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3 December 2020

A remarkable sensory organ in the beaks of ancient fossil birds

Newly published research by an all-women team from the University of Cape Town (UCT) shows how one of the most ancient groups of birds (from the time of the dinosaurs) was able to detect minute mechanical vibrations in the soil using their beaks referred to as remote-touch.

Birds that feed on small prey items (such as worms, molluscs and small fish) buried in mud or under water often do so blindly – without the aid of visual cues to help them locate their prey.

They capture their prey by probing their long beaks into the substrate and pulling out the prey, a feeding method known as probe-foraging. Some probe-foraging birds have this "sixth sense" called remote-touch, which is possible using a specialised organ at the tips of their beaks. This organ is found in three families of living probe-foraging birds: ibises, kiwi and sandpiper-like shorebirds. This bill-tip organ consists of densely clustered mechanoreceptor cells embedded in pits in the bones of the birds' beaks.

Intriguingly, a structurally-similar, but functionally mysterious, bill-tip organ occurs in ostriches, emus and their relatives – the paleognaths, an ancient group of birds. This study set out to determine why such an organ was found in all the paleognaths (even those that do not probe-forage), and to try and investigate when this remarkable sense developed among birds.

"What's been really exciting to palaeobiologists studying the evolution of birds, aside from remote-touch being a remarkable sensory adaptation that has cropped up multiple times in the avian record, is that this bill-tip organ has the potential to be preserved in the fossil record as it appears to potentially be characterised by large numbers of bony pits on the surfaces of the beak bones," said lead author, Carla du Toit a PhD candidate at UCT.

The scientists hypothesised that the bill-tip organs found in all living paleognaths, even those that do not probe in the ground for food, might be a vestigial organ remaining from their most recent common ancestor. Luckily, exquisitely preserved beaks of some of the most basal paleognaths, the lithornithids, have been found in North America and Europe. These small (roughly chicken-sized) birds with relatively long beaks and legs are believed to have co-existed with dinosaurs in the Cretaceous period before the extinction event that killed-off all non-avian dinosaurs. This study shows that some, if not all the wetland-dwelling lithornithids

were likely able to use remote-touch to locate buried prey in much the same way that modern day ibises and kiwi do.

This suggests that modern paleognaths retained the structural components of the ancestral bill-tip organ even though it became functionally redundant, much like the hind limb bones of whales or pythons.

"We've been puzzled by the bill-tip organs of ostriches and emus ever since they were first described by South African researchers about five years ago. We knew what this kind of beak was in probe-foraging birds like kiwis, which are also paleognaths, but it didn't make sense that these structures were present in their giant non-probing relatives as well especially as ostrich and emu brains are not wired to deal with the kind of tactile information a bill-tip organ provides.

"Discovering that the earliest known paleognaths – the lithornithids – were thought to be probe-foraging wetland birds, and that there were beautifully preserved fossils available was really a lightbulb moment for us," said Dr Susan Cunningham, senior author and avian sensory ecology specialist as well as lecturer at UCT.

These findings suggest that remote-touch evolved very early in modern birds, perhaps from snout tactile specialisations of their non-avian dinosaur ancestors. As some of these dinosaurs were very large compared to modern birds (for example, the 7.5m long and over 2m tall *Neovenator salerii*) they were certainly not probing in the ground for worms like the birds do, but may have hunted in opaque waters for fish and large reptiles and used tactile receptors in their jaws to sense the vibrations underwater similar to the way modern crocodiles and alligators hunt.

This facial sensitivity could then have given rise to the highly specialised bill-tip organ we see today in ibises and kiwi and which the study has shown evolved millions of years ago in some of the most ancient birds known in the fossil record.

"This is such an incredibly cool study! We've been able to show that the Mesozoic ancestor of ratites (such as ostriches, rhea, and emu) was a probe-feeding bird like modern ibises and kiwi. Furthermore, our finding suggests that the remote-sense organ in the beaks of birds most likely originated from the sensitive snouts of their dinosaurian ancestors," said co-author and leading dinosaur palaeontologist, Professor Anusuya Chinsamy-Turan of UCT.

The scientists involved in this study believe that this research will significantly contribute to understanding the evolution of sensory and neuroanatomical systems in birds and their dinosaurian relatives. This work will further drive understanding of both the ancient ancestors of birds as well as living probe-foraging birds among which are some of the most threatened species of birds.

Note to editors

Paper: du Toit CJ, Chinsamy A, Cunningham SJ. 2020. Cretaceous origins of the vibrotactile bill-tip organ in birds. *Proceedings of the Royal Society B* 287: 20202322. https://doi.org/10.1098/rspb.2020.2322

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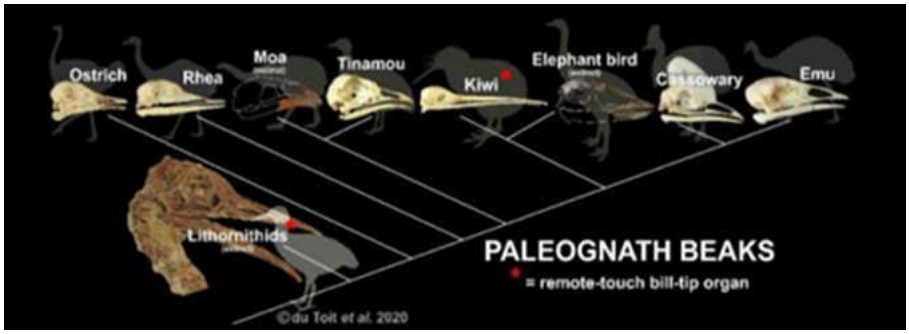

Phylogeny/family tree of paleognathous birds, showing their beak shapes and the occurrence of the remote-touch bill-tip organs.
Credit: Carla du Toit

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