

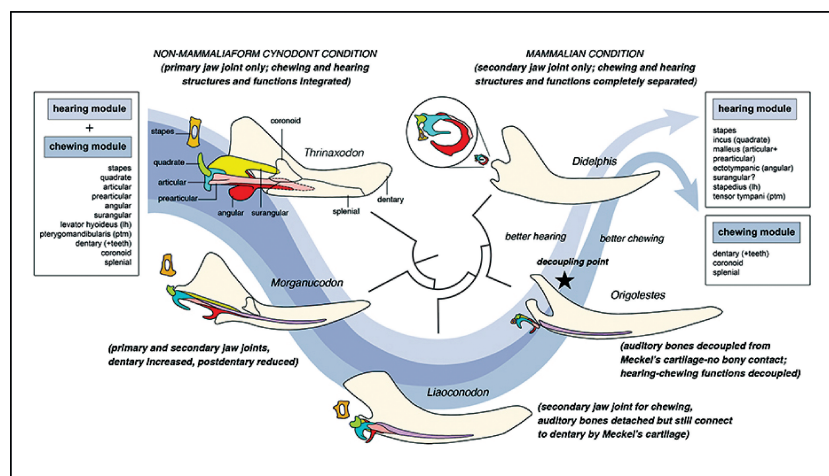
# Diverge modular evolution of mammalian middle ear and lower jaw

With the support by the National Natural Science Foundation of China and the Chinese Academy of Sciences, in a study published in *Science* (2020, 367: 305–308), Dr. Mao FangYuan (毛方园) and colleagues from the Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, together with the American Museum of Natural History, New York, reported a new Early Cretaceous stem therian mammal and proposed the modular decoupling of the hearing and chewing apparatuses, a key evolutionary event that had potentially played a critical role in evolution of mammals.

The mammalian middle ear differs from that of reptiles in having a chain of ossicles: the stapes, incus, and malleus; plus, the ectotympanic as the frame supporting the tympanic membrane also plays a role. In contrast, the middle ear of reptiles has one bone, the stapes. Developmental and paleontological studies have long shown that the mammalian malleus, ectotympanic, and incus are homologous with the reptilian articular, prearticular, angular, and quadrate, respectively. Recent studies have also demonstrated that the genetic mechanisms regulating the patterning of the reptilian articular-quadrate joint and the mammalian malleus-incus articulation are similar.

In mammal-like reptiles, the articular, prearticular, angular, and quadrate have been greatly reduced and had functioned for both hearing (transmitting sound vibrations to the inner ear) and chewing (as the jaw bones). Thus, in these forms, the two functions and structures responsible for them were highly integrated as a complex system such that hearing and eating would interfere with each other. Mao et al.'s study were based on fossils of stem therian mammals from the Early Cretaceous Jehol Biota, northeastern China; it revealed the critical moment, as an evolutionary snap-shot when the middle ear apparatus was separated from the lower jaw, which implies separation of the hearing and chewing functions. Mao et al. proposed that the evolution of mammalian middle ear and jaw was in a unique modular fashion: Starting as a complex system with highly integrated structures and functions in mammal-like reptiles, the hearing and

chewing modules must have been regulated by their own genetic mechanisms, respectively, during the evolution of synapsids and eventually decoupled under selective pressure for better hearing and chewing during evolution. The decoupled modules removed the physical constraint that they imposed on each other, which allowed the burden-free hearing module to be more sensitive for hearing high-frequency airborne sounds and the chewing module more efficient in processing diverse foods.



**Figure** Diagram illustrating evolutionary stages from the condition in non-mammaliaform cynodonts to that in mammals.