DEEP DIVERS

Humans and animals that go to the extreme...

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In 2008 talented freediver, William Trubridge "pushed the bubble" of human freediving again and extended his world record. On April 8th William performed the incredible and earned his esteemed place amongst other deep diving mammals when he descended, unassisted on descent or ascent, and without fins, to 86 metres below the sea surface and returned, fully conscious, on one breath of air.

Photo by IgorLiberti

Through yogic relaxation and breath-control techniques, William swam down, frog-like, for one minute and 40 seconds to two metres beyond his previous record, before starting his trip to the surface which he then completed in a similar time. This New-Zealand born former pupil of the legendary Umberto Pellizari has developed manouvers that he practices in dry training which bring on bradycardia (a reduced resting heart rate) and hypometabolism, an abnormal decrease in normal metabolic rate. By blocking the regular breathing reflexes using a combination of the yogic 'bandhas' and a certain position of the tongue and soft palate William can slow his heart rate to 25 beats per minute from a resting heart rate of 53 beats per minute.

Trubridge also attributes his success to psychological factors and his ability to switch off the rational, thinking mind during a dive, as he considers it slow and inefficient.
"Through visualisation and positive affirmation we can 'program' the unconscious mind so that it responds to situations and contingencies with far greater efficiency. Nevertheless it can be difficult to quell the negative psychology and 'chatter' of the rational mind, and rather than try to block it, which is usually unsuccessful, I try and concentrate on lengthening the gap between the thoughts" he underlines.
"It seems like the brain very quickly changes to slower frequency alpha waves during a dive, much as in meditation, or when athletes reach 'the zone' after long-duration aerobic exercise" he continues.

As far as his emotions go, these are even more subdued, and he can't remember the last time he felt any strong emotion, be it fear or excitement, during a dive, his emotions normally dissipating after the duckdive and not returning until after surfacing.

Exceptional though they are for a human, William's near superhuman feats pale in comparison to those of other air-breathing, deep-diving mammals and birds. According to research by Castellini, Kooyman, and Ponganis in 1992, larger animals are more capable of reaching greater depths due to their size giving them a greater aerobic dive limit. California sea lions have been recorded to dive to 274 minutes in 9.9 minutes, Beluga whales plunge to 350 metres over 19 minutes. Emperor penguins reach beyond 500 metres, Leatherback turtles and Northern elephant seals descend to the maximum light penetration limit of one kilometre deep when foraging, and the supreme deep-diver is, beyond any doubt, the Sperm whale. This 18-metre, 50-tonne cetacean has been recorded at 2.25 km down, and the presence of a certain species dogfish in the stomach contents of one individual would suggest that it descended to 3000 metres. That these species use yoga to assist their deep diving abilities is unlikely, but it has been proven that they have adapted different physiological and biochemical mechanisms to increase dive duration and depth.

Human divers are prone to hypoxia, or oxygen starvation to the brain, and nitrogen narcosis (a semistupor, lightheadedness, or euphoria experienced by deep-sea divers when nitrogen from air enters the blood at higher than atmospheric pressure) on even relatively shallow dives. Although research is not yet fully conclusive, it is believed that Cetaceans perform total lung collapse to deal with these two phenomena. At depth, oxygen partial pressures raise the pressure of arterial oxygen whilst simultaneously lowering lung oxygen pressure. During ascent, lung expansion further reduces lung oxygen tension, with the potential of causing oxygen to diffuse in the lungs to cope with it being of a lower pressure than that of venous blood. The result over the last 10 metres of a dive, where there is the greatest expansion of lung volume, is that arterial oxygen levels drop to intolerable levels in the brain. In cetaceans, total lung collapse negates this situation, and also prevents the levels of nitrogen absorption found in humans.

Any muscle movement in any creature is carried out either aerobically or anaerobically. Anaerobic metabolism generates energy using a chemical reaction that does not require oxygen but creates a by-product called lactic acid. It is useful when oxygen is in short supply, but it cannot be sustained for long as it is less efficient than aerobic metabolism, and the lactic acid accumulation results in muscular soreness.

Researchers have devised mathematical formulas to calculate aerobic dive limits ("ADL") or the amounts of time various marine mammal species can stay underwater before anaerobic metabolism kicks in, and studies show that whilst most animals stay within their ADL, certain species significantly exceed it when prey is difficult to catch. Australian and New Zealand sea lions typically dive nearly 1.5 times longer than their ADL, meaning that one-third of each dive was anaerobic. As a result they have to rest longer between dives than, for example, fur seals that stay within their limits.

Prey type also plays a factor as species such as sea lions are believed to hunt a single prey such octopus and large squid on the seabed, rather than multiple smaller prey closer to the surface, giving added incentive to go beyond aerobic limits. According to Daniel Costa, professor of ecology and evolutionary biology and co-author of findings published in Comparative Biochemistry and Physiology "They're either doing something we don't understand or they're routinely exceeding their aerobic limit," Costa said. "It's interesting that the populations that are working very hard are the ones that are not doing well." Although scientists differ on how to calculate an animal's aerobic dive limit, the study results are nevertheless sound, Costa said. "Even with the most conservative measures of the aerobic dive limit, these animals

are pushing or exceeding their limit," he said. Other deep free divers employ the same bradycardia technique as Trubridge. By slowing down their heart rate, less oxygen is consumed. Whilst rare human individuals, after training and practice, can reduce their heart rate by half, many deep-diving mammals, far exceed this slow down. Dolphins commonly reduce it from 120 b.p.m. to 40, various seals reduce it fivefold from 100 to 20, and, according to P.J.Butler and David R. Jones, grey and elephant seals can sometimes achieve a staggering five beats per minute. During later stages of descent and ascent muscle movement is minimal, the animals going into glide mode to move in the most energy-efficient way possible. It is also possible that reduced heart rates are linked to a reduced metabolic rate, of up to 60% in some species, where organs like the liver and kidney are not perfused through vasoconstriction during dives, and "catch up" during post-dive rests.

The different positions of oxygen stores also play a role, as can myoglobin levels. Whilst humans are mainly dependent on lung-stored oxygen which is rapidly nullified at depth, some penguins and dolphins store more than a third of their oxygen in muscle cells, and over half in the case of the King penguin. Myoglobin is an oxygen-binding protein that is far more prevalent in diving mammals than non-divers, and is unaffected by the oxygen pressure in the surrounding tissue, contrary to the more common oxygen transporter, haemoglobin.

The master deep diver though, is the Sperm whale. Not only must it adapt to withstand the incredible water pressure at depths into the total blackness beyond 1000 metres, but it must also be able to maintain neutral buoyancy at any depth. It has a head, making up 25% of its body length and 33% of its bodyweight, holding huge organs storing wax, called spermaceti oils, which give it its name. The density of the wax can be modified, thus affecting buoyancy, allowing the whale to hang motionless in the water consuming very little oxygen whilst searching for its prey. The wax also serves as an acoustic lens that focuses sounds via refraction through its concentric layers, creating a highly efficient echolocation device.

As with many marine subjects, research is only scratching the surface of our understanding, and further studies are in progress on different species and in new domains. A team lead by Terrie Williams, professor of ecology and evolutionary biology at the University of California is looking into two recently discovered oxygen carrying "brain proteins"; neuroglobin and cytoglobin. By researching their roles in helping deep-diving mammals function with very low brain oxygen levels, Williams wonders whether humans could train their brains to produce higher levels of these proteins to prevent brain ageing and strokes. And maybe, just maybe, to go beyond Trubridge's current world record?

Christopher Barlett

Christopher's occupations are as varied as his passport entries. Part French, part British, Christopher has wandered around much of the southern hemisphere and Europe. As a dive master and field guide he always strives to learn more. As a freelance journalist he has shared his discoveries in magazines from Mexico to Malaysia. As an ex-brewery founder, he still makes a decent pint.