,000ft and above, eight climbing to 28,000ft, both with and without supplementary oxygen. At these heights, ascents without using oxygen are at the limit of what is medically and physiologically possible, yet it was still unclear whether the use of oxygen was as effective as acclimatisation in generating a performance adequate to reach the summit. It was the solution of this problem by Dr Griffith Pugh and his colleagues at the Medical Research Council in London and on the Cho Oyu expedition in 1952 that was to be a key factor in the first ascent of Everest.

The use of supplementary oxygen before the Second World War

Some of the best respiratory physiologists had helped early Everest expeditions. Haldane, Barcroft and others had been adamant that supplementary oxygen should be used for the ascent. Their opinion was influenced by the death of two Frenchmen in 1875 at 28,000ft, an altitude to which they had ascended by balloon without supplementary oxygen. Tissandier, the third member of the party, only just survived. However, in the late 19th century, Conway had climbed to 24,600ft on Pioneer Peak in the Karakoram without the use of oxygen, and Clinton Dent in 1893 had stated his conviction that Everest (which he called Gaurisankar) could be climbed without supplementary oxygen and Alexander Kellas in 1920 had reached the same conclusion.

Medical scientists who had underestimated the effects of acclimatisation
were amazed when mountaineers on early Everest expeditions in the 1920s and 30s reached heights of 28,000ft without supplementary oxygen. In fact oxygen was used on these expeditions, but it did not give as much benefit as it should have done and, confusingly, some mountaineers seemed to climb as fast (or faster) without supplementary oxygen as those who were using it. However, Finch (later Professor at Imperial College, London) reached 27,000ft on Everest in 1922 using supplementary oxygen. He was convinced of its effectiveness and noted that sleeping oxygen combated fatigue and maintained the climber’s physical condition. Unfortunately he was not chosen for the 1924 expedition on which four men, climbing without supplementary oxygen, reached 28,000ft; at this height, Mallory and Irvine, using open-circuit oxygen, were last seen by Odell. On this expedition, too, Somervell, a surgeon, was able to measure the amount of oxygen in the depth of the lungs at the highest altitude yet attained.

On expeditions in the 1930s mountaineers and scientists made many contributions. In 1933 Greene developed a very efficient open-circuit apparatus and also advocated the use of oxygen in the treatment of frostbite. This comprised a 500 litre cylinder with a capacity for delivering up to 3 litres per minute and it weighed 12lb 12oz. With hindsight, neither the flow rate nor the amount of oxygen would have been adequate to provide a sufficient boost to performance for long enough. The apparatus was never used on the mountain because, after the two attempts without supplementary oxygen (which had priority) had failed at 28,000ft, the weather became so bad that the party retreated to Base Camp. Unfortunately the slopes of the North Col then became so dangerous from avalanches that no further attempt was possible. Warren, the medical officer in 1935, 1936 and 1938, was initially very keen on the closed-circuit apparatus, and in 1937 he tested it in the European Alps, on the Matterhorn and Wellenkuppe. Because of bad weather the 1936 expedition only reached about 23,000ft, but in 1938 Warren and Lloyd used the closed-circuit apparatus high on the mountain. As a result of technical and practical difficulties in the field, Warren, who had initially been keen on the closed-circuit apparatus, changed his mind and became an advocate of the open circuit, as did Lloyd.

Tilman, who led the 1938 expedition, had little regard for oxygen, nor indeed for any other kinds of scientific investigation on expeditions, since his preference was for keeping things as small and simple as possible. In 1938 he had compromised these principles by taking along, under protest, four sets of oxygen. Oxygen sets for use on Everest, developed in connection with high-altitude flying in the Second World War, were discussed by Roxburgh of the Institute of Aviation Medicine in the 1947 Geographical Journal. But there was still, by 1951, no consistent evidence that supplementary oxygen had given a significant boost to performance on the mountain.

Two types of oxygen apparatus had been developed for mountaineers to use at extreme altitude. In the open-circuit apparatus oxygen is added at different flow rates to the air that the mountaineer is breathing. The ‘altitude in the depths of the lungs’ is determined by the flow rate of the oxygen, enabling the mountaineer to be at a ‘lower’ altitude than that at which he is actually
climbing; this should enable him to climb faster. The exhaled breath is vented to the atmosphere. The apparatus is simple and rugged but a considerable number of oxygen cylinders have to be carried by the climber.

With the closed-circuit apparatus the climber breathes pure oxygen from the cylinder carried on his back, the exhaled air is passed over a soda-lime canister, $\text{CO}_2$ is absorbed and the oxygen is recycled, hence the term ‘closed-circuit’. Obviously a lower flow rate of oxygen is used than is necessary in the open-circuit apparatus. The mountaineer is at or near sea-level in the depths of the lungs and this gives him a greater boost, but the apparatus is heavy and, being more complicated than the open-circuit, it is more likely to break down. If it does so, sudden exposure to extreme altitude can cause severe problems, since the mountaineer, at one moment at ‘sea-level’, is suddenly exposed to the extreme altitude at which he is actually climbing. This occurred to Bourdillon at 26,000ft on the South Col in 1953.

Another important observation at altitude was made by Sir Bryan Mathews FRS (later Director of the Institute of Aviation Medicine at Farnborough and Professor of Physiology at Cambridge) who highlighted the point that heat loss could occur through the lungs as a result of increased respiration, and that this could lead to general body cooling and frostbite. The part played by dehydration in deterioration at extreme altitude was later discussed at an informal meeting at Farnborough in 1947, and the suggestion was made by Rudolf Peters, Professor of Biochemistry at Oxford, that this was due in part to the high rate of breathing.

Throughout the 1920s and 1930s opinion on the use of supplementary oxygen at altitude was divided. In general, the doctors and scientists favoured its use, whilst others thought that reliance could be placed on acclimatisation alone. A third group, of which Tilman was one, were the purists who disapproved of the use of supplementary oxygen on principle.

**Operation Everest I in the USA (1946)**

In 1946 Charles Houston took part in a landmark experiment in high-altitude studies called ‘Operation Everest I’. A flight surgeon in the US Navy from 1941 to 1946, he had been a member of the successful British-American party that made the first ascent of Nanda Devi in 1936 and had led the 1938 American attempt on K2. With this background he had been working in altitude research and, in 1946, he and the distinguished respiratory physiologist Richard Riley and others conducted ‘Operation Everest I’ in a decompression chamber at Pensacola Air Base, Florida. In this five-week study, four volunteers were gradually decompressed to a simulated altitude equal to the ‘summit of Mount Everest’. However, they used an aneroid barometer calibrated by the International Standard Atmosphere table, and the reading actually corresponded to the barometric pressure found at 30,000ft rather than 29,028ft. Two of the four volunteers managed to exercise on a stationary bicycle ergometer for 20 minutes ‘on the summit of Everest’ without supplementary oxygen, thus producing the first solid evidence that such efforts were possible at such a height.
On the ground, however, mountaineers without supplementary oxygen at 28,000ft were climbing so slowly that, even from a camp at 27,000ft, it seemed unlikely that they could reach the summit of the mountain and return without an enforced bivouac. Although the technical climbing difficulties of the last 1000ft on Everest did not appear insuperable, the prevailing weather conditions and the lack of modern protective clothing made it a dangerous undertaking. Climbers at this altitude in the pre-war period had suffered from hallucinations, some had died from cold injury, one porter had developed a hemiplegia (stroke), dehydration was marked, fatigue overwhelming and loss of weight extreme. Muscle wasting was so severe that one climber, Smythe, observed that he could almost encircle the muscles of his thigh with the fingers of one hand after a period at extreme altitude.

Medical Research Council in the UK (1951–52)

An event which made a vital contribution to the first ascent of Everest was the involvement of the Medical Research Council in the summer of 1951. At the end of the previous year (1950) a new Department of Human Physiology had been set up for the purpose of carrying out research into all aspects of extreme environments on man. It was here that Michael Ward, an RAMC officer attached to the Brigade of Guards in London while doing his National Service, first met Dr Griffith Pugh, whose research was to play such a vital part on Everest in 1953. Ward, with W H Murray and Tom Bourdillon, was planning an expedition to investigate the Nepalese side of Everest in the autumn of 1951. The introduction to Pugh had come from Tom Bourdillon’s father, Dr R B Bourdillon, who had heard about the important new unit through his position as a member of the MRC staff working in the Electro-Medical Unit at Stoke Mandeville Hospital. He rang Ward about it, saw him at the hospital and then Ward went to see Pugh at the MRC laboratories in Hampstead.

Griffith Pugh was a clinical physiologist with an unusual background, ideal for the solution of the high-altitude problem of Everest. An Olympic-class skier and an experienced mountaineer, he had been posted in the Second World War to The Cedars in the Lebanon to join the Mountain Warfare Training Centre. Here he investigated all aspects of the effects of the mountain environment on man, including high altitude, and with A D M Cox, then ‘Chief Instructor, Rock’, and W J Riddell, ‘Chief Instructor, Snow’, wrote army manuals on all aspects of mountain warfare. Discharged from the army in 1945, Pugh was taken on the staff of Professor John McMichael’s unit at the Postgraduate Medical School, Hammersmith, London, on the strength of his research work in the Lebanon and his wide experience in medicine. This medical school was and has remained one of the powerhouses of British and world medicine.¹⁰

Pugh was an obvious candidate for the new MRC unit at Hampstead, but as he had never run a department a suitable Director was found in Otto Edholm, at that time Professor of Physiology at the University of Western Ontario.¹¹ Edholm, with A C Burton, had recently completed a classical monograph on *Man in a Cold Environment*, and work on high altitude was complementary
30. The 1952 Cho Oyu expedition, from L: Secord, Pugh, Colledge, Shipton, Hillary, Evans, Lowe. (p42)

31. Gyachung Kang, 7,922m, and Nup La from Nepal. In 1952 Edmund Hillary and George Lowe made the first crossing of Nup La into Tibet. (p42)
to the department’s expertise on cold. Before the departure of the 1951 Everest Reconnaissance expedition, and during its time in Nepal, Pugh’s work at the unit gave him ample opportunity to study the problems of high altitude, which became part of the formal programme carried out by this department.

Pugh’s methods were similar to those used regularly by physicians and surgeons to investigate and obtain a diagnosis and treat patients; only in this instance the ‘diseases’ were cold and high altitude. A study was made of the narratives of expeditions from many different countries to the world’s highest peaks. Symptoms were identified, together with signs observed by medical officers and fellow climbers. Investigations included noting air temperature, wind speed and climbing rate. To these were added Pugh’s own work, both in the laboratory and in the field, to clarify the diagnosis. Finally ‘treatment’ was suggested, including increased rates of supplementary oxygen, improved insulation for clothing and sleeping-bags, better food and adequate drinking water. At the time, Pugh’s approach to the problems of high altitude was innovative, but well tested and successful in the clinical field.

In the summer of 1951 after Eric Shipton returned to the United Kingdom from a diplomatic appointment in Kunming in South-West China, he took over the leadership of the 1951 Mount Everest (autumn) reconnaissance. Edmund Hillary and Earle Riddiford also joined the expedition to Nepal. Before attacking the Khumbu Icefall Shipton and Hillary gained a vantage point at just over 20,000ft on Pumori, from which they were able to see the way clear to the South Col. An ascent by this route at last appeared to be a viable possibility, so on his return to the United Kingdom in December 1951 Shipton asked Pugh and the Medical Research Council to help with the scientific problems of an attempt on Everest. In the meantime Swiss mountaineers had obtained permission to attempt Everest from Nepal.

Swiss Everest expeditions in 1952 (spring and autumn)

Most of the Swiss mountaineers who took part in the two 1952 expeditions came from a small but extremely active club in Geneva, L'Androsace. They were an exceptionally strong party, many members having completed routes in the European Alps of far greater difficulty than any that our own 1953 party had done, and requiring more expertise and experience. This was partly because the Swiss had been able to climb during the war, and also because British mountaineering standards in the 1930s had lagged behind those on the Continent.

In sheer mountaineering expertise, therefore, the Swiss group posed the greatest ever challenge to Mount Everest. In the spring of 1952 they easily made the first ascent of the Icefall, made a direct ascent of the South Col by the Geneva Spur and camped on the South Col; but because of a design fault, Lambert and Tenzing could only use supplementary oxygen at rest. As a result there was no boost to performance and they had to stop exhausted at 28,000ft. Another attempt in the autumn failed again, at 26,000ft, as winds of 60mph and temperatures of 50 degrees of frost were encountered on the South Col. This made it impossible to survive for more than a few minutes in the
open because the wind chill made the temperature on the exposed skin approach minus 100 degrees C. Even to these experienced Swiss mountaineers 28,000ft seemed to be a physiological barrier.

British research in 1952: the Cho Oyu Expedition

Whilst the Swiss were attempting Everest in the spring of 1952, a British–New Zealand training party went to Cho Oyu, the sixth highest peak in the world and about 20 miles west of Everest. Led by Shipton, its purpose was both to build up a nidus of high-altitude climbers who would eventually go to Everest and to test out oxygen sets, clothing, stoves, tents and all the other equipment to be used in an Everest attempt. Pugh obtained a grant from the Royal Society and insisted that he should go on this expedition in order to complete, at altitude, various experimental procedures that he had started at sea-level. The most important of these was to establish the flow rate of oxygen in the open-circuit sets that would give a boost to mountaineers at extreme altitude by increasing their climbing rate and improving their stamina and physical and mental effectiveness. Despite Houston’s work on ‘Operation Everest I’, of which Pugh was well aware, he believed that the use of adequate supplementary oxygen was absolutely vital if there was to be any hope of climbing the last 1000ft of Everest. For there appeared to be no mountaineer in the UK, or indeed anywhere, whose climbing rate at altitude was fast enough to enable him to get to the summit and descend in a day without the use of supplementary oxygen.

Unfortunately, some members of the party became ill before they reached Cho Oyu. Moreover, the route with the best hope of success lay in Tibet, which carried the risk of a brush with the Chinese communists, and the alternative route from Nepal was obviously too difficult. Shipton now felt that the objective of the expedition, which was to get high-altitude experience, would best be served by the extensive exploration of the then little known Everest region. The attempt on Cho Oyu was therefore abandoned and much valuable exploration carried out.

From the point of view of high-altitude science this expedition was eminently successful. A physiological camp, the first of its type, was set up at 19,000ft on the Menlung La. With Bourdillon, Secord and Colledge to help him, Pugh carried out some of the most important studies in the history of high-altitude research. He showed that a flow rate of four litres of oxygen per minute was essential to counteract the weight of the open-circuit oxygen sets, and also to provide a boost to the climber at great altitude (over 25,000ft). The key effect was that it enabled climbers to ascend continuously rather than intermittently. This was the solution to the high-altitude problem of Everest. The smooth and relatively eventless ascent to the summit by Hillary and Tenzing contrasts dramatically with Norton’s agonising description of climbing without supplementary oxygen at 28,000ft: ‘Our pace was wretched. My ambition was to do twenty consecutive paces uphill without a pause to rest and pant, elbow on bended knee; yet I never remember achieving it – thirteen was nearer the mark.’
Pre-war Everest expeditions and the spring 1952 Swiss party had only used a flow rate of about two litres per minute and sometimes less – barely enough to counter the weight of the set. This would explain the paradoxical observations of climbers using supplementary oxygen yet getting no boost at extreme altitude on pre-war expeditions. In addition, Pugh confirmed the beneficial effects of using oxygen while asleep, as observed by Finch. Another important finding was the confirmation of the remark made by Professor Peters in 1947 that dehydration at high altitude was severe, loss of water being due to the greatly increased rate of breathing. An intake of about three litres a day was necessary to counter the effects of dehydration. This water intake is rarely if ever accomplished and is one of the reasons for rapid deterioration at great heights. Many other medical and scientific observations were made by Pugh and his team and incorporated in a report to the Medical Research Council.

**The Everest 1953 Expedition**

In the months following the party’s return to the United Kingdom from Cho Oyu, there was controversy as to the leadership of the proposed 1953 expedition and little mountaineering organisation was carried out, but there was no pause in the critical scientific buildup; the decision to use supplementary oxygen in 1953 was taken by the Himalayan Committee of the Alpine Club and the Royal Geographical Society.

While the advantage conferred by the use of supplementary oxygen had not been decisive in the pre-war expeditions, those, like Lloyd, who had used it to 27,000ft on Everest in 1938, were satisfied that it did give an increased boost the higher the climber ascended. This was amply confirmed by Pugh’s work on Cho Oyu. The increased flow rate that Pugh considered essential would require more oxygen carried at a high pressure, and this could be accommodated in cylinders made of high strength and lighter materials that had been developed during the war. There was obvious scope, too, for reducing the weight of the sets. Finally, both Swiss and French teams were eager to make an attempt on Everest and the oxygen option had to be taken seriously.

In the meantime, Tom Bourdillon and his father and others had been constructing and testing a closed-circuit oxygen set. Though this provided a greater boost than the open-circuit system, its weight was considerable, incorporating as it did the soda-lime canister which absorbed the exhaled carbon dioxide; it was also less reliable. Using closed-circuit oxygen sets, Bourdillon and Evans made the first ascent of the South Summit at 28,250ft from the South Col – but one set then malfunctioned. They very sensibly turned back, as the risks of set failure would involve sudden ‘ascent’ to 28,250ft from near sea-level in the ‘depths of their lungs’, and this could cause coma and death. Up to this point their climbing rates had been amazingly fast because, although each carried about 60lbs, in the ‘depths of their lungs’ they were near sea-level and able therefore to climb at near sea-level rates of ascent.

On Everest in 1953, 198,000 litres of oxygen were taken. Open-circuit oxygen, at a flow rate of four litres per minute, was used from an altitude of
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Effects of High Altitude
Protective Equipment
Porterage
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The Index to Griffith Pugh's Report to the Medical Research Council showing the depth and extent of his work on the Menlung La in 1952
32. Cho Oyu, 8210m, seen from Tibet: the NW face. (p42)

33. Camp on Nangpa La, looking into Nepal and the N side of Menlungtse. From near here, in 1951, Murray and Bourdillon saw a possible route up Cho Oyu via its W face. (p42)
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26,000ft and above by Hillary and Tenzing and was undoubtedly one of the main reasons why this pair were successful. In fact they used a slightly lower oxygen flow rate of about three litres per minute in their ascent from the last camp, at about 27,900ft, to the summit. The use of adequate supplementary oxygen prevented high-altitude deterioration and contributed to the remarkably good physical and mental condition of the whole party. Pugh's rules on supplementary oxygen were that 4 litres/minute should be used on ascent, 2 litres/minute on descent, and 1 litre/minute when sleeping. These were reinforced by attention to the detail of Pugh's work on dehydration, food, protective clothing and other important factors. There were no accidents and only two cases of mild frostbite on this expedition, and this can be attributed to the physical and mental mobility of the members of the party. Using adequate supplementary oxygen, they were able to adjust to and, when necessary, counter events rapidly and correctly, a dangerous feature of oxygen lack being mental slowness to respond to new and potentially lethal situations.

If all this scientific support and expertise had been available to the Everest expeditions of the 1920s and 1930s, the highest peak in the world would probably have been climbed then. Many factors - good weather, good luck and, in particular, good management - contributed to the successful ascent in 1953, but a critical part was also played by the application of good science to a medical-physiological problem imposed on a mountaineering ascent. Within the next few years every one of the world's ten highest peaks were climbed using these principles.

The ascent of Everest without supplementary oxygen

Man's ability to remain alive depends on the pressure of oxygen in the depths of the lungs (alveolar pressure), which itself is dependent on the barometric pressure, or the weight of the atmosphere on the Earth's surface. At extreme altitude the barometric and therefore oxygen pressure is much lower than at sea-level and at the summit of Everest life can only just be sustained without supplementary oxygen.

When expeditions to the Himalaya were resumed after the Second World War, it gradually became apparent, largely through the work of Pugh in the Everest region in 1952, on Everest in 1953, and on the Silver Hut expedition of 1960–61 in the Everest region, that the barometric pressure on Himalayan peaks was higher than predicted and that it might be possible to climb Everest without supplementary oxygen.

A number of physiological changes contribute to man's ability to acclimatise and function efficiently at high-altitude. In sea-level dwellers it has been shown that some individuals are able to take in more oxygen than others when working maximally during exercise. This was the basis of much of Pugh's work for the selection of ski and mountain troops in the Lebanon in the Second World War, and is now used for the selection of athletes in different disciplines. In some sea-level dwellers the oxygen transport system is more efficient than in others, and some climbers are more efficient in the way that they move, thus not 'wasting' movements and therefore oxygen.
It has been known for many years that stay at great altitude results in both mental and physical deterioration and, as long ago as 1907, Longstaff, with the Gurkha soldier Karbir and the Brocherel brothers, ascended and descended 6000ft in a day on Trisul (23,360ft), thus avoiding both acute mountain sickness and altitude deterioration. A number of rapid ascents and descents of Everest have been made without supplementary oxygen after suitable acclimatisation up to about 17,000ft; but the dangers are considerable, in particular the thickening of the blood due to an increase in the red blood cells may lead to thrombotic or other vascular episodes, and predispose to frostbite as the small peripheral skin vessels tend to get clogged up.

The first ascent of Everest without supplementary oxygen was made in 1978, and by now more than 30 people have climbed to the summit without its use. Each of the world’s ten highest peaks have been climbed by at least two mountaineers without supplementary oxygen and one Sherpa has climbed Everest six times.

As the modern mountaineer has the opportunity to ascend to great altitude on many occasions in one season, he is therefore fitter, better acclimatised and more efficient than his forebears. However, if supplementary oxygen is not used it is essential that he moves up and down the mountain quickly. At sea-level if an athlete fails to produce an Olympic-class performance he may lose a race or a title; near the summit of Everest he may lose a limb or his life.

( Early experiments in the use of supplementary oxygen on Kamet in 1920 and in Oxford in 1921–22 will be discussed in a further article in the Alpine Journal 1994.)

REFERENCES


**APPENDIX I**

<table>
<thead>
<tr>
<th>Year</th>
<th>Scientists</th>
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<tbody>
<tr>
<td>1921</td>
<td>A M Kellas, A F R Wollaston</td>
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<tr>
<td>1922</td>
<td>T H Somervell, T G Longstaff, A W Wakefield</td>
</tr>
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<td>1924</td>
<td>T H Somervell, R W G Hingston</td>
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<tr>
<td>1933</td>
<td>C R Greene, W McLean</td>
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<tr>
<td>1935</td>
<td>C B M Warren</td>
</tr>
<tr>
<td>1936</td>
<td>C B M Warren, G N Humphreys, E H L Wigram</td>
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<tr>
<td>1938</td>
<td>C B M Warren</td>
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<tr>
<td>1950</td>
<td>C S Houston (US)</td>
</tr>
<tr>
<td>1951</td>
<td>M P Ward</td>
</tr>
<tr>
<td>1952 (Spring)</td>
<td>E Wyss-Dunant (Switzerland)</td>
</tr>
<tr>
<td>1952 (Autumn)</td>
<td>G Chevalley (Switzerland)</td>
</tr>
<tr>
<td>1952 (Cho Oyu)</td>
<td>R C Evans, L G C E Pugh</td>
</tr>
<tr>
<td>1953</td>
<td>R C Evans, L G C E Pugh, M P Ward</td>
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</table>
PERFORMANCE AT ALTITUDE ON EVEREST WITH AND WITHOUT SUPPLEMENTARY OXYGEN

(See References 15 and 21)

<table>
<thead>
<tr>
<th>Party</th>
<th>Altitude Difference</th>
<th>Load</th>
<th>Rate of Climb</th>
<th>Oxygen Apparatus</th>
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<tbody>
<tr>
<td>1922</td>
<td>25,000–27,000</td>
<td>–</td>
<td>320</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>25,500–27,200</td>
<td>40</td>
<td>6400</td>
<td>2.4 l/min. Open</td>
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<td>1924</td>
<td>25,300–26,800</td>
<td>–</td>
<td>333</td>
<td>None</td>
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<tr>
<td>1952</td>
<td>25,800–27,200</td>
<td>40</td>
<td>233</td>
<td>O2 at rest</td>
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<tr>
<td>1953</td>
<td>25,800–27,200</td>
<td>40</td>
<td>622</td>
<td>4 l/min. Open</td>
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<td>25,800–27,200</td>
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<td>494</td>
<td>4 l/min. Open</td>
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<td></td>
<td>25,800–27,200</td>
<td>52</td>
<td>933</td>
<td>Closed</td>
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<td>25,800–27,200</td>
<td>17</td>
<td>210</td>
<td>3 l/min. Open</td>
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Note: (1) Similar climbing rate when using no supplementary oxygen and when using open circuit oxygen at 2.4 litres/minute.

(2) Increased climbing rate when using (a) closed circuit oxygen, and (b) open circuit oxygen at 4 litres/minute.
SIGNIFICANT EVENTS PRECEDING THE FIRST ASCENT OF EVEREST 1945–53

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>People/Organisations</th>
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</thead>
<tbody>
<tr>
<td>1945</td>
<td>First map showing topographical detail and spot heights of Tibetan and Nepalese sides of Everest</td>
<td>Milne/Hinks (London)</td>
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<tr>
<td></td>
<td>First secret flight over Everest from Nepal</td>
<td>684 Squadron</td>
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<tr>
<td>1946</td>
<td>‘First ascent’ of Everest in decompression chamber (Florida, USA)</td>
<td>Houston/Riley</td>
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<tr>
<td>1947</td>
<td>Second secret flight over Everest from Nepal</td>
<td>Neame</td>
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<tr>
<td>1949</td>
<td>The opening of Nepal to foreigners</td>
<td></td>
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<tr>
<td>1950</td>
<td>Tibet occupied by Chinese communists and sealed off to Westerners</td>
<td>Houston/Tilman</td>
</tr>
<tr>
<td></td>
<td>First reconnaissance expedition to Nepalese side of Everest</td>
<td></td>
</tr>
<tr>
<td>1951</td>
<td><strong>Spring</strong> Cartographic and photographic evidence discovered of a possible route to the summit from Nepal</td>
<td>Ward</td>
</tr>
<tr>
<td></td>
<td><strong>Summer</strong> Involvement of the Medical Research Council in solving the high-altitude problem</td>
<td>Ward/Pugh</td>
</tr>
<tr>
<td></td>
<td><strong>Autumn</strong> Reconnaissance expedition confirms possible route to the summit of Everest</td>
<td>Shipton/Murray Bourdillon/Ward Hillary/Riddiford</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
<td>People/Organisations</td>
</tr>
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<tr>
<td>1952</td>
<td>Spring Swiss reach 28,000 ft on Everest</td>
<td>Lambert/Tenzing</td>
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<td></td>
<td>Cho Oyu expedition (Nepal)</td>
<td>Shipton (leader)</td>
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<td></td>
<td>Menlung La physiology camp: solution of the high-altitude problem of Everest</td>
<td>Pugh/Bourdillon, Secord/Colledge</td>
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<td></td>
<td>Summer Preparations for Everest</td>
<td>Medical Research Council/Institute of Aviation Medicine/Royal Geographical Society/Alpine Club</td>
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<tr>
<td></td>
<td>Autumn Swiss reach 27,000 ft on Everest</td>
<td>Lambert/Reiss/Tenzing/seven Sherpas</td>
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<td>Visit to Zurich for data from Swiss on their two expeditions</td>
<td>Pugh</td>
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<td>Leader of British 1953 expedition appointed</td>
<td>Hunt</td>
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<tr>
<td>1953</td>
<td>May First ascent, South Summit (Nepal)</td>
<td>Bourdillon/Evans</td>
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<td>First ascent of Everest</td>
<td>Hillary/Tenzing, Hunt (leader)</td>
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