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Reaching the Heights of Respiratory Physiology

Professor John B. West is a renowned respiratory physiologist and researcher. He joined the faculty of the University of California San Diego in 1969, where he is Distinguished Professor of Medicine and Physiology in the School of Medicine, where he still teaches first-year medical students. He is author of *Respiratory physiology - the essentials*, which has been translated into many languages, and is now in its 10th edition. His YouTube Lectures in Respiratory Physiology have attracted over 400,000 views and rave reviews. He is past president of the American Physiological Society, and was the founder Editor-in-Chief of the journal *High Altitude Medicine and Biology*. He has received numerous honours and awards from around the world for his research and teaching, and is the author of over 500 articles and 19 monographs.

Out of your many achievements what are you most proud of?

Firstly, the research we did leading to respiratory measurements on the top of Mount Everest. Second the measurements of the function of the lung in space, which we did for the first time with the NASA Programme. Finally, the effects of gravity on the lung, particularly the distribution of blood flow.

How has your research advanced critical care practice?

My work on pulmonary gas exchange that involved measuring ventilation-perfusion inequality in the lung added important information. In critical care medicine my research on the effects of gravity on the lung is important.

What is the most vexing unknown about respiratory physiology?

I wish we knew more about what determines the mechanical strength of pulmonary capillaries. We're not sure about that and I wish we were. I am also particularly interested in the function of permanent residents at high altitude, those people who have been at high altitude for generations. Have they completely adapted to severe hypoxia? They have severe hypoxaemia and the question is whether they are completely adapted to that or not. In particular, is their cognitive function as good as it would be if they were at a lower altitude? We don't know the answer to those important questions, and I think in a few years people will do some more research in this area.

You have donated your papers to the University of California San Diego Library, and you have written about the history of medicine (including West 2015a). Why is the history of medicine important?

Particularly in medicine, the work that has been done can illuminate a lot of the work done at the present time. If you don't know about history, you might make terrible mistakes. I have a special interest, because the archive at the University of California San Diego is a repository of high altitude medicine and physiology papers. It started with Griffith Pugh, the pioneer Everest physiologist, who went on the Everest expedition in 1953. I knew him well, and after he died I asked his widow whether I could have his papers, which she donated to the university. We have collected a lot of things since for this archive, and we welcome people from all over the world. In general, history is very important, and I like to think that we are contributing.

You joined Edmund Hillary's Silver Hut Everest expedition in a serendipitous way. It's a wonderful word and a wonderful concept—what part has serendipity played in your career?

There have been several very serendipitous events in my career. I was at a meeting of the British Physiological Society in London in 1960, and the woman sitting next to me told me that Edmund Hillary was planning an expedition to Mount Everest, which was physiological in its aim, and that the chief physiologist was Griffith Pugh. I was young at the time, but well trained in respiratory physiology. I didn't know anything about high altitude, but I applied to join the expedition and I was very fortunate that I was accepted, even though I'd never been on a high mountain before. I've done a bit of skiing, but I am not a climber. That was the Silver Hut expedition in 1960-61, which turned out to be a very productive expedition (Milledge 2002). The idea was to study what happens to lowlanders, people who live at low altitude, when they go to a very high altitude, in this case 5,800 metres (19,000 feet), and spend several months there. Nobody had ever done that before, and I've not come across any other example. It was very new and we made a very extensive series of measurements. We had quite sophisticated equipment in a structure called the Silver Hut, because it was painted silver. It was a very successful expedition and I became very interested in high altitude as a result. At the end of the expedition, we went across to a mountain called Makalu, which is within 10 miles of Everest, and the climbers tried to climb it without supplementary oxygen. If they had been successful, it would have been the highest peak to be climbed without supplementary oxygen, but they were not successful. One of the climbers became acutely ill in the final stages and I helped in getting him off the mountain alive, because it was a desperate situation. The end result was I made some measurements with Michael Ward, another physiologist climber, at an altitude of 7,400 metres or so, which were the highest measurements at the time of physiological function. That experience in 1960 prompted me to wonder whether it would be possible to get measurements at the summit of Mount Everest, the highest point in the world. That was the objective of the 1981 American Medical Research Expedition to Everest (AMREE) that I led.

Another serendipitous event was when I was working at Hammersmith Hospital in London. There was a new respiratory physiology programme being developed, and Charles Fletcher, one of the principal physicians there, recommended that I go to the pneumoconiosis research facility in South Wales, learn some physiology and come back with ideas. When I came back, the Medical Research Council (MRC) cyclotron started on line and it produced radioactive oxygen with a half life of only two minutes. Nobody had used radioactive oxygen before in physiological measurements. So we inhaled the gas, and that was the beginning of my interest in the distribution of pulmonary blood flow, because we found that the radioactive gas was removed from the top of the lung much slower than from the bottom of the lung. It was a striking regional difference in blood flow, which had never really been described before; there had been intimations of it only, from bronchospirometry and other measurements. We made the first clear measurement of the uneven distribution of blood flow. That was an extremely serendipitous event.

> **"I think oxygen conditioning has a great future for people living at high altitude"**

You are a strong proponent of oxygen conditioning for people living at high altitude. Please explain.

As with so many things in medicine, this idea comes from advancements in technology. I have only recently realised that it is possible to reduce the physiological altitude of people by adding oxygen to inspired air on a large scale. I compare it with air conditioning, which has completely changed the wellbeing and productivity of people in hot places. Air conditioning in the USA is enormously important: 90% of new homes have air conditioning. Oxygen conditioning has the same potential. This has to do with improving the conditions at high altitude for visitors, and also what we call sojourners, who are people from low altitude who are living and working at high altitudes. All those people are certainly going to be improved by oxygen conditioning, which helps your physical and cognitive functions. Even adding oxygen to a single room has a potential benefit. In Peru you can go to a hotel and ask for an oxygen-enriched room, and oxygen conditioning is used in a mine in Chile and in China on the Qinghai-Tibet Railway, which travels to a 5000m altitude. Some people think it's going to be too expensive, but air conditioning is also expensive, but considered absolutely essential. Oxygen and air-conditioning share a number of features, and I think oxygen conditioning has a great future for people living at high altitude (West 2015b).

In the 1981 American Medical Research Expedition to Everest, the most important finding was hyperventilation. Could you elaborate on that please?

The objective of the American Medical Research Expedition to Mount Everest (AMREE)'s was to try and understand how someone from low altitude—sea level, or thereabouts—can possibly tolerate the extreme hypoxia on the summit of Mount Everest. The summit of Mount Everest is very interesting because it is right at the limit of human tolerance to oxygen deprivation. You may try to think of an evolutionary reason for that, but there is none of course. It's probably one of these cosmic coincidences. At the summit, the most important thing is that people develop extreme hyperventilation. For example, on the summit of Mount Everest, the alveolar PCO_2 we measured was between 7 and 8 mmHg as opposed to the normal value of 40 mmHg at sea level. So they were increasing their alveolar ventilation by about five times—a tremendous increase. One of the climbers had a tape recorder with him and he dictated the recording of barometric pressure for the first time. He was desperately short of breath, pausing between every one or two words. One of the things about the hyperventilation is that you get an extreme respiratory alkalosis, which we did not expect. We expected there would be hyperventilation because we'd done a modelling study. What we didn't realise is that the kidney, for reasons we still don't fully understand, was "reluctant" to excrete bicarbonate at these great altitudes. And the base excess changed only a small amount between 6,300 metres and the summit, 8,800 metres. For some reason, there was very little metabolic compensation of respiratory alkalosis. This was a very interesting situation. We think that may have to do with the fact that climbers are always volume depleted, always so dehydrated, that the kidney is not able to excrete bicarbon-

Michael Ward and John West assembling the stationary cycle to make measurements of maximal oxygen consumption at an altitude of 7440m (24,400 ft). These are the highest reported measurements to date.

ate. It turns out that this alkalosis is valuable because it increases the uptake of oxygen by the lung at this altitude. This is fascinating and it never occurred to us before. If you look at the whole animal kingdom, you find that all sorts of animals increase their oxygen affinity in their haemoglobin in hypoxic situations. And it's absolutely fascinating that the climber does the same thing by a completely different and unexpected method—the alkalosis.

You have written that a sound knowledge of respiratory physiology will always be necessary for the intelligent practice of medicine. Could you comment on that?

Some people are worried that physiology is passé, and some physiology departments have changed their name to human biology. It will never be passé. The study of medicine requires you to understand the function of the lung, and the whole system. It's absolutely critical that people in the intensive care environment understand gas exchange and mechanics. The work on the human genome and on molecular medicine is magnificent, but physiology has not lost its importance.

You have compared the features of the avian lung to the mammal lung and observed that many features of the bird lung are superior to those in mammals and that in the future we may be able to exploit some of these.

I'm interested in many aspects of physiology, including comparative physiology. I've done a lot of work on the bird lung, which is absolutely fascinating. For one thing, in the bird lung the gas exchange and ventilation functions have been separated. In the human lung, we use delicate alveoli for both gas exchange and pumping the air. If you think about this, it is a crazy solution. The alveoli walls have only a fraction of micron of thickness; why use those for pumping? Birds have air sacs, which do not take part in gas exchange; they don't have any capillaries. But the air sacs do the pumping and the gas exchange is done by another structure within the lung called the parabronchi, where you have the pulmonary capillaries. In many ways it's a much better design. Nowadays people are thinking about making artificial lungs that conceivably one of these days could take the place of diseased lungs. If you're going to bio-engineer a lung, you might want to take a close look at the bird lung because in my opinion it has a better design than the mammalian lung.

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You are renowned as an educator. Do you have any secrets to share?

At my high school, Prince Alfred College in Adelaide, Australia I had a marvellous teacher, Ray Smith. I always like to mention that, because people often underestimate the importance of teachers. He taught me in my final years in high school. He had a wonderful ability to put himself in the place of the pupil, and that rubbed off on me as the secret of teaching. It's difficult for many teachers to do that for medical students. I teach the first year medical students here, and I get good reviews from them. I think the reason is that I realise their intellectual point of view as beginning medical students and I think that helps with teaching. I would like to put in a plug here for the American system, where there is a four-year college period between high school and medical school. It's a great idea. I went straight to medical school from high school at the age of 17, which is far too young. ■

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