Early Birds Breathed Easy

When thinking of paleontology and the study of fossilized remains, we typically envision a white, petrified skeleton lying in some desert badland, exposed by wind and rain. However, recent discoveries have put an ever-increasing focus on the preservation of non-skeletal fossil remains – that is to say, the preservation of soft tissues that have remarkably survived the test of time, sometimes hundreds of millions of years. Published in *PNAS* in October, an international team of scientists led by Drs. Jingmai O'Connor and ZHOU Zhonghe at the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), Chinese Academy of Sciences (CAS) have identified probable lung tissue in an exceptionally well-preserved specimen of *Archaeorhynchus spathula*, a very basal member of the Ornithuromorpha (that is the clade that includes all modern birds nested within), that was part of the Jehol Biota and lived approximately 125–120 million years ago.

Lung tissue being previously though impossible to preserve, scientists have long struggled to understand the evolution of modern avian respiration within the Dinosauria using skeletal indicators such as the morphology of the rib cage – especially that of boney processes that project off the ribs, called uncinate processes (which are primitively unfused to the ribs in *Archaeorhynchus*), as well as indicators of skeletal pneumaticity such as pneumatopores that indicate a bone has been invaded by pneumatic air sacs that aid in respiration in living birds, as well as reduce the weight of the skeleton for flight (indication of which are absent in *Archaeorhynchus* except for the cervical air sacs plesiomorphic to most dinosaurs). Scientists are

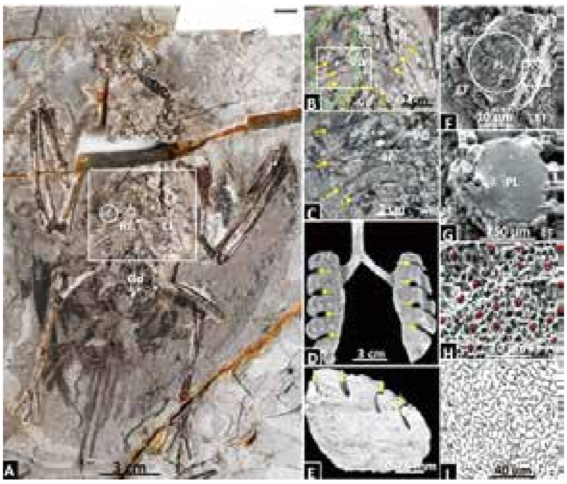
Exceptionally well-preserved soft tissues are identified in a fossilized early bird that lived approximately 125–120 Million years ago, named the *Archaeorhynchus spathula*. The soft tissues might include remains from lungs of the bird. (Image by WANG Min)

interested in avian respiration because it is extremely specialized compared to that of other reptiles* and more

*Although when I was in primary school I was taught that birds are their own distinct group (Class Aves versus Class Reptilia), Aves (living birds and their descendants, all members of the clade Neornithes) are in fact derived members of the Reptilia. They belong to the clade Archosauria, a group of reptiles that includes dinosaurs (the group to which birds belong), pterosaurs, and crocodilians (the only other surviving lineage besides birds).

efficient than that of mammals. Compared to mammal lungs, birds not only can inhale greater amounts of air but they can also extract more oxygen with every breath. This is probably one factor that has made birds the most successful clade of amniotes alive today and makes possible incredible physical feats, such as geese that fly over the Himalayan Mountains during migration.

This unlikely specimen of *Archaeorhynchus*, the fifth to be described but the first to preserve significant soft tissue, preserves what we identify as lung tissue based on anatomical position and microstructure, as revealed through scanning electron microscopy (SEM). The preserved microstructure revealed the network of air and blood capillaries forming the functional tissue of the lung and indicated that this tissue was extremely subdivided, as it is in bird lungs today. This extreme subdivision increases surface area and helps to facilitate birds' ability to meet the high oxygen demands of powered flight – the most physically demanding form of locomotion. Although preservation of lung tissue, which – if you have ever dissected or slaughtered a chicken – you will have noticed appears thin and delicate, seems unlikely or even impossible, in fact, this is not the first documented occurrence of preserved lung tissue in the fossil record (though it is the first to be informative). Lung tissue was reported in *Nature* (https://www.nature.com/articles/nature14905) in a mammal a few million years older than this specimen of *Archaeorhynchus* and has also been documented in a few amphibians from the Cenozoic (the oldest being 40 million years old). Although very thin, the tissue that forms the avian lung contains type IV collagen, which is a strong connective tissue that may have facilitated preservation of this soft tissue. This discovery indicates that specializations of the lung tissue date back at least 125 million years and



Microscopic structure of the fossilized soft tissues in the specimen, in comparison with those of an existant bird. (Image by WANG Min)

predate skeletal specializations that have previously been studied as indicators of advanced respiratory function.

The authors of the study include WANG Xiaoli (Linyi University), Jingmai O'Connor (IVPP), John Maina (University of Johannesburg), PAN Yanhong (Nanjing University), WANG Min (IVPP), WANG Yan (Linyi University), ZHENG Xiaoting (Linyi University) and ZHOU Zhonghe (IVPP).

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Contact:

Jingmai O'Connor (Co-first author of the study)
Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), CAS
jingmai@ivpp.ac.cn