American Medical Research Expedition to Everest

John B. West, M.D., Ph.D., and John Evans

The chief objective of this unusual expedition was to study the function of man at extreme altitudes, and we were fortunate enough to have considerable success. An extensive scientific program was completed, including some measurements on the summit of Mount Everest itself (8848 meters, 29,028 feet). Five people reached the summit, and everyone returned home safely.

Doctors have been interested in the effects of extreme altitudes on man for many years. One reason for this is that the problems that climbers face at these great altitudes, because of the low pressure of oxygen in the air, are similar to some of the difficulties facing patients with severe lung or heart disease. A climber on the summit of Mount Everest who has removed his oxygen mask probably has an oxygen pressure in his arterial blood of about 25 mmHg whereas the normal value at sea level is 90 to 100 mmHg. A patient with respiratory failure because of severe chronic bronchitis or emphysema is often in the same predicament.

There is also the purely scientific interest of how the body manages to transfer enough oxygen into the tissues for the climber to survive under these conditions of extreme oxygen lack. Historically, physiologists were astonished when the Duke of the Abruzzi reached an altitude of 7500 meters (24,600 feet) on Chogolisa in the Karakoram in 1909. Even more consternation resulted from the climb of Norton to over 8580 meters (28,150 feet) on Everest in 1924. The ultimate feat was the “oxygenless” climb of Everest by Messner and Habeler in 1978. Such an achievement is right at the limit of human physiology and has stimulated a great deal of interest in how man can tolerate extreme oxygen deprivation.

Prior to the present expedition, the most extensive physiological studies at extreme altitude had been done during the Himalayan Scientific and Mountaineering Expedition of 1960-61. On that occasion a group of scientists wintered near the Mingbo La (southeast of Ama Dablam) in a prefabricated hut erected at an altitude of 5800 meters (19,000 feet).
Subsequently some measurements on a stationary bicycle were made on Makalu up to an altitude of 7440 meters (24,400 feet). However the altitudes above that are of great medical interest because the maximal work rate of man falls off very rapidly. Indeed, predictions based on models of oxygen transport indicate that on the summit of Mount Everest, almost all the oxygen available is consumed in keeping the body alive and almost none can be used for additional work. This is the most severe hypoxia that normal man ever encounters and it can only be tolerated if a climber is well acclimatized. A sea-level dweller who is suddenly exposed to the low levels of oxygen found at the Everest summit would lose consciousness within a minute or so.

In the early planning of the expedition, we tried to graft a scientific team onto a regular climbing expedition. However, the objectives of the
two groups are so different that this proved impossible. We therefore (ambitiously) decided to put together a special expedition with physiological research as its primary objective.

The design of the expedition was very unusual. First there was a group of six highly experienced high-altitude climbers including John Evans (deputy leader-climbing), David Jones, Chris Kopczynski, Jeff Lowe, Glenn Porzak, and Michael Weis. Next there were six "climbing scientists;" these were all strong climbers, but in addition, they were M.D.'s with an interest in high-altitude physiology. The group comprised Steven Boyer, David Graber, Peter Hackett, Christopher Pizzo, Frank Sarnquist, and Robert Schoene. Their responsibility was to carry out the measurements at extreme altitudes. Finally, there was a third group of physiologists who worked in the two laboratories at Camp II (6300 meters, 20,700 feet) and Base Camp (5400 meters, 17,700 feet). They were F. Duane Blume (deputy leader-logistics and finance), Sukhamay Lahiri, Karl Maret, James Milledge, Richard Peters, Michele Samaja, John West (expedition leader) and Robert Winslow. There was also a Base Camp manager, Rodney Korich.

Physiological measurements were carried out at four sites on the mountain. These were largely determined by the topography of Mount Everest as approached from the Nepalese side (see diagram). It is relatively easy to walk to the Base Camp situated on the Khumbu Glacier but beyond that the route becomes very treacherous because of the steep, unstable Khumbu Icefall. This leads into a high, relatively flat valley, the Western Cwm, which was the site of Camp II (6300 meters, 20,700 feet) where the main laboratory was located. At the top of the Cwm is the headwall leading to the South Col, and at about 200 feet above this was Camp V (8050 meters, 26,400 feet). Finally a few measurements were done on the summit itself (8848 meters, 29,028 feet).

The diagram lists the main projects of the physiological program. The majority of the measurements that were planned were successfully carried out (indicated by check marks).

A. Summit 8848 meters (29,028 feet)

1. Barometric pressure and temperature. The barometric pressure is particularly important to physiologists because it determines the pressure of oxygen and therefore the driving force moving oxygen into the body. Barometric pressure and temperature were obtained by Chris Pizzo, M.D. on October 24. The pressure was measured with a light hand-held barometer containing a crystal transducer with a digital output. Although final calibration of the barometer has yet to be done, it is clear that the pressure was between 250 and 253 mmHg. This is the first direct measurement of pressure on the summit and agrees well with predictions based on radiosonde meteorological data. However it is about 15 mmHg higher.
PLATE 20

Photo by Yong Tenzing

Chris Pizzo taking alveolar gas samples on Everest’s summit, October 24, 1981.
than the standard altitude-pressure tables would suggest. The temperature was $-8.8^\circ C$, indicating relatively balmy conditions for the Everest summit.

2. **Samples of air from the lungs.** The importance of these is that the pressure of carbon dioxide in the air in the lungs is essentially the same as that in arterial blood. This in turn reflects the amount of increased breathing done by a climber under these conditions of oxygen lack, and is a measure of the degree of acclimatization. It is not, of course, practicable to collect blood on the summit. The air samples were collected into small pre-evacuated aluminum cans which were closed by spring-loaded valves. To take a sample, the climber breathed into the mouthpiece of a special sampler. He then made a rapid complete exhalation and pulled the trigger of the device. This action opened and then closed the valve of the sample can, thus trapping the last exhaled air. Six samples were taken by Pizzo and their analysis is still in progress at the time of writing.

3. **Continuous electrocardiogram.** This was measured because it gives information on heart rate and rhythm, and on the degree of oxygenation of the heart muscle. There is considerable interest on how the heart performs under these conditions of severe oxygen deprivation. The electrocardiogram was recorded on a small, slow-running cassette recorder kept in the pocket of a special vest worn by the climber. The recorder was switched on in the morning at Camp V and continuously recorded the electrocardiogram throughout the day. Data were obtained on both of the medical summiters, Chris Pizzo and Peter Hackett.

4. **Breathing during maximal exercise.** This is a measure of the amount of air moved by the lungs during hard climbing and it gives information on the way the lungs respond to low levels of oxygen. The measurement was made by having the climber breathe through a mouthpiece connected to a small turbine flow meter; pulses from the turbine were recorded on one channel of the tape recorder. Measurements were obtained from both Pizzo and Hackett on the way to the summit from Camp V.

**B. Camp V 8050 meters (26,400 feet)**

1. **Maximal work capacity and oxygen uptake.** This was the only project that was planned but not carried out on the expedition. Although both the special science tent and stationary bicycle were successfully carried up to Camp V, the winds proved to be so fierce that it was not possible to pitch the tent. This was ironic since this project was thought to be much less ambitious than the tests successfully carried out above the Col. Maximal work capacity had been successfully measured on the Makalu Col (7440 meters, 24,400 feet) during the Himalayan Scientific
Science Laboratory at Camp II. Pumori at left.
and Mountaineering Expedition of 1960-61 but the winds were not so severe at that time.

2. Blood samples. Striking changes in the blood occur at high altitude as part of the acclimatization process. These include an increase in the number of red cells and changes in the blood’s acidity. Venous blood samples were obtained on both Pizzo and Hackett at Camp V on October 25 and immediately taken down to the Camp II laboratory where the analyses were made.

3. Electrocardiogram during sleep. Continuous recordings on a slow-running tape recorder were obtained from Hackett, Kopczynski and Pizzo.

C. Main Laboratory 6300 meters (20,700 feet)

1. Maximal exercise studies. These measurements were done on a stationary bicycle. At the same time the level of oxygen in the arterial blood was measured using an ear oximeter (a device that determines the color of the blood by shining a light through the ear). Several subjects were studied while breathing a low inspired oxygen concentration in order to simulate the conditions found on the South Col and summit. Surprisingly high maximal work capacities were found and the reasons for this are not known at present. The levels of oxygen in the blood dropped to astonishingly low levels.

2. Sleep studies. These were carried out because of evidence that the amount of oxygen in the blood can fall to very low values during sleep at altitude. Indeed some physiologists believe that the hypoxia of sleep may largely determine a climber’s tolerance to high altitude. Our studies showed marked unevenness of breathing with very low levels of oxygen in the blood at times.

3. Blood studies. Extensive measurements were made on everybody at Camp II. One of the findings was that the increase in red blood cells was not apparently as marked as has been reported on some previous expeditions. The reason for this is not known as yet.

4. Metabolic studies. Exposure to low levels of oxygen over long periods of time causes many alterations in the biochemistry of the body. To study these, samples of blood were taken from everybody at Camp II and frozen. The frozen samples were brought back to the United States and are presently being analyzed.

5. Intestinal absorption. Almost everybody loses weight at high altitude and the reasons for this are not fully understood. There is some evidence that absorption of food by the gut is impaired. To study this we made several measurements of intestinal absorption.

6. Psychometric tests. In order to determine whether the oxygen deprivation affected short-term memory, manipulative skills, etc., measurements were made in both the Camp II and Base Camp laboratories and compared with baseline measurements made before and after the expe-
Plate 22

Expedition Photo

Steve Boyer on the bicycle ergometer at Camp II on Everest.
dition. No obvious changes were seen but analysis of the data is not complete.

D. Base Camp 5400 meters (17,700 feet)

1. **Control of breathing.** The most important feature of the acclimatization process is an increased breathing. This was studied both in the Westerners and the Sherpas, both awake and asleep. An interesting finding was that some Sherpas did not show the unevenness of breathing during sleep which is typically seen in Westerners.

2. **Blood studies on Sherpas.** Sherpas who live permanently at high altitudes have a notoriously high work capacity. The reasons for this are not known and furthermore there is a good deal of conflicting data on their blood physiology. Our measurements should clarify this confusing area.

3. **Effects of hemodilution.** Some physicians, especially in Europe, believe that the high concentration of red cells in the blood that occurs as a result of the acclimatization process may be harmful. The reason for this is the increased viscosity of the blood which results in uneven flow in the smallest blood vessels, and also increased work for the heart. These physicians therefore advocate removing some blood and replacing it with cell-free fluid. We tested this on four members of the expedition who had high red cell concentrations by making measurements on the stationary bicycle and psychometric tests before and after hemodilution. No obvious changes were found but further analysis is needed.

At the time of writing most of the data referred to above are still being analyzed. In some instances this will take many months. However it is already clear that the expedition was an outstanding success from a scientific standpoint.

In conclusion it is worth adding a word or two about the relationships between the climbers and scientists on this unusual expedition. As noted above, it is normally difficult to combine science and climbing because of the very different objectives. However, in this instance where the primary purpose of the expedition was science and this was recognized by everybody before the personnel were chosen, the relationships between the climbers and scientists were excellent. Indeed, some of the climbers found the expedition unusually satisfying because of its medical research orientation. Whereas on the usual type of expedition a climber who is unable to go very high for some reason may feel frustrated, in this instance everybody clearly contributed to the expedition goal irrespective of the altitude he attained. Personally I was astonished by the interest in the physiology of high altitude shown by the climbers. For example, at Base Camp when a storm interrupted carries through the icefall at the beginning of September, a number of informal seminars on high-altitude medicine were held in the afternoons and these were popular. This was a happy expe-
dition quite apart from its successes from the climbing and scientific points of view.

JOHN B. WEST, M.D., PH.D.

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The drizzling rain was turning to a drab wet snow as I slogged toward Base Camp—or toward what would soon become Base Camp—on August 31. The approach march had not been the idyllic stroll we had hoped for. The rain, mud, and leaches were certainly bearable, but porter problems had caused us to divide and re-divide to maintain a semblance of forward momentum. Even now we were behind schedule and apprehensive about a hundred loads which had fallen behind, and as I trudged up the boulder-strewn glacier, it seemed that a good break of some kind was overdue.

As the icefall came into view my spirits rose. Though I hesitated to believe it, the icefall appeared to be in great condition! Clearly we could avoid troublesome séracs for the lower half, and although the upper part cannot really be assessed from Base, it certainly did not look any worse than usual.

Although Base was not yet set up, we decided to start the icefall reconnaissance on September 1 as scheduled. Boyer, Kopczynski, Pizzo, and Porzak left by headlamp in the pre-dawn darkness, and by eight A.M. had scouted the route more than halfway through the icefall. The day was bright and clear, and our spirits soared.

By September 3 the icefall route was more or less established, despite setbacks from deteriorating weather and the fact that our icefall ladders were late reaching Base. Nearly the entire team had worked on the icefall with almost no Sherpa support. As a safety measure, we had set up a climbing school under Hackett's able direction and adopted a policy that all Sherpas had to participate before going into the icefall. This may have been a factor in our excellent safety record; in any case, it was well received by our Sherpas, many of whom had been on numerous expeditions without receiving any such instruction at all.

Poor weather stymied progress the entire second week of September. Our nice icefall route had one drawback; in order to skirt an appalling array of séracs at the top, our route veered a bit too close to the west shoulder. In good conditions it was bomb-proof, but any build-up of snow on the shoulder presented avalanche hazard to the route. The scale of the terrain made this hazard deceptive; a large trough between our route and the shoulder would certainly divert most avalanches, but what about a slide starting near the top of the shoulder nearly 3000 feet above? We adopted a policy of waiting a full day for the slope to clear after new or wind-transported snow—a policy that astonished the Sherpas and caused some frustration and disagreement among the climbers, but at least no one got hurt.
This stormy week gave us the opportunity to revise climbing plans. Since nearly all climbers were so healthy, apt, and eager, since we had such an enormous amount of research gear to go to Camp II, and since we wanted to avoid any unfavorable surprises with our proposed route variant to the left of the Geneva Spur, we decided to send teams of climbers ahead to pioneer and fix the route as quickly as possible, and to leave the Sherpas behind to concentrate on the loads. Also at this time it became apparent that we had a strong climber in one of our two liaison officers, Yogendra Thapa; he was added to the climbing team forthwith.

Thus Camp I was occupied by six climbers on September 12 and relocated the following day—the same day that four more climbers moved up to Camp I. Also on the 13th, Camp II (Advance Base) was sited by Porzak and Weis, at what appeared to be the point of least avalanche hazard—centered in the cwm abeam of the Scott route on Nuptse at about 20,670 feet.* The following day we made a carry to Camp II while the final two climbers moved up to Camp I. On the 15th Camp II was occupied by Jones, Schoene, Pizzo and Weis; the latter pair also reconnoitered the upper cwm, discovering that despite the apparent closeness, the bergschurnd was nearly two hours away.

By the time the Sherpas caught up with us on September 23, we had carried 51 loads to Camp II, fixed lines to Camp III (23,800 feet), and made seven carries to Camp III in anticipation of a move-up the following day. Meanwhile, the Sherpas had brought 250 loads up the icefall and taken over the task of carrying to Camp II. Thus the scheme of leaving the Sherpas behind had worked well for us; we enjoyed the feeling of self-sufficiency but were now ready for help with the high carries—not to mention the cooking and dishwashing chores.

We had planned all along to try to reach the col via the left side of the headwall in the hope that this fairly direct line would expedite progress, avoid the seemingly greater avalanche hazard of the Lhotse Face, lead to a protected site for Camp V, and provide a bit of new—though straightforward—terrain for the climbers. In retrospect these assumptions were correct, but the hope that we could find easy campsites at the obvious rock outcroppings did not materialize. Our route differed from the original Hillary-Tenzing route in that ours ascended to the left (north) of the Geneva Spur and to the right of the southwest face. It totally avoided the Lhotse Face and stayed more or less between the 1980 Polish southwest buttress route and the line Miura took for his descent in 1970. The headwall ranged in steepness from 35° to 45° and had sections of ice near camp III. Both Camps III and IV had excellent avalanche protection but minimal snow. In anticipation of this, we had

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* This was only slightly below the Camp II site on IHE '71 and I was astonished to find that our elevation was so low. Clearly the elevation of Camp II has been overestimated in the past.
Karl Marek working on equipment in the Camp II laboratory.
brought special aluminium platforms designed by Jeff Lowe. Getting these in place put us behind schedule again, although without them we probably could not have done this route.

Jones and I moved to Camp III on the 24th, intending to fix ropes above on the following days. Unfortunately my stomach was unhappy there, so I traded with Kopczynski. By the 26th, the two of them had fixed rope to Camp IV (24,500 feet) and Sherpas were making daily carries to Camp III. The weather was mostly good—despite the audible roar of the winds above—and we had visions of reaching the col by the end of the month.

But this was not to be. A violent windstorm at Camp II, combined with heavy snow at Base and major movement in the icefall, prevented progress for a week. During this period, a reappraisal of our status led to another change of strategy: rather than completing the buildup of Camp V—assuming we were ever to reach the col—we would send summit teams up at the earliest possible chance and try to maintain occupancy there in the hope of catching a good day for the summit. Also at this time, a near consensus arose that our earlier optimism had led to a debilitating avoidance of oxygen, and most climbers decided to begin using oxygen at Camp III henceforth.

On October 5, Porzak and Lowe set up and occupied Camp IV and in the next two days fixed rope to very near the col. Just above Camp IV they departed from the Polish route, which continued directly up to the south summit, and they headed to the right for the southeast ridge. By ascending the steep snowfield to the left of the Geneva Spur, the route would intersect the southeast ridge 200 feet above the South Col at 26,400 feet, the site of Camp V. They were replaced by Boyer and Graber, and despite the fact that the weather at Camp II was mostly fair, the winds above remained merciless and the col elusive. Radio failures and aborted carries helped make this an extremely frustrating period, and only by a determined effort was a feasible site for Camp V, nestled against a sheltering rock cliff, located by Boyer on October 10. On that same day, the first “summit team” of Jones, Kopczynski and Pizzo moved up to Camp III with three Sherpas, and with the very optimistic plan to complete fixing rope to Camp V, establish and occupy that camp, and make a summit bid.

More heroic efforts enabled them to do all of this except for the summit bid, which was thwarted by horrendous winds. Boyer and Graber came down on the 13th and Jones, Kopczynski and Pizzo came down the following day; ironically it was calm at Camp II that morning, and a second summit team of Hackett, Porzak, Sarnquist and Thapa left early to go up to Camp III. The 15th was absolutely perfect except for the fact that we had no one at Camp V for a summit push. Sarnquist had a bad night at Camp III and elected to make a quick carry to Camp V and
Camp III on Everest was erected on an aluminum platform because of the steepness.
descend. Hackett, Porzak and Thapa spent some time sorting loads at Camp III and then moved up to Camp V, arriving so late that they were not able to mount a summit bid on the 16th, though the weather was almost reasonable. The winds again increased to hurricane force that night, destroying all but one of the Camp V tents; the second summit party bailed out in desperate conditions and returned to Camp II. On the 18th, two more pairs of climbers headed up: Boyer and Kopczynski, and Lowe and Weis, the latter pair hoping to make an oxygenless ascent. High winds held them up at Camp IV for a day, and on the 20th Boyer developed symptoms of HAPE (his second bout of this on the trip) and descended to Camp II. Lowe also was having some difficulties and returned to Camp IV. When Weis and Kopczynski arrived at Camp V they found only a single tent standing, and Weis opted to withdraw, feeling that Kopczynski and Sherpa Sundare had the best chance of success.

Hackett and Pizzo started up early on the 21st with hopes of doing some physiological experiments on the col. At the same time, Kopczynski and Sundare were leaving Camp V in strong winds for a summit attempt. To their astonishment, the winds abated and didn't become fierce again until near the south summit. They reached the true summit in the incredibly fast time of under four-and-a-half hours, and by four P.M. had descended all the way to Camp III—even after stopping on the way down to brief Hackett and Pizzo at Camp IV.

This was Sundare's second time to reach the summit, the first being on October of 1979 when he lost nine of his toes to frostbite in a valiant but futile attempt to help his two companions, Ray Genet and Hannelore Schmatz. The body of Frau Schmatz, most regrettably, was found unprotected on the route, but we did not have the resources to perform either a burial or an evacuation; Ray Genet's body was not encountered.

A Sherpa dropped a crucial stove at Camp IV and Hackett and Pizzo were held over for a day of beautiful weather. Fortunately the weather held, and on the 23rd they moved up to Camp V, recovered the scientific gear which had been buried in a tent, and made preparations for a summit bid in the morning.

Pizzo and Sherpa Yong Tenzing left Camp V at about 6:30 A.M. in strong winds and also found calm conditions from just above Camp V to near the south summit. Pizzo's ice axe had been buried in an earlier storm at Camp V, so he started up using a tent pole. Before an ice axe became crucial, he fortunately found one lying in the snow! They summited about 12:30, again in strong winds, but with the temperature a balmy +16° F. Pizzo measured the barometric pressure, collected samples of expired air, took a few pictures, and, before descending, lofted a frisbee into Tibet—thus establishing himself as the holder of the world's record for a high-altitude frisbee toss!

Meanwhile, Hackett and Sherpa Nuru Dzambu had started up an
hour behind Pizzo and Tenzing, but Dzambu could not get his feet warm and very soon returned to Camp V. As conditions were excellent, Hackett decided to keep going, hoping to make it to the south summit. At about two o'clock he met Pizzo and Tenzing just below the south summit coming down. Tenzing had a nearly full bottle of oxygen and Pizzo encouraged Hackett to take it and continue. Hackett summited around four P.M. and started down after only a few brief moments on top. He had a close call on the descent when he slipped at the Hillary Step, but at 5:45 P.M. he rendezvoused with Pizzo who was waiting below on the ridge. They descended in the dark to Camp V, arriving about eight P.M. and returned to Camp II the following day.

The damaged tents at Camp V and the lines on the headwall were left in place despite our hopes of completely clearing the route. All other camps, as well as all the rope and ladders in the icefall, were removed, and we had a big cleanup of Base before withdrawing on October 31.

JOHN EVANS

Summary of Statistics:

AREA: Mount Everest, Nepalese Himalaya.

ASCENTS: Mount Everest, via a variant of the South Col Route, October 21, 1981 (Kopczynski, Sundare); October 24, 1981 (Pizzo, Yong Tenzing, Hackett).

PERSONNEL: John B. West, M.D., Ph.D., leader; John Evans, climbing leader; F. Duane Blume, Ph.D., deputy leader for logistics; Christopher Kopczynski, David Jones, Jeff Lowe, Glenn Porzak, Michael Weis, climbers; Steven Boyer, M.D., David Graber, M.D., Peter Hackett, M.D., Christopher Pizzo, M.D., Frank Sarnquist, M.D., Robert Schoene, M.D., scientist-climbers; Sukhamay Lahiri, Ph.D., Karl Maret, M.D., James Milledge, M.D., Richard Peters, Michele Samaja, Robert Winslow, M.D., scientists; Rodney Korich, Base Camp manager.

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