Sachs, from the Technische Universität München, Germany, decided to investigate in more detail with the help of his aerospace engineering background (p. 4222).

As GPS technology has become much smaller and more advanced in recent years, Sachs and his PhD student at the time, Johannes Traugott, realised they could use GPS loggers to investigate the albatrosses' movements in fine detail. By manipulating the loggers to increase data recording to 10 times per second and developing a special computational algorithm, Sachs and Traugott could track both horizontal and vertical movements to within decimeters. Equipped with 20 GPS loggers, Traugott then made the long journey to the remote Kerguelen Islands in the Indian Ocean. With the help of biologist Anna Nesterova, a post-doc in Francesco Bonadonna's lab at the CNRS Centre d'Ecologie Fonctionnelle et Evolutive, France, he was then able to attach his loggers to albatrosses just about to depart the islands on a long foraging trip.

From the logged data, the team could then characterise the small-scale soaring and diving movements the birds made, into four distinct phases: (1) a climbing upward phase against the wind, (2) a leeward turn, (3) a downward descent with the wind and (4) a windward turn just above the sea to reorient themselves against the wind for their next climb. The GPS data also provided the team with information of the albatrosses' speed and altitude so they could calculate where and exactly how most of the energy was gained. While some energy was gained because of an increase in altitude, most of the harnessed energy was kinetic energy, gained after the albatrosses had made their leeward turn and were heading downwards with the wind behind them.

With some further analysis, Sachs found that albatrosses will climb to different altitude levels: in one case this was 9 m above sea level and in another it was 15 m, suggesting that they will fly high enough to enable them to the gain sufficient energy to sustain continuous non-flapping flight. Next, Sachs calculated the maximum propulsive force generated from this wind and found that it was more than 10 times higher than anything the albatross could create by merely flapping its wings. This conclusively showed, for the first time, that at no point during their four-step routine do the albatrosses resort to this energy-draining mode of flying.

What's more, with his calculations, Sachs was also able to rule out a number of other theories. He shows that the energy gain cannot be explained by the wind gradient alone, which predicts that energy would be gained on the upward stage of flight. He also ruled out that gusts caused by crashing waves helped, as several albatrosses started their acrobatic manoeuvres whilst still over land and there were no sudden gains in energy. All in all, the albatrosses seem to have mastered a very complicated flight manoeuvre that allows them to fly for 'free'.

10.1242/jeb.097212

Sachs, G., Traugott, J., Nesterova, A. and Bonadonna, F. (2013). Experimental verification of dynamic soaring in albatrosses. *J. Exp. Biol.* **216**, 4222-4232.

Nicola Stead

LIVING THE HIGH LIFE, HOW GROUND SQUIRRELS COPE

If you've ever experienced altitude sickness, you'll know that living at high altitude isn't easy. However, the lower oxygen levels at higher altitudes don't cause problems for everyone, and in the mountain ranges of western North America some species of ground squirrels can live quite happily at elevations of up to 4300 m above sea level. What's more, these small mammals are used to low oxygen levels found in their poorly ventilated burrows during hibernation. So what makes them so resilient to poor oxygen conditions? Angela Fago, from the Aarhus University, Denmark, and Jay F. Storz, from the University of Nebraska, USA, joined forces to find out (p. 4264).

Fago and Storz began by assembling a team that travelled from Nebraska to the Rocky Mountains of Colorado and then onto Alaska to collect blood samples from six different species of ground squirrel living at different altitudes ranging from 200 to 4300 m. Back in the lab, Fago's group began their experiments by measuring the effects of two allosteric effectors, 2,3-diphosphoglycerate (DPG) and chloride anions, on the ability of the oxygen-carrying protein haemoglobin to bind oxygen. 'These small molecules and ions normally bind to the haemoglobin and they tend to decrease the oxygen affinity of the haemoglobin', explains Fago. 'This is favourable for species living at sea level, but in species living at high altitude, these co-factors normally don't bind so strongly, so that the haemoglobin remains in a high affinity form.' In fact, in the case of the ground squirrels, Fago's team found that neither allosteric effector affected oxygen uptake whatsoever.

The team then went on to investigate the effect of lowering pH on blood samples from two ground squirrel species inhabiting different altitudes. Fago explains that lowering pH stabilises the haemoglobin in a low-affinity conformation, in what is known as the Bohr effect, and this helps to release oxygen where it is needed in the tissues. Animals living at high altitude often show a bigger Bohr effect to compensate for the fact that their haemoglobin generally already has a higher affinity for oxygen, and indeed both samples were strongly affected by lowering the pH. However, unusually, both the highland inhabitant (2000–4300 m) and the lowland inhabitant (200–2000 m) performed as well as each other and Fago believes that 'it shows that subterranean life puts a kind of stress on these animals so they are able to withstand different conditions and already had what it takes to be able to colonise high-altitude environments.'

Meanwhile, Storz's team focused on analysing the haemoglobin proteins in more detail. Looking at the amino acid residues that are crucial for binding H^+ ions and aiding the Bohr effect in human haemoglobin, the team found amino acid substitutions that would in theory reduce, not increase, the Bohr effect. To add to the riddle, Storz's group found that all the amino acids that bind allosteric effectors in human haemoglobin remained unchanged in the ground squirrel's haemoglobin, even though Fago's results suggested that neither DPG nor chloride could bind the haemoglobin to an appreciable extent. It appears that, because of some subtle differences in structure, identical amino acids do not have identical effects in human and ground squirrel haemoglobins. Fago concludes, 'We still have a lot to learn from doing comparative measurements and although the human haemoglobin is one solution to the problem, it's not the only solution.'

10.1242/jeb.097030

Revsbech, I. G., Tufts, D. M., Projecto-Garcia, J., Moriyama, H., Weber, R. E., Storz, J. F. and Fago, A. (2013). Hemoglobin function and allosteric regulation in semi-fossorial rodents (family Sciuridae) with different altitudinal ranges. *J. Exp. Biol.* **216**, 4264-4284.

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