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DEVELOPMENTAL BIOLOGY

Bonemaking Protein Shapes Beaks of Darwin's Finches

Darwin's finches are to evolutionary biology what Newton's apple is to physics. After exploring the Galápagos Islands in 1835, Charles Darwin later became intrigued by the varying shapes and sizes of the closely related birds' beaks. Each beak appeared to be specialized for a task, such as cracking seeds or drinking nectar. Once Darwin formulated his ideas about evolution, he realized that these birds exemplified the principles he was proposing. Today, these songbirds are often cited as a perfect example of how new species arise by exploiting ecological niches.

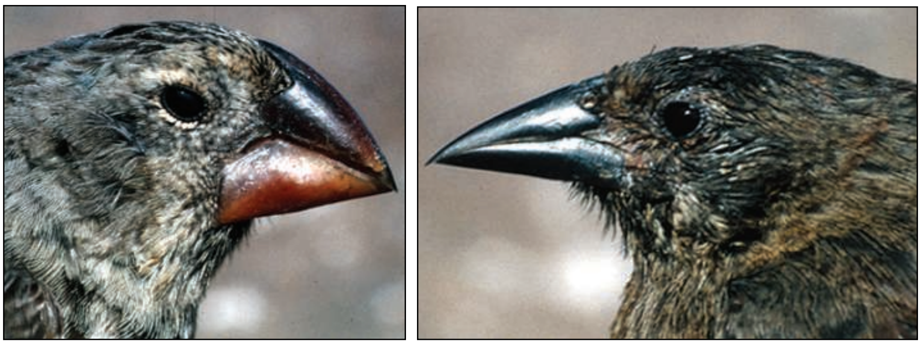
Now developmental biologists have added a new twist to this classic story. Two research teams have discovered that a protein normally associated with the development of the skull and other bones is one of the molecules that tailors the shapes of beaks. Different shapes arise depending on where and when this signaling molecule, called bone morphogenic protein 4 (BMP4), is turned on during development, says Cheng-Ming Chuong, a evolutionary developmental biologist at the University of Southern California (USC) in Los Angeles.

On page 1465, Chuong's team describes BMP4's role in building beaks in chickens and ducks. And on page 1462, developmental biologist Clifford Tabin of Harvard Medical School in Boston and his colleagues show that the expression of BMP4's gene varies, just as the beaks do, in six species of Darwin's finches. Both groups also demonstrated that they can cause birds to develop misshaped beaks by altering BMP4 levels during development.

The two groups' results provide a window into the molecular basis of diversity, says Dolph Schluter, an evolutionary biologist at the University of British Columbia in Vancouver, Canada. He was particularly taken with Tabin's work. "This paper represents a step in answering [how diversity arises] in the most celebrated example of adaptive evolution, the radiation of the Darwin's finches," he notes.

An outgrowth of the jaw, a beak forms as six processes extend from jawbones in a coordinated manner. Chuong's USC research associate Ping Wu followed one of the processes, the frontonasal mass, in developing ducks and chicks and discovered that the growth patterns differ in the two species. Moreover, the actively growing areas contained BMP4. To test the protein's role in shaping beaks, the researchers increased the amount of BMP4 by injecting it or its gene into the tissue that helps form them. The excess BMP4 resulted in longer, wider, and deeper beaks, Wu and his colleagues report. When they did the reverse experiment, adding a gene whose protein counteracts BMP4, the beaks ended up smaller than normal.

The work "is an experimental test that the molecule could be manipulated in a way to [recapitulate] beak shape," says Jeff Podos, a behavioral ecologist at the University of Massachusetts, Amherst. Adds Jill Helms, a developmental biologist at Stanford University, "This work underscores that [morphological] changes do not take much [genetic change]."



Pecking away. Researchers now know that a protein is key to the diversity of beaks in Darwin's finches.

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Working independently, Tabin and his colleagues actually studied Darwin's famous birds. Aided by Princeton University field biologists Rosemary and Peter Grant—renowned for their studies of these Galápagos birds—Tabin's team collected eggs of six *Geospiza* species. Three species, the ground finches, had stout bills for cracking seeds; the other three, the cactus finches, had the slender, pointed bills needed for retrieving nectar. As such, these beaks are "a wonderful model for understanding the interaction between environment and evolution on speciation," says Chuong.

Tabin's postdoctoral fellow Arhat Abzhanov looked at finch embryos at different points in development, documenting when and where the genes for 10 different growth factors were expressed among the six species. BMP4 was the only growth factor to distinguish ground finches from cactus finches. The two groups of birds differed in both the amount of BMP4 and the timing of BMP4 activity. The ground finches, with larger beaks, make more BMP4 protein at an earlier stage, Tabin explains.

Each ground finch species had its own distinct pattern of BMP4 expression. *G. magnirostris* begins making its BMP4 much earlier than the other ground finches examined, for example. "To see the beaks of the different ground finch species light up with different patterns of BMP4 expression was a thrill," says Schluter.

Tabin's results, coupled with Chuong's, offer convincing evidence that BMP4 shapes beaks, says Podos. Other genes and molecules will also be involved, cautions evolutionary biologist R. Craig Albertson of the Forsyth Institute in Boston, Massachusetts. Indeed, neither group knows what makes the BMP4 gene more active in birds with bigger bills.

Whatever the underlying molecular cause of beak diversification, Podos hopes that further investigations of BMP4 in other bird species will lead to insights into why some birds, such as the finches, rapidly form new species—with the different lifestyles that are possible because of changes in their shapes—while others living in the same place, for example, warblers, do not.

That's the beauty of this work, Podos says: "It translates genetic variation into something we can sink our teeth into. Maybe we are beginning to understand something about [morphological] plasticity."

Darwin would be pleased.

–Elizabeth Pennisi