Research finds how diving mammals evolved underwater endurance

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Sperm whale. Image credit: Ocean Footage

Scientists at the University of Liverpool have shed new light on how diving mammals, such as the sperm whale, have evolved to survive for long periods underwater without breathing.

The team identified a distinctive molecular signature of the oxygen-binding protein myoglobin in the sperm whale and other diving mammals, which allowed them to trace the evolution of the muscle oxygen stores in more than 100 mammalian species, including their fossil ancestors.

Myoglobin, which gives meat its red colour, is present in high concentrations in elite mammalian divers, so high that the muscle is almost black in colour. Until now, however, very little was known about how this molecule is adapted in champion divers.

Proteins tend to stick together at high concentrations, impairing their function, so it was unclear how myoglobin was able to help the body store enough oxygen to allow mammals, such as whales and seals, to endure underwater for long periods of time without breathing. Elite mammalian divers can hold their breath for over an hour while they hunt in the depths of the oceans, while land mammals, such as humans, can hold their breath for only a few minutes.

Dr Michael Berenbrink, from the University's Institute of Integrative Biology, who led the international team, explains: "We studied the electrical charge on the surface of myoglobin and found that it increased in mammals that can dive underwater for long periods of time. We were surprised when we saw the same molecular signature in whales and seals, but also in semi-aquatic beavers, muskrats and even water shrews.

"By mapping this molecular signature onto the family tree of mammals, we were able to reconstruct the muscle oxygen stores in extinct ancestors of today's diving mammals. We were even able to report the first evidence of a common amphibious ancestor of modern sea cows, hyraxes and elephants that lived in shallow African waters some 65 million years ago."

Dr Scott Mirceta, PhD student on the project, added: "Our study suggests that the increased electrical charge of myoglobin in mammals that have high concentrations of this protein causes electro-repulsion, like similar poles of two magnets. This should prevent the proteins from sticking together and allow much higher concentrations of the oxygen-storing myoglobin in the muscles of these divers."

"We are really excited by this new find, because it allows us to align the anatomical changes that occurred during the land-to-water transitions of mammals with their actual physiological diving capacity. This is important for understanding the prey items that were available to these extinct animals and their overall importance for past aquatic ecosystems."

The research, funded by the Biotechnology and Biological Sciences Research Council (BBSRC), could also help improve understanding of a number of human diseases where protein aggregation is a problem, such as Alzheimer's and diabetes, and could inform the development of artificial blood substitutes.

Dr Berenbrink added: "This finding illustrates the strength of combining molecular, physiological and evolutionary approaches to biological problems and, for the first time, allows us to put 'flesh' onto the bones of these long extinct divers."

The research, in collaboration with the University of Manitoba, Canada, and the University of Alaska,US, is published in *Science*.

More information: "Evolution of Mammalian Diving Capacity Traced by Myoglobin Net Surface Charge," by S. Mirceta et al. *Science*, 2013.

Provided by University of Liverpool

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