New study identifies energy metabolism adaptations linked to soft shell turtle evolution

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Around 250 million years ago, terrestrial-bound turtles began to explore the aquatic environments, and with it, a profound, new ability first developed.

Breathable skin, made possible by the loss of their hard shells. Losing the hard shell is a feature that evolved independently in three turtle lineages during the Late Cretaceous, providing greater swimming speed and maneuverability.

And the loss of hard shells at different evolutionary branch points resulted in adaptive changes because of changes in respiration. They could maintain aerobic respiration for longer periods of time, and sustain deeper dives.

Now, scientists Tibisay Escalona, and Agostinho Antunes from the CIIMAR research institute in Porto, Portugal, and Cameron Weadick from Sussex University in Brighton, United Kingdom have traced the origin of these adaptations to different genes that are part of the mitochondrial respiratory complex in soft shelled turtles.

"It's reasonable to hypothesize that turtle mitochondrial DNA-encoded proteins may have undergone adaptive evolutionary changes associated with the loss of shell scutes and the invasion of highly aquatic eco-physiological niches," said the authors.

Mitochondria, which are passed along solely from mothers to offspring, are known as the powerhouses of the cell, responsible for aerobic respiration and 95 percent of the cell's energy currency in the form of ATP.

The research team investigated patterns of evolution in the mitochondrial DNA (mtDNA) protein coding genes across 53 Cryptodiran turtle species (representing a total of 10 families), testing for adaptive or divergent patterns of mtDNA evolution associated with the evolution of soft-shells.

The researchers identified positively selected sites that occurred in the mitochondrial-encoded proteins of the oxidative phosphorylation system by using various models and mapped these mutations onto the three-dimensional structures of the proteins, and predicted the severity of these structural changes on respiratory function.

They've shown that subtle amino acid changes can have large functional effects and saw the largest changes effecting complex one, the first and the largest domain of the OXPHOS pathway. Complex I, is responsible for an estimated 40 percent of the proton current that drives ATP synthase.

"Our data supports the notion that the adoption of highly aquatic lifestyles in soft-shelled turtles was associated with altered patterns of selection on mitochondrial function. Our analyses thus revealed that positive selection strongly affected mtDNA evolution along two (Trionychidae and Carettochelyidae) of the three lineages associated with the evolution of soft-shells, and that positive selection targeted multiple mtDNA genes in both cases," said the authors.

However, they did not see this adaptation in leatherback sea turtles. Why not? "This suggests that the evolution of a soft-shell in leatherbacks may have been linked to thermoregulation, not respiration, enabling the species to regulate heat gain and loss," said the authors.

Their findings highlight the valuable role of mitochondrial in the larger context of mitochondrial protein biochemistry, human diseases and turtle ecology.

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