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BASICS

In Mammals, a Complex Journey to the Middle Ear

By NATALIE ANGIER

Imagine what a dinner conversation would be like if you had decent table manners, but the ears of a lizard. Not only would you have to stop eating whenever you wanted to speak, but, because parts of your ears are now attached to your jaw, you'd have to stop eating whenever you wanted to hear anybody else, as well. With no fork action on your end, your waiter would soon conclude that you were obviously "done working on that" and would whisk your unbreached baked ziti away.

Sometimes it's the little things in life that make all the difference — in this case, the three littlest bones of the human body. Tucked in our auditory canal, just on the inner side of the eardrum, are the musically named malleus, incus and stapes, each minibone, each ossicle, about the size of a small freshwater pearl and jointly the basis of one of evolution's greatest inventions, the mammalian middle ear. The middle ear gives us our sound bite, our capacity to masticate without being forced to turn a momentarily deaf ear to the world, as most other vertebrates are. Who can say whether we humans would have become so voraciously verbal if not for the practice our ancestors had of jawboning around the wildebeest spit.

The middle ear also explains why mammals, as a group, have the sharpest hearing on Earth and the greatest diversity of listening styles, from the bats and dolphins that can detect pressure waves bouncing around at the spiky, ultrasonic end of the bandwidth, to elephants and humpbacked whales that can hear infrasonically, capturing the long, low sound prints muttered by their peers for miles around. All told, a new study suggests, the middle ear was such a great invention, such an essential part of being a mammal, that once evolution had seized upon it, no crude substitute or older model would do.

In the current issue of the journal Science, paleontologists report on the fossilized remains of a newly discovered mammal from the Mesozoic era, some 123 million years ago. The snouty, 3-ounce, chipmunk-size animal, named Maotherium asiaticus, lived in what is now northeastern China and darted around the feet of the dominant dinosaur overlords, as mammals had been doing for some 100 million years.

What makes this proto-Alvin noteworthy are its ears: the crisply preserved fossil indicates that Maotherium's middle ears were of a middling sort, half mammal and half reptile. Given the timing of the fossil, and evidence from still earlier mammalian fossils, the researchers believe that Maotherium represents backsliding, a reversion toward a more ancient auditory design.

But not to worry. Evolution would rediscover its three-part invention at least once, if not again and again; for by the time the ancestors of today's mammals arose, the trait had been set. Every one of the 5,400 or so known species of mammal — whether placental, pouched marsupial or weird outlying, egg-laying platypussian monotreme — has three ossicles freed from the tyranny of the mandible, freed to be all ears, all the time.

"For those of us dealing with mammalian evolution, the evolution of the middle ear is a holy grail," said Zhe-Xi Luo, curator of vertebrate paleontology at the Carnegie Museum of Natural History in Pittsburgh and an author of the new report. "Sensitive hearing made it possible for early mammals to coexist with the dinosaurs; it was really a matter of life and death." The new fossil, he said, "gives us insight into the complex evolutionary process behind this central mammalian feature."

Nature walks in delirious ways, said Neil Shubin, author of "Your Inner Fish" and a professor of organismal biology and anatomy at the University of Chicago. "This paper shows how the mammalian ear didn't proceed in a linear progression," he said. "Either it evolved multiple times independently, or it flipped back and forth, but in any event we're talking about a bush with many buds and twigs."

The finding also dovetails with recent work in molecular genetics and developmental biology. Among modern mammals, the middle ear of a fetus is one of the last structures to mature and migrate to its proper position, and even after birth the little bones may retain a few lingering filaments of so-called Meckel's cartilage, which connects the ear to the jaw in the early embryo. Dr. Luo and his colleagues suggest that a mutation to a developmental timing gene responsible for this late-stage disengagement might have essentially locked Maotherium's ears into a permanent embryonic state, just as can happen with rare human craniofacial disorders like Treacher Collins syndrome. "Fossil hunters, developmental biologists, medical geneticists, we're all meeting eye-to-eye," Dr. Luo said.

Researchers have long known that the middle ear bones of a mammal evolved from the jawbones of their reptilian forebears, and that the "repurposing" of the bones, as Dr. Shubin put it, for the sake of improved hearing occurred in parallel with the refinement and elaboration of

mammalian dentition. “You go from a jaw composed of many bones in reptiles to a jaw with a single bone in mammals,” Dr. Shubin said. You also go from simple, generally conical reptilian teeth arranged willy-nilly in the mouth to matched sets of molars, bicuspids and canines that come together in happy occlusion. “You see mammals actually chewing their food,” said Christian A. Sidor, an expert in mammalian evolution at the University of Washington.

In other words, where a mammal’s streamlined mandible might have lacked the snapping power of a crocodile jaw, its complex teeth could pick up the feeding slack and free the extra jaw bones to take on higher tasks.

Or rather, higher frequency tasks. Researchers propose that one selective pressure driving the evolution of the mammalian middle ear might have been the need to find a steady supply of insects, and even non-insectivorous humans remain exceptionally sensitive to high-pitched noises like a mosquito’s whine.

The mammalian ear is also a master at detecting very quiet sounds: as an incoming pressure wave wiggles the ear drum and the ossicles abutting it, the fulcrumed motions of the bones help amplify the wave’s energy before sending it along. Early mammals were probably nocturnal, the better to avoid day-hunting dinosaurs, and even today most mammals prefer to come out after dark. “It was fundamental for mammals that their elaborated sensory system was one well-adapted for a nocturnal niche,” Dr. Luo said.

Or for dinner by candlelight with a few silver-tongued friends.