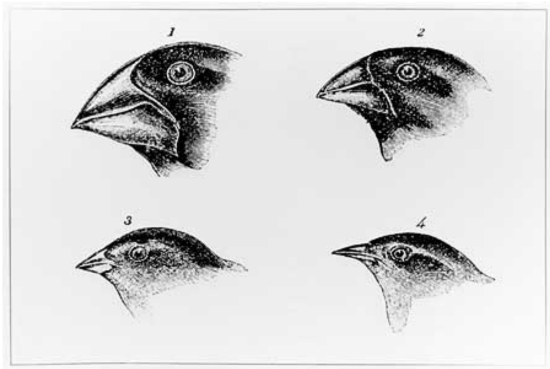
ScienceWatch – Genetic Control of Beak Variation in Darwin's Finches: The Long and Short of It



Darwin's finches comprise 14 closely related species that differ in beak shapes and sizes and live on the Gala□pagos islands. The *Geospiza* group includes six species of ground-dwelling birds that feed on different sized seeds or on the nectar of cacti. Their beaks range from the thick, heavy, seed-crushing bill of the large ground finch (*G. magnirostris*) to the long, slender nectar-drinking bill of the cactus finch (*G. scandens*).

The finches vary so greatly in appearance that it took Darwin, who collected them in 1835, years to realize that all the finch species arose from one ancestral form that had adapted to a variety of feeding conditions. Today the finches are considered a perfect example of *adaptive radiation*, in which one species diversifies into many to exploit a wide range of habitats, and they continue to be studied by Peter and Rosemary Grant of Princeton University. This husband/wife team has discovered that the finches rapidly adapt to sporadic deluges and droughts caused by El Niños and La Niñas. Rainfall, or lack of it, determines whether large or small seeded plants will become abundant, and birds with the right sized beaks rapidly proliferate in response to which seed size predominates. The ability to change beak size and shape rapidly is therefore crucial for survival.

The science of genetics didn't exist in Darwin's time, so while he recognized that the vast array of species resulted from natural selection, he had no way to determine how these "most wondrous forms" were produced. Working in the 21st century, the Grants have been able to team up with others adept at using the tools of molecular genetics to discover exactly how these birds can change so readily. For example, in a 2004 study they looked at genes known to regulate bone and cartilage development in the face. By examining differential gene activities between the small-beaked versus the large-beaked finches, they showed that a single gene, BMP4, coding for a bone-growing protein, is responsible for producing heavy, wide beaks – *see* - *Sciencewatch* - *Beak Variation in Darwin's Finches: It's in the Genes* (November/December 2004). The BMP4 protein acts as a signal to stimulate beak growth and is found in large amounts in the skull of large ground finch embryos, and in lesser amounts in embryos with smaller, thinner beaks. The greater the gene activity in the developing embryo, the more BMP4 protein is made, and the more the beak tends toward the wide, deep beak of the large ground finch.

A new study published in the August 2006 issue of the journal *Nature*, describes how the same team has discovered a second gene that acts in a complementary fashion to the first. This gene does not affect depth or width of the beak; instead, it causes beak elongation. The extreme result of this gene's action is the elongated, slender beak of the cactus finch. Using an approach similar to that used in 2004, the researchers looked for genes associated with beak morphology that are differentially active among various finch species. In this fashion they found a gene that is highly active in the beaks of cactus finch embryos as compared to other finch embryos. This gene makes Calmodulin (CaM), which is a calcium-binding protein that can bind to other proteins concerned with cellular functions. CaM acts as a molecular signal to turn on or turn off the functioning of these cell proteins, and in this manner it controls tissue differentiation in the developing embryo*.

Since the CaM gene was highly active in beaks of cactus finch embryos and not others, it may be assumed that it is responsible for creating these beaks. However, the research team went beyond mere correlation. They inserted the mutant gene of another protein, targeted by CaM and involved in tissue differentiation, into the developing beaks of chick embryos. This protein normally requires CaM to become active, but the mutant protein is highly active even without CaM. In this way they could mimic the effect of high levels of CaM. Chick embryos treated in this manner developed longer but not wider beaks.

These results show that regulation of beak development by one gene, CaM, controls beak length and is responsible for the longer beaks that cactus finches use to probe for nectar in cactus flowers and fruit. As described above, the team's earlier work showed that the BMP4 gene controls beak depth and width and is responsible for the broader, heavier beaks found in the seed-eating ground finches. It is becoming clear that modulating the effects of these two genes yields the wide array of beak sizes and shapes present in Darwin's finches. Moreover, control of these important characteristics by just two (or a few) genes may explain why these birds can adapt so readily to a constantly changing environment.

A hundred and fifty years after aiding Darwin in formulating his theory of natural selection, Darwin's finches are still providing valuable insights into the origin of species.

Saul Scheinbach

*CaM may be thought of as a molecular tool, e.g., a wrench, which when properly sized, can turn on a switch that starts some physiological process. To continue the analogy, the binding of calcium to CaM changes its shape so that it can now fit the switch in the same way a mechanic sizes a wrench to fit a particular nut or bolt.