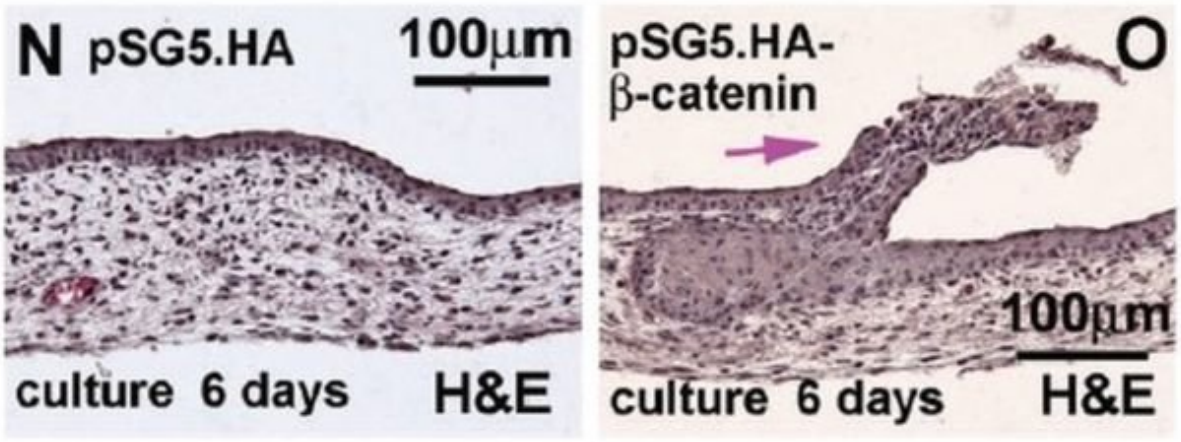
Using modern genomics to turn alligator scales into birdlike feathers

November 23 2017



Normal embryonic scales (left) compared with the elongated feather-like appendage following genetic manipulation (right). Credit: USC

Upon first glance, most people wouldn't think alligators or birds were evolutionary cousins. But indeed, reptiles are the closest living relatives of birds, and all descended from the archosaurs, the "ruling reptiles" who once dominated the Earth 250 million years ago.

Archosaurs gave rise to the age of the dinosaurs and, eventually, birds and reptiles as their only living descendants.

Recently, many transitionary dinosaur fossils with full or partial

plumages have been uncovered. Scientists speculate these primitive "proto-feathers" of feathered dinosaurs may have evolved to help endothermy, attract mates, gave them an ability to better outrun predators, and eventually glide and fly.

But exactly how the outer skin and underlying tissues specify feathers versus scales—and ultimately the evolution of flight—has remained a mystery.

However, this rich evolutionary heritage should be still embedded within all living bird and reptile DNA.

For scientists like regenerative medicine physician Dr. Cheng-Ming Choung, a professor of pathology at the Keck School of Medicine of USC, the field is now ripe for the plucking with the advances in modern genomics that can hone in on the molecular clues responsible for the evolution of feathers and flight.

And in a new study published in the advanced online edition of *Molecular Biology and Evolution*, Chuong has led an international team to identify a plethora of new genes involved in scale and feather development.

"We now have a potential molecular explanation for these hypothesized missing links," said Chuong.

They have also demonstrated the ability to turn scales into feathers, by turning on and off key molecular circuits at critical stages of scale growth and development.

"These results show that different perturbations cause different levels of scale to feather conversion, implying that scales have the capability to form feathers given the proper molecular signals," said Chuong.

For the research study, the team performed a complete RNA transcriptome and DNA genomic analysis of developing chicks and alligators to identify their gene expression differences and the key genes in scale or feather formation.

Next, they placed these unique chicken feather genes within alligator eggs, carefully turning them on or off underneath their growing skin to reawaken an ancient programming that can turn scales into feathers.

"Our analyses led to the identification of five morpho-regulatory modules that are essential for modern feather formation," said Chuong. "We propose that these modules may originally evolve as different strategies for better adaptation. Eventually, the integrative combination of five morpho-regulatory modules achieves the highly successful feather architecture today, allows the Ave class to claim most of the open sky as their ecological niche."

These key circuits lead to the budding and elongation of appendages, follicle with stem cells and dermal papilla to allow cyclic regeneration, barb ridge formation with different branching forms, and specific feather keratin differentiation.

Some molecules could only induce one of the five criteria, e.g., the Sox2 gene can turn on feather budding and totally inhibits scale formation, while Grem1 can induce barb-like branching.

"Other molecules, such as retinoic acid or Sox18, have a greater ability to induce scutate scales to form feather-like skin appendages," said Chuong. "These feather-like appendages display all five criteria defining feathers, suggesting that they act at a higher hierarchical level in this evolutionary pathway."

These master regulators may have been the very first genes to adapt

during ancient archosaur evolution and gain a newfound ability toward the making of today's complex feathers.

"Intriguingly, some of these phenotypes are similar to the unusual filamentous appendages found in the fossils of feathered dinosaurs."

Inspired by the "flying dragon," Ping Wu wants to challenge alligator scales to form feathers. By forced expression of sprouty and beta-catenin, genes they found to help convert chicken scales to feathers, they are able to cause the formation of elongated scales in alligator embryonic skin.

The study significantly adds to the growing list of genes and molecules known to induce feather-like structures in birds and has established a powerful new system in alligators to test and further explore the evolution of flight.

More information: Ping Wu et al, Multiple regulatory modules are required for scale-to-feather conversion, *Molecular Biology and Evolution* (2017). DOI: 10.1093/molbev/msx295

Provided by Oxford University Press