Supplement 2

Instructor Notes on Supplemental Video: The Origin of Species, the Beak of the Finches

Total length: 15:30 minutes

Video: http://www.hhmi.org/biointeractive/origin-species-beak-finch
Describes the work of Peter & Rosemary Grant, on rapid speciation & how new species form.
Daphne Major: 600 miles from the coast of Ecuador
Research started 1973, continues 40+ years later

Galapagos islands are a group of geologically young volcanic islands; < 5 million yrs old.
- Islands differ in size, elevation, topography: islands with high elevations have large trees, those that are mostly low in elevation have mostly cactus, grasses, & shrubs.
- Home to 13 species of finches, have different beak sizes & shapes as well as other traits
    - warbler finch – needle like beak for eating small insects
    - woodpecker finch – more robust beak, eat beetle and termite larvae (from wood)
    - cactus finch – longer, more pointed beak for probing into cactus flowers
    - large ground finch, medium ground finch, small ground finch have corresponding beak sizes

How did 13 species come to be on the islands?
- could all have arrived separately from the mainland
- 1 species arrived to an island, then subsequently colonized the other islands and evolved into different species
- DNA evidence supports that the 13 species are more closely related to each other than any 1 species is related to the mainland species of finch…thus they all come from a single common ancestor. How did this occur?

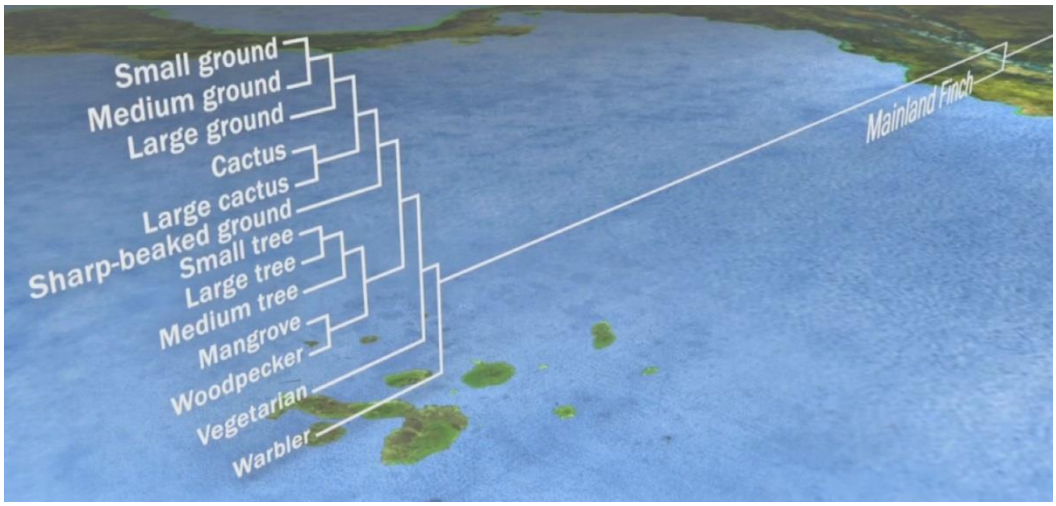

Fig. 1. Screen shot from video showing phylogeny of 13 species of finches in Galapagos Islands based on DNA analysis.

Grants' research focused on 1 species on Daphne Major: Medium Ground Finch (*Geospiza fortis*).

Why Daphne Major? Small, accessible all over by foot, so they could capture/follow every individual on the island (or almost).

Netted birds every morning, recorded data:

- size & shape of beak, body weight, tagged them for identification
- tracked the lifetime mating & reproductive success of birds over time:
  - how many times a particular male bred, which years he bred, how many mates he had, how many offspring he produced, how many of his offspring survived to reproduce

In first 4 years of study (1973-1977), little changed.

In 1977, a drought occurred:

- virtually NO rain for 18 months. Most vegetation disappeared – all that remained were a few trees w/no leaves & cactus bushes.
- medium GF had to compete for scarce food

- prior to drought, seeds of a variety of sizes were readily available; drought killed off the grasses and vegetation that normally produced mall seeds….so only large, woody, spiny seeds were left
- large, tough seeds required larger beaks to open

Fig. 2. Screen shot from video showing large vs. small seeds.

- birds w/smallest beaks had the most trouble finding food; they were scraping in rocks for food, plumage was so worn they could barely fly

- > 80% of the MGF's died that year
- 1 trait had the most influence on survival: beak depth

- graph shows the frequency of beak sizes of birds in 1976 (red), overlaid with those of birds that survived the 1977 drought (in **black**); birds that had the largest beaks survived.

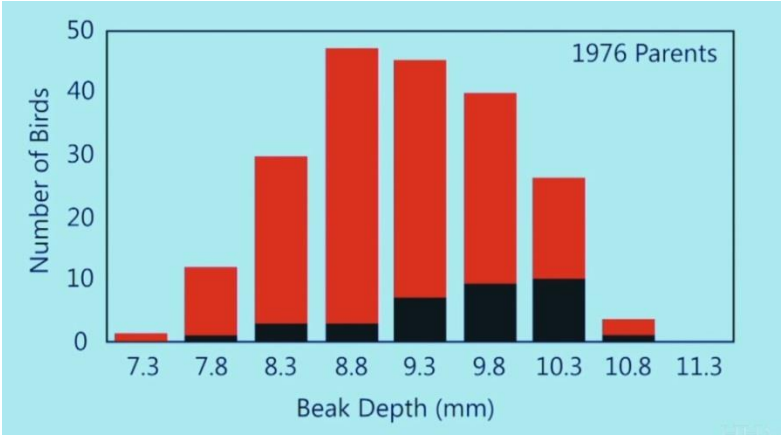

Fig. 3. Screen shot from video of data on finch survival and beak size collected in 1976.

- the next generation of birds (1978) had beak depth more than 4% larger than previous generation
[Directional selection]

The very short time required for evolutionary change to occur in the population was unexpected. Was this a fluke? Or do changes like this happen all the time?

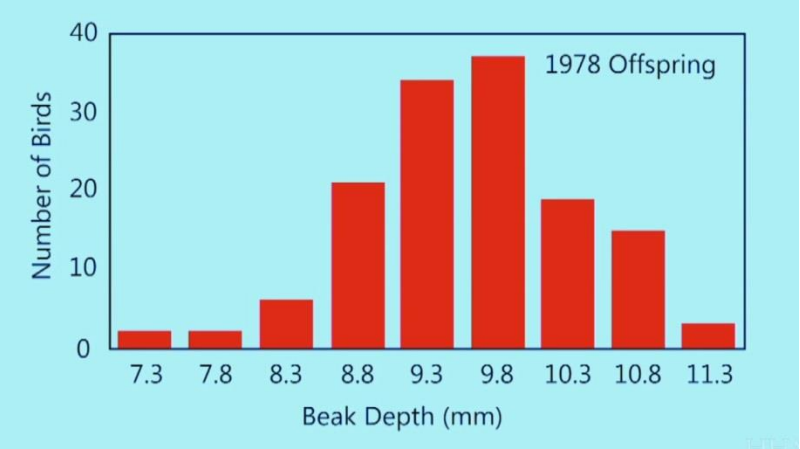

Fig. 4. Screen shot from video of data on finch survival and beak size collected in 1976.

[10:03] **In 1983, an unusually strong El Nino resulted in 10X more rain than normal.**
- island was overrun with vines that even covered cactus; changed vegetation on the island
- lots of food, lots of reproduction
- when drought struck again 2 yrs later, larger seeds became scarce (small seeds produced by vines were more abundant)
- birds w/large beaks had difficulty picking up small seeds, many more birds with small beaks survived & reproduced successfully

[what film does not describe is that it was more complicated than just the weather; a larger competitor arrived to the island in 1982 & established a breeding colony; *G. magnirostris* was much more efficient then *G. fortis* at eating the large seeds, thus competition & character displacement also contributed to the shift toward smaller beak size in *G. fortis*; see article Grant & Grant, 2006.].

Thus, Grants documented evolutionary change occurred 2X (shift to large beaks, shift to small beaks) in a short span of 10 yrs.

[11:25] **How did Finches with different beaks become distinct species?**

- 'species' are defined as: different populations who's members do not interbreed

How does 1 species split into 2?

- due to geographic separation and adapting to different conditions; they undergo enough change that they do not interbreed when reintroduced, or contact occurs…at this point they are Reproductively Isolated

Grants wanted to know: what keeps different finch species in the Galapagos from mating?

- different species have very different songs
- played songs through a loudspeaker; male birds were attracted to songs of their own species, ignored other species' songs

- mounted stuffed female specimens to branches to see if males would respond to them; males only courted females of their own species (similar body size & beak type/size)
** thus both song and physical appearance play a role in keeping different species from mating, AND contribute to the rapid evolutionary shift in traits associated with change in ecological conditions & food availability
- so when populations are separated, and traits change, some of those traits are associated with mating (preferences) and set the stage for formation of new species

[14:00] **Geography & ecology are the keys to the evolution of Galapagos Finches.**
Most likely Scenario:
1) 2 million years ago, a single finch population arrived to an island from the mainland.
2) Descendants of this population arrived on another island, and faced new conditions there. The population adapted to these new conditions, their traits changed.
3) If changes in traits included traits involved in mating (song, physical appearance, courtship behavior) and populations came back into contact again later on, then they no longer interbred with ancestral population on the original island, they were distinct and separate species.

Provides general insight into the biodiversity of species: the more diverse the environment, the more opportunities for evolutionary change to produce new species.

Explains how the great diversity of life arose & continues to evolve.

Student Worksheet on Supplemental Video: The Origin of Species, the Beak of the Finches

1. The scientists featured in the video were:

2. Where did their research take place (on which specific island)? Where is this island located?

3. How many species of finches occur in the Galapagos islands? How do they differ?

4. Where did all these species of finches come from (how did they come to inhabit the Galapagos)?

What evidence supports this & what does it show?

5. Starting in 1973, the researchers netted and captured birds every morning and tagged them with unique identifying numbers as part of their research. What data were they collecting on these birds?

6. What happened starting in 1977?

What was the result of this prolonged 18 month event?

What effect did this have on the finches?

7. As a result of the event that occurred in 1977-78, what phenomena were the Grants able to document? Describe this specifically.

8. What happened in 1983? As a result of this event, what phenomena did the Grants document?

9. How are ‘species’ typically defined by biologists?

10. What is the likely explanation for how one ancestral species of finch resulted in several distinct species? Explain how this would occur.

11. The researchers wanted to determine how the different finch species in the Galapagos remained as distinct species and did not interbreed with each other. What two experiments did they do to answer this question?

What two characteristics did they find that prevented birds from breeding with different species?

12. What key factors are responsible for the evolution of the finch species in the Galapagos Islands?

13. Likely sequence of events for how evolution resulted in 13 species of finches in the Galapagos:

Key terms: natural selection, ecological niche, geographic isolation, sexual selection, reproductive isolation, biodiversity, speciation.

Key to Student Worksheet on Supplemental Video: The Origin of Species, the Beak of the Finches

1. The scientists featured in the video were:
   Peter & Rosemary Grant

2. Where did their research take place (on which specific island)? Where is this island located?
   Daphne Major, 600 miles off the coast of Ecuador

3. How many species of finches occur in the Galapagos islands? How do they differ?
   13 species, differ in feeding habits & beak size and shape (as well as body size)

4. Where did all these species of finches come from (how did they come to inhabit the Galapagos)?
   From one ancestral species of finch that came from on the mainland
   What evidence supports this & what does it show?
   DNA evidence shows that the species in the Galapagos are more closely related to each other than to any species on the mainland

5. Starting in 1973, the researchers netted and captured birds every morning and tagged them with unique identifying numbers as part of their research. What data were they collecting on these birds?
   Body size and weight, beak size and shape
   Tracked their breeding history (who they mated with, how many offspring they had) and also tracked the survival and breeding history of each generation of offspring

6. What happened starting in 1977?
   Prolonged drought

What was the result of this prolonged 18 month event?
   Vegetation and food availability on island severely reduced; small seeds were scarce, mostly large, tough seeds were left

What effect did this have on the finches?
   Many finches died, especially those with small size beaks

7. As a result of the event that occurred in 1977-78, what phenomena were the Grants able to document? Describe this specifically.
   Rapid evolutionary change (also microevolution & directional natural selection, but they will probably not know these terms until the next week's lab).

   The finch population in 1978 had an average beak depth that was (4%) larger than the previous generation (from 1976).

8. What happened in 1983? As a result of this event, what phenomena did the Grants document?

An El Nino event occurred; 10X the normal amount of rain, which drastically increased the food supply & especially the supply of small seeds. The result is a another evolutionary shift in beak size, this time to a smaller average size beak.

9. How are 'species' typically defined by biologists?

By Reproductive Isolation; i.e., a species does not or cannot interbreed with other similar species (and/or produce fertile offspring).

10. What is the likely explanation for how one ancestral species of finch resulted in several distinct species? Explain how this would occur.

Finches colonized different islands/geographic areas with different types of habitat and food availability; over many, many generations natural selection resulted in characteristics that were better adapted for those conditions & each species became specialized for living in different ecological niches.

11. The researchers wanted to determine how the different finch species in the Galapagos remained as distinct species and did not interbreed with each other. What two experiments did they do to answer this question?

Played recorded songs; males only responded to songs of their own species.
Placed stuffed females in trees; males only courted stuffed females of their own species.

What two characteristics did they find that prevented birds from breeding with different species?

Song & physical appearance.

12. What key factors are responsible for the evolution of the finch species in the Galapagos Islands?

Ecological differences (different food supply & habitat; i.e., ecological niches & natural selection), Geographic isolation (living on different islands), Mating preferences (prefer to mate with birds that have similar characteristics; sexual selection)

Note: I doubt they will be able to get this one on their own; let them try first on their own, then make this part of the lab overview & conclusion that you go over as a class at the end of lab. Make sure they understand how each factor above plays a role in how evolution occurred in the finches, & then ask them to come up with a likely scenario.

13. Likely sequence of events for how evolution resulted in 13 species of finches in the Galapagos:

1) 2 million years ago, a single finch population arrived to an island from the mainland.
2) Descendants of this population arrived on another island, and faced new conditions there. The population adapted to these new conditions, their traits changed.
3) If changes in traits included traits involved in mating (song, physical appearance, courtship behavior) and populations came back into contact again later on, then they no longer interbred with ancestral population on the original island, they were distinct and separate species.

Galapagos Finches provide general insight into the biodiversity of species: the more diverse the environment, the more opportunities for evolutionary change to produce new species.