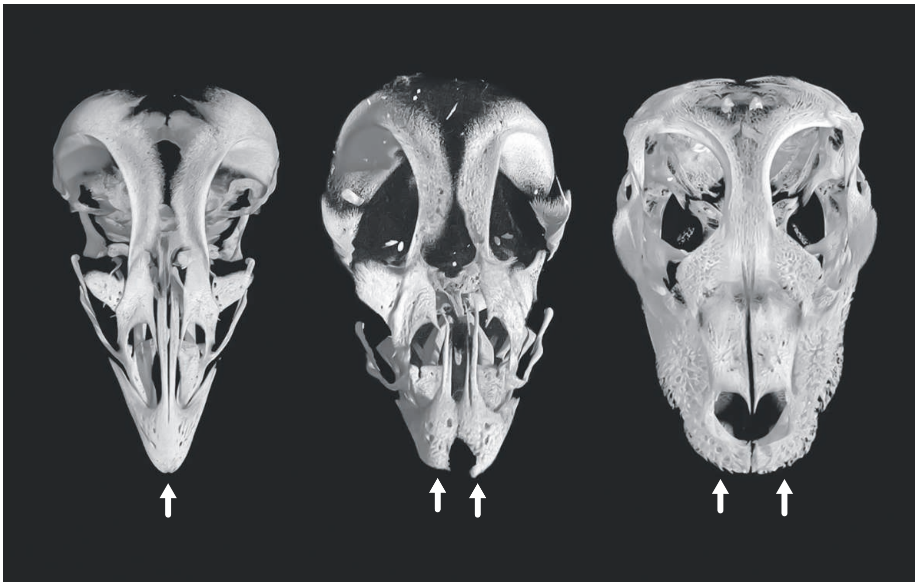

The fused pair of bones that form a beak in a chick embryo (*left*, arrow) are rounded and unfused in treated chicks (*middle*), like in alligators (*right*).

EVOLUTION

How birds got their beaks

Combining fossils and lab studies, researchers home in on genes that transformed a snout into a bill

By **Elizabeth Pennisi**

When birds got their wings, they lost the clawed fingers wielded by their dinosaur relatives. But they evolved a new "finger"—in their face. And what a boon that has been. Agile beaks of all shapes and sizes, from the gulping gape of a pelican to the needle nose of a hummingbird, have enabled the 10,000 avian species to thrive from the Arctic to the tropics, build intricate nests, and eat many different foods.

Now, researchers may have identified genes that transformed an ancestral snout into a bird's bill. By manipulating the genes' proteins, they have seemingly turned back the evolutionary clock, producing snouts in developing chicken embryos that resemble those of alligators today. "We're trying to explain evolution through developmental studies," says Harvard University evolutionary developmental biologist Arhat Abzhanov, who, with colleagues, describes the work this week in *Evolution*.

Their conclusions are at odds with an earlier study. But even those who disagree with the result say Abzhanov and his student Bhart-Anjan Bhullar, now a postdoctoral fellow at the University of Chicago in Illinois, have demonstrated a powerful new approach: pinning down how anatomy changes using fossils, then trying to recapitulate the changes in the lab by tinkering with genetic signals. "The value of this paper is their ability to blend paleontology with evolutionary developmental biology," says Richard Schneider of the University of California, San Francisco (UCSF), who has linked beak evolution to different genes.

To define just what changed in the face of bird ancestors, Bhullar examined scores of skulls of dinosaur fossils, birds, and alligators and other reptiles, taking hundreds of pictures at different angles. A computer compiled these images into 3D scans and precisely determined differences in bone size, shape, and configuration between the animals.

In ancestral reptiles, a pair of small bones makes up the tip of a snout. In today's birds, those premaxillary bones are long, narrow, and fused, producing the upper bill. The ancient bird *Archaeopteryx* reveals an intermediate step. Its premaxillary bones were not very expanded, but in later avian species the bones are progressively more fused. Other work had also implicated the premaxillary bones in beak evolution.

So Bhullar searched for earlier studies of genetic pathways that control development of these bones. Work in mice and chickens had implicated two sets of signals. A gene called Fibroblast growth factor 8 (*Fgf8*) becomes active in the front part of the face as it takes shape in 3-day-old chick embryos; later, just before bones form, a gene called *WNT* helps drive the proliferation of cells in the middle of the face, where it may prompt expansion of the premaxillary bones. In mammals, lizards, turtles, and alligators, in contrast, activity of the *WNT* gene is highest on the sides of the embryonic face.

To explore these genes' roles, Bhullar and Abzhanov treated bird embryos with inhibitors of the WNT and Fgf8 proteins. When the two signals were most curbed, the premaxillary bones became round and never fused, as in birds' dinosaur relatives, instead of growing long and pointy.

To the pair's surprise, a palatal bone, which makes up the roof of the mouth, also changed dramatically. In many vertebrates, this bone is flat and fused to surrounding bones. But in birds, it's reduced and disconnected, which frees the top part of the bill to move upward, expanding birds' gape. In the treated chick embryos, the palate looked more like it does in other vertebrates: flat and seemingly reconnected to the jaw bones. The studies suggest that *Fgf8* and *WNT* signaling changes allowed skulls of ancient birds "to evolve in a whole new direction" and form a beak, Abzhanov says.

Not everyone agrees. In 2014, UCSF's Nathan Young and Ralph Marcucio, working with Schneider, carried out extensive skull measurements on a variety of embryonic vertebrates and determined the point during development at which the bird face begins to diverge from those of other vertebrates. The work and later experiments supported a 2009 idea proposed by Marcucio that the activity of another gene, *SHH* (for sonic hedgehog), was critical for forming the beak. Unlike *Fgf8*, he says, it's active in the right place and right time in bird embryos.

Marcucio, a developmental biologist, also worries that the changes in facial structure observed by the Harvard team may stem from unintended cell death caused by the inhibitors they used. "Adding the fossil record to this work is really an important step, but I think they are just looking at the wrong pathway," he says. Abzhanov and Bhullar counter that *Fgf8* and *SHH* are often coexpressed and may work together; also, they saw no excess of cell death.

Neutral parties predict this face-off over bird beaks will not be resolved quickly. "There undoubtedly are many more genes involved in these pathways and these will need to be sorted out," says Joel Cracraft, an evolutionary biologist at the American Museum of Natural History in New York City. ■

PHOTO: BHART-ANJAN BHULLAR