In this issue

Beyond the Limits

Of the many organisms that feature in the pages of this journal, *Homo sapiens* appears rarely. But this is set to change with this Special Issue. Hans Hoppeler, who edited the edition, says 'the intention is to look at human physiology from a JEB perspective. We wanted to show the reader that there is an aspect of human physiology that fits the journal'.

The reviews discuss different aspects of human adaptation to extreme environments: and there is nothing more extreme than high altitude, ultra-cool temperatures, and ultimately space!

Because it's There

The front cover shows one of our review authors, Thomas Hornbein, ascending the West Ridge of Everest in 1963. Happily, Hornbein made a successful expedition to the mountain, but as Raymond Huey and Xavier Eguskitza point out (p. 3115), getting to the top isn't all there is to it: the majority of climbers die on the descent. Of course a more common experience for the mountaineer is that of mountain sickness. Acute mountain sickness is still poorly understood (p. 3161). Robert Roach and Peter Hacket review evidence that the nervous system is central to the problem.

Hornbein's experience at the summit of Everest qualifies him to describe the effects of hypoxia on the brain, during and after the ascent (p. 3129). Alarmingly, mountaineers who have successfully scaled mountains over 8000 m frequently show some permanent loss of neurological function. He believes that the neurobiological effects of altitude are the most significant limitations for human survival at extreme altitudes.

Of course, satisfying the body's oxygen demands also depends on the efficiency of gas exchange at the lungs. Robert Schoene points out that even breathing uses energy, and that lower atmospheric pressures also reduce the rate of O_2/CO_2 exchange across the lung wall (p. 3121). But he does finish on an optimistic note, pointing out that despite the hardship, humans function remarkably well in extreme environments.

In his own review, Hans Hoppeler, writing with Michael Vogt, warns that for people acclimatised to life at sea level extended periods at high altitude can result in muscle damage (p. 3133). However, mountain peoples, such as the Quechuas from Peru, have adapted over the generations to protect their muscles from the ill effects of life in this so-called extreme habitat. Other studies of mountain populations look at the effects of altitude on fertility. V. Vitzthum concludes that the relatively low fertility rates associated with mountain peoples probably have more to do with cultural differences than the physiological effects of altitude (p. 3141). Some human adaptations have evolved in response to hypobaric conditions, and these are reviewed by J. L. Roberts and P. W. Hochachka. They discuss the methods that people have used to look at human adaptations to living at high altitude and point out that it isn't clear whether these adaptations are due to the genetic characteristics of the population or to an individual's innate ability to adapt (p. 3151).

What is our Metabolic Limit?

In 1997, Jared Diamond asked 'what is our metabolic limit?' He wondered why an organism's energy output is limited, and what are the limiting factors? The papers in this section of the journal discuss various aspects of human physiology that might be involved in limiting the amount of energy a human can expend when physically challenged.

Everyone knows the feeling of being out of breath, but how is human aerobic performance limited by our ability to take up oxygen ($\dot{V}_{O_2}$) (p. 3195)? This effect was thought to set a major constraint on human aerobic performance. Some athletes go to great lengths to increase their oxygen delivery capacity in an attempt to extend the limit. But Stan Linstedt and K. Conley suggest that simply improving oxygen delivery doesn't increase $\dot{V}_{O_2}$, and that athletes might perform better if they concentrated on other aspects of aerobic fitness.

Diet is certainly a key part of a training regime, but how is human endurance limited when we have access to an unlimited diet (p. 3183)? Klaus Westerterp considers the effect of exercise on energy intake and body composition. He points out that highly trained individuals can almost double their endurance, if they combine exercise with a high-energy diet.

Other stresses that push human endurance to the limit are the availability of oxygen and warmth (p. 3171). Most animals experience both stresses at some time of their lives, but hibernating creatures have developed strategies to survive conditions that would otherwise be fatal. These animals are able to downregulate their metabolism and protect themselves from the type of tissue damage that we would suffer if starved of oxygen or exposed to subzero temperatures. Bob Boutilier reviews a host of comparative studies of hibernating animals that have contributed to our understanding of hypoxia and hypothermia.

Two other groups look at ways that metabolism may limit human energy output, either through a 'central governor' mechanism, or by limiting the supply of ATP to muscle. Juha Peltonen and colleagues discuss evidence that supports the 'central governor' theory, which suggests that a neural regulator protects the heart from damage through overwork (p. 3225). An alternative view is that the ATP supply limits the work that a muscle can do. Kevin Conley and his colleagues describe how cellular metabolism limits the level of cellular ATP, protecting the body from overwork by simply cutting off the fuel (p. 3189).

Finally, Robert Dudley discusses the theory that modern humans evolved under slight hypoxic selection at altitudes ranging from 1000-2000 m and the effect that this may have had on modern human locomotion. He draws a comparison with the hummingbird's metabolism. These animals live at similar altitudes to humans and have evolved an incredible tolerance to the hypoxia, which they experience when hovering (p. 3235).

Zero Gravity

Fans of Star Trek all know that space is the final frontier. When you begin to probe into the effects that even short periods of time in space have on the human body, you begin to see that this isn't an over-statement in terms of human physiology.

Microgravity is an environment that only a handful of human beings have ever encountered. The most obvious effect of space flight is severe muscle atrophy. Robert Fitts and his colleagues describe the catastrophic effects of microgravity on rat and human skeletal muscle (p. 3201). The muscle loses some of its contractile proteins, and some muscular functions are altered by a lengthy space flight. However, V. R. Edgerton (p. 3216) describes a series of experiments where astronauts returned to earth with enhanced function in flexor and extensor muscles. He points out that this could have more to do with the training regimes that NASA impose on their astronauts, rather than the environment itself.

Another system in the body that is disrupted by microgravity is the cardio-vascular network (p. 3209). In the absence of a gravitational force, body fluids redistribute dramatically. This causes in an increase in antidiuretic hormones that ultimately result in a significant decrease in the astronaut's body fluids. Although this may not impair the astronauts during the flight, it probably causes problems when they return to earth.

Every author who has contributed to this issue has described incredible feats of human endurance under difficult circumstances. Whether discussing the effects of microgravity, or the body's response to oxygen levels that can barely sustain life, they present an organism functioning at its physical limit. Hans Hoppeler believes that characterising these adaptations at the molecular level is the coming challenge for extreme physiologists. So, if you're doing micro-arrays on an 'Iron Man' or visualising the neurobiology of mountain sickness, the Journal of Experimental Biology wants to hear from you.

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