SCIENTIFIC ASPECTS OF THE EXPEDITION TO MOUNT EVEREST, 1953

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THE 1953 EXPEDITION to Mount Everest received scientific assistance which was more comprehensive and effective than that given to any previous British Himalayan expedition. Since the last British attempt on Mount Everest in 1938, much more had been learnt about human efficiency in extreme environments, and the results of the personnel research methods used with such great effect during and after the Second World War could be coordinated and applied to the many relevant problems. There was also the accumulation of knowledge from previous expeditions to Everest to be drawn on; and the experience of the Swiss party in the spring of 1952, generously made available by them, was of particular value. Further important information was derived from the physiological data collected on the British expedition to Cho Oyu in 1952. This expedition had been designed, partly with the object of climbing Cho Oyu (26,800 feet), the sixth highest mountain in the world, but mainly with the idea of forming and training a nucleus of climbers capable of attempting the ascent of Mount Everest the following year. A physiologist had accompanied the party* in order to study the effects of supplementary oxygen on men at high altitudes and also problems of nutrition, acclimatization and equipment. The expedition did not succeed in reaching an altitude greater than 22,500 feet but the information which was obtained made an important contribution towards predicting the requirements for the 1953 expedition.

Acclimatization.—The Cho Oyu party, like the Swiss on Everest, went straight up to high altitude within a few days of arrival in Sola Khumbu, and did not return to lower altitudes until after the attempt on the summit.

The party was insufficiently acclimatized, and lost a great deal of weight. They also suffered a high incidence of sickness due to diarrhoea and upper respiratory infections. It was thought probable that these infections were contracted from the local inhabitants and porters, and although hygiene could obviously be considerably improved, it seemed unlikely that the introduction of infection into a party on its arrival in the Himalaya could be altogether prevented. It was therefore urged that the forthcoming expedition to Everest should spend a month in the Sola Khumbu district in order to become acclimatized to altitude and to pass through the stage of initial infections before going on to the mountain itself. Experienced Himalayan climbers hold the view that little is to be gained by spending too much time below 14,000 feet when adaptation is required to altitudes above 18,000 feet,

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and this view is supported by the observation that Sherpas living at Namche (about 12,000 feet) complain of headaches and shortness of breath in crossing the Nangpa La at 19,000 feet. The plan was therefore adopted of spending three or four weeks on acclimatization, but instead of ascending by slow stages, the party should make short visits to heights of about 18,000 feet and return in the intervals to 13,000 feet to rest. This procedure proved extremely successful, and was thought partly to account for the greatly improved physical condition and freedom from illness shown by the party during the subsequent operations on the mountain.

**Oxygen.**—Oxygen had been taken on every expedition to Mount Everest except the reconnaissance of 1921 and 1951. The equipment available to prewar expeditions was still however insufficiently developed to be effective and it was not easy to persuade mountaineers of the usefulness of oxygen for their purpose. British parties in 1924 and 1933, and the Swiss in 1932, reached an altitude of about 28,000 feet by their own unaided efforts and were turned back by a combination of factors of which lack of oxygen was only one. Many mountaineers therefore thought (and some still think) that, given ideal conditions, Mount Everest could be climbed without the help of oxygen. Oxygen apparatus was however tried between 23,000 feet and 27,300 feet by Finch in 1922, by Odell in 1924, and by Lloyd in 1938.3 They each used open circuit apparatus weighing in the region of 28 lb. Finch and Lloyd, using 2·2 litres (NTP) of oxygen per minute, claimed increased speed of climbing and reduction of fatigue, but their companions climbing without oxygen, were not convinced that their own performance had been bettered. Odell, who used 1·0 litres per minute, obtained little benefit from his oxygen and found he went better on the whole without it. The conclusion generally drawn from the prewar experience was that the weight of the apparatus very nearly counterbalanced any benefit derived from the oxygen.9,10

The experimental work done on Cho Oyu provided data permitting a reassessment of the oxygen problem. It became clear that higher flow-rates of the order of 4 litres per minute were needed and much more oxygen would therefore have to be provided than had been taken before. Although the net effect of oxygen on the rate of ascent of men climbing at 20,000 feet was found to be small, it was predicted that, given enough oxygen, above 26,000 feet the rate of ascent would be about doubled because of the elimination of the need for rests every few steps to recover breath. Because of reduction of fatigue, men would be able to do a much longer day with the help of oxygen than without it. The successful use of oxygen would however depend on the ability to overcome the practical difficulties of transporting adequate quantities of it to the higher camps.

Many people in both scientific research establishments and industry were concerned with the preparation of the oxygen equipment for the 1953 expedition. First a choice had to be made between the open and closed circuit types of set.

With open circuit apparatus the climber breathes in a mixture of air and oxygen and exhales to the atmosphere. The partial pressure of oxygen in the inspired gas mixture depends on the altitude, the air temperature, the
flow-rate of oxygen and the minute-volume of lung ventilation. At oxygen flow-rates of 2 and 5 litres per minute which are within the practical range for Mount Everest, a climber near the summit of the mountain inhaling 80 litres of air and oxygen per minute would be getting oxygen at a partial pressure equivalent to that of the oxygen in the atmosphere at about 22,000 feet and 13,500 feet respectively.

Closed circuit apparatus has two outstanding advantages. The climber breathes pure oxygen at a pressure even greater than the pressure of oxygen in the atmosphere at sea level. Secondly, loss of heat from the body via the lungs in warming and humidifying the inspired air is practically eliminated. This factor was considered important, for it was calculated that 50 per cent. of the total metabolic heat production of the body would be lost in this manner in men climbing at 28,000 feet at a temperature of \(-40^\circ\) C. \((-40^\circ\) F.). Closed circuit sets are however more difficult to operate than the open circuit type and are liable to develop faults which cannot be identified and corrected under the conditions of use on a mountain. They had already been used in 1935 and 1938 without success.

Existing closed circuit sets designed for fire fighting and mine rescue are unsuitable for mountaineering use as they have neither the endurance required nor the capacity to handle the very high volume of lung ventilation needed in climbing at high altitude. If closed circuit sets were to be used, an entirely new design would have to be developed and it was doubtful if this could be done in the time available. The open circuit type was given first priority (on the advice of the Oxygen Advisory Committee under the Chairmanship of Professor Sir Bryan Matthews) on the grounds of simplicity and reliability, and because Finch and Lloyd had already shown that it could be used successfully under mountaineering conditions. However on account of the great potential advantages of the closed circuit type of set, some of these sets were produced for trial purposes and were taken on the expedition.

The amount of oxygen sent out to Nepal was 193,000 litres. This figure may be compared with the 29,000 litres sent out in 1922 and the 20,000 litres taken by the Swiss party in autumn 1952. Of the 160 cylinders containing the oxygen, seventeen were found to have leaked on arrival; one-third of the remaining 150,000 litres was used for training and a small quantity for experimental purposes. About 16,000 litres were left over at the end of the expedition; this would have been barely enough for a third assault. The climbers were carefully trained in the use of their oxygen equipment. They wore their masks for part of each day on the approach march, and made training ascents with both the open and the closed circuit sets. They also learnt to sleep comfortably wearing lightweight masks and breathing 1 litre of oxygen per minute.

Open circuit sets proved satisfactory apart from a few minor technical difficulties which were overcome and some trouble with ice formation round the mask and its connections. Respiratory resistance, which had always been one of the chief difficulties encountered in oxygen apparatus used on Everest, was reduced to a minimum even at high work rates. For strenuous work, 4 litres of oxygen per minute were needed, but men moving slowly behind a leader making tracks and cutting steps found 2 litres adequate. Using 4 litres
per minute, Hillary and Tenzing climbed at 630 feet per hour from 25,850 feet to 27,300 feet in a track prepared by their support party. The final climb from the top camp (27,900 feet) to the summit, when they only used 3 litres per minute (less than had been intended), took 5 hours.

The closed circuit sets were used successfully under the supervision of Bourdillon, who had been associated with their construction, but even he found difficulty in tracing faults which developed on the South Col. He and Evans used these sets on the first assault and climbed nearly 3000 feet from 25,850 feet to 28,700 feet and back in a day. From 25,850 feet to 27,300 feet they averaged 930 feet per hour making their own track—this, for men carrying 50 lb. loads, must be accepted as an Alpine standard of performance. On the last 700 feet after changing soda lime cannisters, Evans’ set gave trouble, but the fault was not identified. Above 26,000 feet the fact that the inspired air was warm and moist proved a great advantage, though at lower altitudes the closed circuit sets were uncomfortably hot.

The most important effect of oxygen was reduction of fatigue and high altitude deterioration. Climbers using oxygen found they could do a much longer day without becoming exhausted. Oxygen at night induced sleep and warmth, and promoted recovery from fatigue. All the climbers commented on the great subjective benefit experienced while climbing; they were able to enjoy climbing again and take an active interest in their surroundings. Climbing rates were not significantly improved up to 22,000 feet but above that altitude the improvement in climbing rate became increasingly apparent. Sudden failure of the apparatus while climbing caused severe breathlessness and weakness, although slow failure was apt to pass unnoticed. No ill effects were noticed on removing the mask, provided the climber first rested and recovered his breath. Hillary removed his mask on top of Mount Everest and was able to take photographs and set the shutter speed of his camera. After ten minutes he noticed his movements were getting clumsy and his thought processes muddled, so he replaced his mask. Bourdillon reported some loss of tolerance of altitude after wearing his closed circuit set for a prolonged period, but there was no evidence of this in the case of Evans.

Nutrition.—Himalayan expeditions have in the past usually subsisted on local foodstuffs supplemented from bulk stores taken out from England (or purchased locally). Below 10,000 feet, rice, dhal (a type of lentil) and atta (stone-ground wheat flour) are staple foodstuffs, and above 10,000 feet potatoes and tsampa (stone-ground parched barley) are eaten. Eggs and chickens are available in limited numbers up to about 13,000 feet and yak and sheep can be purchased between 12,000 feet and 14,000 feet and sent up on the hoof to 18,000 feet.

Most of the food for the day on a Himalayan expedition is consumed at two meals, breakfast and supper, and since the daily intake of Calories is 4000 to 4500—at least at the lower altitudes—these have to be very large meals. Very large quantities of tea are drunk, and with the serving of curry each evening and the strange, bulky diet, a considerable strain is placed on the digestive system. Digestive disturbances are relatively common, and cases of chronic diarrhoea occur which are probably of infective origin but are kept
going by an unsuitable diet. The majority of climbers however eventually become completely adapted to the diet and do well on it.

Cooking is done over wood fires up to 18,000 feet. Above that, fresh problems arise; the production of cooked meals and adequate quantities of liquid becomes increasingly difficult. Paraffin stoves are used, and all water has to be obtained by melting snow. Owing to the reduced boiling-point of water (176°F at 20,000 feet), pressure cookers are essential if hot meals are to be provided. It is a curious fact that mountaineers have only recently come to accept pressure cookers as an indispensable part of their equipment; as recently as 1951, pressure cookers supplied free by the makers were discarded before the approach march.

Above 18,000 feet diet becomes unpalatable and monotonous. For this reason, and also because of the effect of altitude on the appetite, the food intake of the climbers becomes progressively reduced. Shipton, on the 1935 expedition, obtained records of food consumed between 18,000 feet and 21,200 feet, and the caloric value worked out at between 1500 and 2000 Calories. At these altitudes, the food preferences of climbers undergo a marked change. They develop an increased appetite for sugar and, if sufficient quantities are available, may consume up to 14 oz. per day. The sugar is taken mainly dissolved in beverages, and these, in spite of their very large sugar content, seem to taste less sweet than at sea level. Climbers, while regarding the food provided as dull and unpalatable, often feel they would enjoy well-cooked food such as they would eat at home. Some men develop cravings for foods that are usually not available, such as salmon, sardines and tinned fruit.

Owing to the inefficient cookers and shortages of fuel, parties on Everest and other high mountains have usually had difficulty in satisfying their fluid requirements and there is much indirect evidence in Himalayan literature that parties have suffered from dehydration. This may also be because the sensation of thirst, like the appetite for food, may be impaired at high altitude, and men may suffer less from thirst than they would with a corresponding fluid shortage at sea level.

On the expedition to Cho Oyu in 1952, the energy value of the diet on the approach march was about 4300 Calories, but intake fell to about 3000 Calories at and above 18,000 feet. This was higher than that reported by Shipton in 1935, probably because ample supplies of sugar were available. Between 5 and 7 pints (3 and 4 litres) of fluid per day were taken. Inconvenience and sometimes hardship were caused by shortage of essential stores due to pilfering and over-consumption of favourite items and to the difficulty of distributing and sorting the bulk rations.

In preparing the 1953 expedition, it seemed wise on general physiological grounds to avoid the sudden change to a strange and bulky diet and to provide a more varied and palatable diet than is available to a party living off the country. Some improved method for the sorting and distribution of rations was desirable and better arrangements for cooking and melting snow at high altitudes were necessary. At the high camps where economy of weight is essential, a special ration was needed which would provide a basic diet consisting largely of sugar, as well as catering for individual food
preferences. To meet these requirements it was decided to break with tradition and use composite rations of the type used in the armed forces for supplying troops operating in isolated groups or small units. Special stoves were designed to ensure an adequate supply of water at high camps, and pressure cookers were provided to make possible the cooking of meat and potatoes at and above the base camp (18,000 feet).

The organization of the packing of the rations was undertaken by the Army, and many of the items were made available from Army stocks. The detailed composition of these rations has been published elsewhere. In brief, two types of ration were taken:

(1) A general purpose composite ration packed in 14 and 28 man-day units. Palatability and variety were achieved by the use of tinned foods combined in a different menu for each day. Economy of weight was not a vital consideration in planning this ration, since there would be no shortage of porters in Katmandu at the time of the year when the party would be setting out from there. It was planned to supplement the ration with rice and potatoes purchased locally and later with fresh meat.

(2) An assault ration for use above 20,000 feet. In this every effort was made to economize on weight and bulk. No tins were used and most of the foodstuffs were vacuum packed. By vacuum packing, a soft item like a bag of granulated sugar is reduced to a hard rectangular block, which becomes soft again once the vacuum seal has been broken. This new method of packing offers very important advantages to all expeditions where economy of weight and bulk is important.

In order to cater for the personal idiosyncrasies shown by men at very high altitude, each climber was asked before the expedition to select one or more foods that he thought he would be able to eat at the high camps. These were packed in bulk and called luxury boxes. It was planned that each climber, before going high, should reject such items as he did not require from the assault ration and substitute the foods of his own choosing from the luxury boxes. At base camp the assault rations were further lightened by removal of superfluous protective wrappings and rejection of certain unpopular items such as pemmican and Service biscuits. The composition of the modified assault ration was then as follows:

Rolled oats . . . 2 x 1 oz. packets  Boiled sweets 1 x 2 oz. packet
Milk powder . . . 2 x 3 oz. packets  Salt . . . 2 x 5½ gm. dispensers
Sugar . . . 4 x 2 oz. packets  Cocoa . . . 1 x 1 oz. packet
Jam . . . 1 x 2 oz. packet  Tea . . . 1 x 1½ oz. packet
Sweet biscuits . . . 2 x 3 oz. packets  Soup . . . 1 x 2½ oz. packet
Cheese . . . 2 x 1 oz. packets  Lemonade powder 2 x 1 oz. packets
Mint bar or banana bar . . . 2 x 2 oz. packets  Gross weight: 4 lb.

The above rations proved on the whole satisfactory. The general purpose composite rations were eaten at a greater altitude than had been anticipated (up to Camp 4 at 21,200 feet), and were supplemented with yak meat, mutton, rice and potatoes. The Calorie value of the diet eaten in the Western
Cwm between 20,000 feet and 21,200 feet was calculated to be about 3800 Calories per day, compared with 3000 Calories the previous year. During the assault, climbers ate most of the sugar and milk in their assault ration but otherwise subsisted on items such as sardines, salmon, cheese, tinned fruit and French saucissons from the luxury boxes, and Vitawheat, Knäckebrot and honey salvaged from the Swiss expedition of the previous year. Fluid and salt requirements were well met, and there was no evidence of significant fluid deficiency having occurred even during the assault phase.

The greater food consumption in 1953 as compared with 1952 is explained by better acclimatization, the provision for normal cooking at high camps and the improved palatability and variety of the food. It was generally agreed among the five men who had taken part in the 1952 as well as the 1953 expedition that the average level of fitness among the party at all stages of the expedition was higher in 1953 than the previous year. Objective evidence in support of this view is provided by the records of body weight. In 1953 the average loss of weight in the first month after reaching Thyangboche (13,000 feet) was 2 lb., whereas the average loss of weight over the corresponding period in 1952 was 11 lb. During the second month of the 1953 expedition, spent for the most part above 20,000 feet, the average loss of weight in five men for whom records are available was 4 lb.

Climatic considerations.—On the expedition to Cho Oyu in 1952 climatic conditions were studied in relation to problems of protective clothing and equipment. The expedition experienced a wide range of climatic conditions, representing many recognized types of climate; for example, dry heat, moist heat, temperate alpine conditions, wet cold and dry cold. The snow-line from April to May extended down to about 17,500 feet, and it was only above that level that special protective equipment against cold began to be needed. The special features of the climate above the snow-line were fairly intense cold at night and low air temperatures combined with high radiation temperatures during the day. Weather conditions were variable: there were snow storms alternating with fine periods, but even in fine weather the onset of mist and snow in the afternoon was usual. Minimum temperatures at night at between 18,000 feet and 20,000 feet were variable and ranged from $-13^\circ$ C. to $-20^\circ$ C. ($+8.6^\circ$ F. to $-4.0^\circ$ F.). Sun temperatures of $69^\circ$ C. ($156^\circ$ F.), measured with the black bulb radiation thermometer were observed in association with shade temperatures near freezing point. High winds were occasionally met with, but not of the force to be expected on ridges and cols above 22,000 feet. Although these conditions were not severe by comparison with those to be expected above 22,000 feet, the climbers complained of being cold in their sleeping-bags and suffered from cold feet while climbing. It seemed desirable that use should be made of modern technical developments in the design of protective equipment for cold conditions, due consideration being given to the special requirements for mountaineering which are an economy of weight, freedom of movement, and adjustability to suit variations in metabolic heat production and in environmental cooling power.

With regard to the question of cold on Mount Everest, no records of temperature were available from previous expeditions for altitudes above 24,000 feet. Balloon observations made at hill stations in India indicated that
minimum temperatures of $-40^\circ$ C. $(-40^\circ$ F.) and wind velocities of up to 100 m.p.h. were to be expected at 28,000 feet. However the fact that mountaineers on Everest had not suffered more casualties from cold than they did suggested that, in the fortnight before the monsoon, temperatures were higher than at other times. By extrapolation from the Cho Oyu data, assuming a lapse rate of $3.5^\circ$ F. per 1000 feet, minimum night temperature at the South Col at 26,000 feet would be between $-25^\circ$ C. $(-13^\circ$ F.) and $-32^\circ$ C. $(-26^\circ$ F.), and at 28,000 feet between $-29^\circ$ C. $(-20^\circ$ F.) and $-36^\circ$ C. $(-33^\circ$ F.).

Wind velocities of 100 m.p.h. would of course put a stop to climbing operations, since in a wind of such velocity even walking on level ground is impossible.

For climbing during the day in fine weather, climbers would have little difficulty in keeping warm as air temperatures by day would be considerably higher than the temperatures at night given above, and they would be gaining a large amount of heat by radiation from the sun. Conditions would however become extremely dangerous if climbers at very high altitudes were overtaken by bad weather or if they were benighted without their sleeping equipment.

**Protective equipment**—A single cotton-nylon fabric, chosen after extensive laboratory tests, was used in the construction of tents and windproof clothing. The outer windproof smock and trousers were greatly improved in design in the light of experience gained in 1952, and by making use of ideas from Polar practice. Particular attention was paid to the fit of these garments—this had been conspicuously at fault in 1952. The main insulating garments were the quilted down jacket and trousers which were similar to those used by British and Swiss parties the previous year. Silken inner gloves, woollen mitts and outer windproof mitts of ventile cloth were provided for protection of the hands, and a number of pairs of very large Swiss down mitts were taken for the assault parties.

Special boots were provided for use above 20,000 feet. These were of an entirely novel design, having relatively thin microcellular rubber soles and very thick kapok-stuffed uppers to provide the required amount of insulation. Both the inner and outer coverings were waterproof so that the boots conformed to the double vapour-barrier principle. This principle has recently been applied in the design of boots for the Allied forces in Korea. Much attention was paid to economy of weight since metabolic experiments have shown that 1 lb. of weight carried on the feet is equivalent to 4 lb. carried on the back. The boots were not entirely successful because they did in fact get wet (owing to tears in the outer covering), and this increased their weight considerably. In spite of the kapok being damp however the insulation afforded by the boots proved adequate for the conditions encountered. The total weight of the protective clothing, including boots and gloves, was 17 lb., compared with 23 lb. for a corresponding Polar clothing assembly.

Many different patterns of tent were taken. In addition to the British tents, American, French and Swiss patterns were taken for trial purposes, as well as a small experimental tent in which the normal tent poles are replaced by a spring steel frame which keeps the tent fabric under tension as in an
umbrella. The essential properties required in Himalayan tents are as follows: They must be quick and easy to erect and strong enough to resist high winds; they should be large enough to provide reasonable comfort for the number of occupants they are designed to shelter; very strong sewn-in ground sheets are needed to resist tearing when the tents are pitched on rock and ice. Ventilation is very important on account of the intense solar radiation during the day which raises the temperature even in well-ventilated tents to about 80°F. (27°C.); for this reason Himalayan tents should have entrances at both ends. Double walls for protection against low night temperatures are not necessary if the sleeping-bags and mattresses are adequate. Sleeve entrances as used in Polar tents provide a method of closing the entrances which will keep out draughts and wind-driven snow. Economy of weight is important but not an overriding consideration, except in assault tents. Of the tents used on the present expedition the modified Meade tents were the most popular and were used on the South Col and in the top camp. These are extremely easy to erect even in a strong wind. The other general purpose tent, the pyramid tent, was a modification of a pattern developed in 1943-4 for snow and mountain warfare and, though very light in weight relative to the number of men accommodated, suffered from the disadvantage of being difficult to erect in a strong wind. It was unfortunate that one of these tents was taken to the South Col.

Sleeping-bags designed for the Himalaya must have an outer and inner compartment to cover the wide range of climatic conditions encountered. About 8 lb. of down are needed to afford sufficient protection for temperatures down to −40°C. (−40°F.), and the inner bag should weigh about 3 lb. The bags should be long enough to pull over the head and wide enough to allow a man to turn over inside the bag, to which end a slippery nylon lining is an advantage. These requirements were met in most of the bags supplied which were of Canadian, New Zealand and British manufacture, but the briefing of the makers was in some instances incorrect. Sleeping mats were of the inflatable type. An ordinary commercial pattern was taken for use up to base camp. At base camp and above, special mats were provided, based on a design developed during the War which gives better insulation and eliminates the characteristic bouncing effect experienced by a person lying on the ordinary type of mat when he turns over. The special mats had a double layer of inflatable tubes which were constricted at the ends, thus buffering sudden displacements of air from tube to tube. These mats provided good insulation from the ground and were very comfortable. The descriptions by the climbers of their experience on the South Col indicates that they suffered rather severely from cold. This was explained by the fact that in order to save weight they left behind the inner components of their sleeping-bags. Had temperatures of −40°C. (−40°F.) instead of −25°C. (−13°F.) been encountered, their situation would have been dangerous.

The role of science in relation to the 1953 Everest Expedition, of which some account has been given in these pages, has been to reduce the stresses imposed by an extreme environment, to increase the climbers' ability to
maintain themselves under extreme conditions and so to preserve a state of health and efficiency sufficient to enable them to achieve their object. From the scientific, as well as from other points of view, therefore, the ascent of Everest is another milestone in the progress of man’s conquest of his environment.

REFERENCES