Forty Years of Evolution in the Galápagos Finches: An Interview with Peter and B. Rosemary Grant

On March 5, 2015, **Peter Grant** (Class of 1877 Professor of Zoology, Emeritus at Princeton University) and **B. Rosemary Grant** (Emeritus Professor and Senior Research Biologist in the Department of Ecology and Evolutionary Biology at Princeton University) presented their research studying evolutionary processes in the Galápagos finches. **Jonathan F. Fanton** (President of the American Academy) opened the program, which served as the Academy's 2019th Stated Meeting, remarking: "For forty years, Peter and Rosemary Grant have examined the beauty and wonder of change over time, and their research has been seminal in numerous fields of study, including evolution, ecology, and population biology. Moreover, their work continues to inspire new generations of young researchers who seek to understand what Darwin once called 'the mystery of mysteries.'" **Jonathan B. Losos** (Monique and Philip Lehner Professor for the Study of Latin America, Professor of Organismic and Evolutionary Biology, and Curator in Herpetology at the Museum of Comparative Zoology at Harvard University) introduced the speakers.

B. Rosemary Grant (Princeton University) and **Peter Grant** (Princeton University), speaking at the Academy's 2019th Stated Meeting.

The program was live streamed to Fellows and guests gathered in New York City and Chicago. **Jonathan Weiner** (Maxwell M. Geffen Professor of Medical and Scientific Journalism at Columbia University Graduate School of Journalism) led a discussion in New York City and **Trevor Price** (Professor of Biology in the Department of Ecology and Evolution at the University of Chicago) led a discussion in Chicago following the video presentation.

After the meeting, **Zackory Burns** (Hellman Fellow in Science and Technology Policy at the American Academy; ethologist) interviewed Peter and B. Rosemary Grant. The following is an edited transcript of their exchange.

Zackory Burns

What inspired you to pursue your research in evolution?

Peter and B. Rosemary Grant

Our initial sources of inspiration were early experiences of a diversity of animals, plants, and fossils in our respective childhoods, followed by learning about genetics at school and university. Studying birds and mice, we always asked *why* as well as *how* questions. We also found certain seminal papers and books to be inspirational; they opened our eyes to what could be discovered through the combination of ecological field studies and genetic analyses. Our immersion in Mendelian genetics, ecological genetics, quantitative genetics, and, finally, molecular genetics opened doors to the direct study of evolutionary processes in contemporary time.

Zackory Burns

What are three takeaway messages from your joint research over the past four decades?

Peter and B. Rosemary Grant

The first lesson is to pick a biological system that is particularly suitable for the scientific question to be addressed. One of our initial questions was why some populations are extremely variable, while other populations of the same species, in the same or similar environments, are not. As it turns out, Darwin's finches are close to being an ideal system for answering this question.

The second message we would share is that when a single approach to a complex problem is clearly insufficient, it is critical to try out a variety of approaches. For instance, the question of variation, mentioned above, demands a broad approach because it encompasses elements of adult morphology, development, ecology, behavior, quantitative genetics, and molecular genetics.

The third takeaway message from our research is that long-term studies of ecology and the evolution of organisms living in their natural environment have immense value. Such studies are certainly not the only way to investigate natural biological phenomena, but they are a powerful way to establish the link between evolution observed in our lives and past evolution inferred from research.

Zackory Burns

In layperson's terms, could you describe your most recent discovery as published in *Nature* 518 (February 2015): the evolution of Darwin's finches and their beaks, revealed by genome sequencing?

Peter and B. Rosemary Grant

The history of a group of organisms like Darwin's finches on the Galápagos lies coded in their genomes: the totality of genetic factors that govern how they develop and how they function. Through partial genetic analyses, we had previously obtained glimpses of that history. But now, by sequencing the genomes of all of the species, we could create as full a record of their history as we shall ever have in the absence of fossils. This record tells us who is related to who. It indicates when the process of species multiplication began in the Galápagos. It tells us, to our surprise, that species have probably been hybridizing throughout the history of the whole group for perhaps as long as one million years.

Further, it has helped us to understand the evolution of beaks, the trait that so impressed Charles Darwin on his epic 1835 visit to the islands. The record has revealed one of the genes that is important in regulating beak shape development. Species differ in beak size and proportions; some beaks are elongated, while others are blunt. We discovered that species with pointed beaks had one particular variant of a gene called *ALX1*, and species with blunt beaks had another variant of that gene. (Interestingly, the same gene is expressed early in human development, and mutations in the gene cause defects in the development of the human face, including cleft palate.)

Zackory Burns

You were able to observe the creation of a new species of Darwin's finch. Why is this significant?

Peter and B. Rosemary Grant

The world has, literally, millions of species of animals, plants, fungi, and microorganisms. Many biologists would like to know how and why they evolved in the way that they did. Charles Darwin's central question – how do new species form – is still with us today, because we don't observe the process from start to finish. The standard explanation is that speciation begins with a population splitting into two. In the Galápagos, it is easy to envisage this happening through colonization of a new island by a few birds, followed by the establishment of a second population: two populations formed from one. The two populations then evolve in different directions, each adapting to its own environment. They become so different that later, when they encounter each other through dispersal of some birds from one island to another, members of the two populations either do not interbreed, or do so rarely.

By carefully following the lifetime fates of measured finches, we discovered an interesting twist to the standard speciation theory: rare hybridization between two species can lead to the evolution of a third. This happens under special circumstances: the genetic and morphological variation of the hybridizing species increases, producing novel genetic combinations and phenotypes. We witnessed this on Daphne Major Island, following the arrival of a hybrid finch. Thus our findings put the spotlight on two interrelated processes that are usually considered to be antagonistic – divergence during speciation is counteracted by hybridization – but can in fact be synergistic.

Zackory Burns

What are the major insights of your book *40 Years of Evolution: Darwin's Finches on Daphne Major Island* (2014) that you hope readers will take with them?

Peter and B. Rosemary Grant

There are three key points a reader of *40 Years of Evolution* might take away. The first is that the physical world is dynamic and ever-changing, albeit slowly, and so are many of the organisms that inhabit it. The second: a surprising amount of new discoveries can be made by studying known and identifiable organisms, year by year, throughout their lives. The third point is that it really helps to think laterally, and not exclusively within the confines of a predetermined research program. This is needed in order to take advantage of the unexpected, as Alexander Fleming did with his discovery of antibiotics, and Conrad Waddington did in his discovery of heat shock proteins. In our case, lateral thinking led us to discover a new finch lineage.

In a similar vein, we are impressed by the potential evolutionary importance of two improbable events occurring close together. In our example, the evolution of a new lineage followed from a hybrid's colonization of Daphne in 1981, and from the exceptional ecological circumstances created by the colonization of a different species during the most intense and prolonged El Niño event of the last four hundred years.

Zackory Burns

Are there any questions left about Darwin's finches to be answered or further research to be explored?

Peter and B. Rosemary Grant

Forty years of research has taught us a lot, but there are many questions left unanswered, and our ignorance remains profound.

Broadly, we cannot yet be sure if there is something special about the finches as a group that explains why more than a dozen species evolved over a period of one to two million years. (In contrast, only four mockingbird species, at most, evolved in roughly the same amount of time, or longer.) We are uncertain about the identity of the finch's ancestral species, and about what it looked like. We still only have a hazy understanding of the early stages of the diversification of the finches, after the archipelago was first colonized, and before the colonizing population split into two.

Specifically, though we do know where all finch species are located, we don't know their evolutionary dynamics, except on Daphne Major Island. We also don't know the extent to which our findings on that small island can be generalized to other species, or to other islands. We do not understand why the two lineages of warbler finches (*olivacea* and *fusca*), the oldest species, never occur on the same island, or whether they would interbreed if they came into contact. We know very little about some of the species in Galápagos, such as highland populations of the sharp-beaked ground finch and the vegetarian finch. And we cannot be sure whether their origin preceded, or followed, the arrival of key elements of their current diets. We have a poor understanding of the single species of finch on Cocos Island. The list goes on and on. With new techniques becoming available in the future, it should be possible to answer several of these questions.

Zackory Burns

What advice would you give to the next generation of evolutionary biologists?

Peter and B. Rosemary Grant

As techniques for probing the cellular and molecular world of living creatures continue to be developed at an extraordinary rate, it is very tempting to probe deeper and deeper into the submicroscopic world. The rate of return there is extremely high.

However, for anyone wishing to follow in anything like our footsteps, we would encourage giving equal attention to organisms living in their natural environment, be it sea, freshwater, land, or air. There is some urgency to do this. Natural environments are being depleted and despoiled at an increasing rate; thus, it is increasingly difficult to gain access to natural environments.

That said, we live in exciting times, with unprecedented opportunities to combine investigations into the evolution of organisms past and present, at all scales, from the community of genes, to the community of species. ■

To view or listen to the presentations, visit https://www.amacad.org/evolution.