BiteScis

Student Handout

Trends in Evolution: Convergence and Divergence

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Introduction

If you visited Cuba, a Caribbean island south of Florida, you might notice that there are many different types of small lizards called *Anolis* lizards, anoles for short. If you then traveled the 1200 kilometers (760 miles) to Puerto Rico, you might feel a sense of deja vu—are these the same species you saw in Cuba? Some species look so similar that even experts sometimes can't tell the lizards from different islands apart. Are they the same species, or are they related? How did they come to look so similar? Evolutionary biology can provide the answers.

Scientists study evolution to uncover the relationships among organisms and to understand how these diverse species came to live in their current habitats. In the past, scientists could only rely on the physical traits of organisms for information. Today, we can also consider molecular information including DNA, RNA, and proteins when generating phylogenies. A **phylogeny** is a hypothesis for how species are related. Another tool of modern evolutionary biology is the computer. Computer models test hypotheses about how different environments and selective pressures have affected the processes of evolution and generated the patterns we see today.

In this lesson, you will explore an exciting example of evolution in Caribbean *Anolis* lizards. You will develop phylogeny models that represent your hypotheses about how these species are related based on how they look, where they live, and their genetic information. You will have the chance to revise your phylogeny model as you learn more about these lizards. Then, you will learn about how computer modeling is taking us one step further by helping us understand the species diversity and distribution that we can observe today.

What To Do

Step 1. With a partner, look at species cards you were given that contain eight different species of anoles. Group them into pairs based on their **phenotype,** which is their observable physical features. Base your decision on the written descriptions, do not try to make your own judgements based on the drawings. This is because the traits such as leg length and tail length are relative to the lizard's overall body length, which can be difficult to eyeball, and toe pad size is a measure of the number of ridges on the underside of the toes, which are not visible in the drawings.

Record your pairs below and briefly describe why you formed the pairs you did.

Pair:				
Pairing based on:				

Step 2. The groupings that you made in **Step 1** is your hypothesis about which pairs of species are more closely related to each other. Model this hypothesis using a phylogeny by first connecting the closely related species pairs and then connecting pairs according to how closely you think they are related. Your final model should be similar to one of the examples in **Figure 2.** Record your model in **Table 1**, using species numbers, not names.

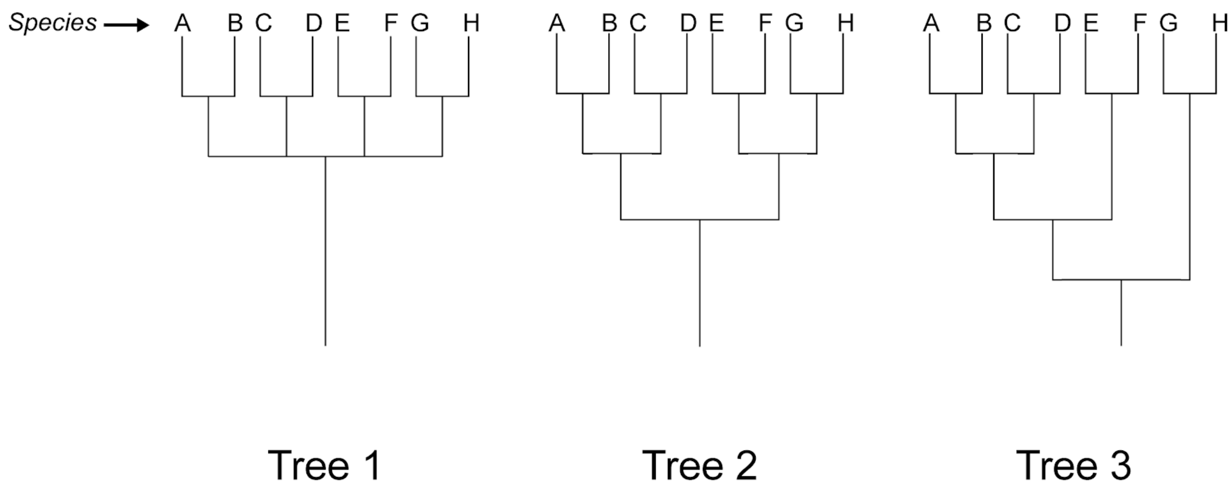


Figure 2. Three Example Phylogenies. These are examples of what a phylogeny might look like. Each start with species pairs A and B, C and D, E and F, and G and H. In Tree 1, no one pair is more closely related to any other pair. In Tree 2, two sets of pairs, A–B/C–D and E–F/H–I, are hypothesized to be more closely related to each other than to the the other two pairs. In Tree 3, pair E–F is more closely related to pairs A–B and C–D than it is to pair H–I.

Step 3. Compare and discuss your phylogeny with your partner pair. What characteristics did you use to determine relatedness? Do you think this is accurate? Do your phylogenies look the same or are there differences? Add notes to **Table 1.**

Step 4. Next, consider the habitat and geographic range of each species in addition to the phenotype information used previously. If needed, revise your phylogeny in the appropriate row of **Table 1**. ***Important!*** *F*rom here out, your phylogeny does not need to look like one of the examples in Figure 2.

Step 5. Again, compare and discuss with your partners. Has your phylogeny changed, and how? How reliable is physical or geographic/habitat information? Add notes to **Table 1.**

Step 6. Finally, look at the "mock genome" for each species of *Anolis l*izard. Each oval in the mock genome represents an individual unspecified gene in this species and the color/letter tells you which allele the species has. Does this new information change your thinking? If needed, revise your phylogeny in the appropriate row of **Table 1**.

Step 7. Once again, discuss with your partners how genetic data has changed your understanding of the relationships of these lizards. Add notes to **Table 1.**

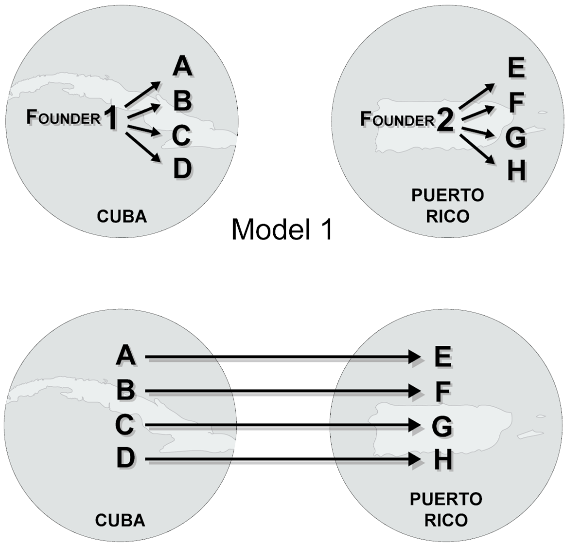
Step 8. Complete analysis questions, reading the Bite when instructed.

Evidence to Use	Draw Your Phylogeny	Discussion Notes
Based on phenotype data **only**		
Based on phenotype **and** habitat / geographic data		
Based on phenotype, habitat/geographic data, **and** genetic data		

Table 1. *Anolis* Phylogeny Models.

Analysis Questions

1. Consider the evidence that you have on your species cards (phenotype, habitat, geography, genotype). Which model from **Figure 3** below would be supported for each type of evidence? Explain your reasoning in **Table 2**.



Model 2

Figure 3. Models to Explain *Anolis* Lizard Distributions. In Model 1, each island was first populated by a founding species that then each diversified into many species. In this model, all of the species on a given island are more closely related to each other than to any species on the other island. In Model 2, species first inhabited Puerto Rico and then traveled to Cuba. In this model, a species on one island has its closest relative on the other island.

Evidence	Claim: Which model is better supported? (1 or 2)	Explain your reasoning
Phenotype		
Habitat/ Distribution		
Genetics		

Table 2. Evidence-Claim-Reasoning. Models and the data that support them.

2. Which model best explains the phylogeny your group developed? Support your answer with evidence from your final model in **Table 1**.

STOP & read Science Bite:

Can A Computer Predict How Species Evolve?

Connect to the Big Question. Scientists can make observations in many different ways—they can observe how animals look, they can observe where animals live, and they can observe patterns in genetic information. Scientists use these different types of data to formulate hypotheses of evolutionary relationships. Today you made observations about many types of data to determine the evolutionary relationships of *Anolis* lizards.

3. Think about all of the types of observations you made as you answer the following questions.

   a. Based upon the phylogeny supplied in the Bite, which model (1 or 2) from **Figure 3** would you support and why?

   b. Considering your answer to part a, which types of data were most helpful/reliable in developing a phylogeny closest to the real phylogeny? (You may find re-reading your answer to Question 1 helpful!)

   c. Why is it important to consider non-genomic data to model evolutionary relationships?

Anolis ecomorphs are named based on their habitat, but the species in each ecomorph share more than just where they live. They also have similar traits. **Table 4** below includes some of the *Anolis* ecomorphs found on Caribbean islands, including those of the species you used to build your phylogenies in this activity.

Ecomorph	Habitat	Traits
Crown-giant	High trunks & branches	Usually green coloration, very long body, long tail, short legs, and large toe pads
Grass-bush	Bush & grasses	Brown coloration, long legs & tail, short body length
Trunk	Tree trunks	Gray coloration, short tail and intermediate leg length
Trunk-crown	Tree trunks, branches, & leaves	Green coloration, very large toe-pads, long tail with short legs
Trunk-ground	Lower trunk & ground	Brown coloration, long limbs & tail
Twig	Narrow twigs	Gray coloration, very short limbs & tail, small toe pads

Table 4. Types of Ecomorphs. This table lists some ecomorphs, where they typically live, and any traits that are characteristic of species belonging to each group. *Source:* Modified from HHMI Biointeractive.

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4. Use the information in **Table 4** to answer the following questions.

a. On a given island, many (but not necessarily all!) of the ecomorphs evolved from one founding species. Consider the ecomorphs shown in **Table 4**. Make a claim about the selection pressure(s) that drove the diversification of the lizards.

b. Do you think it is likely that new ecomorphs will evolve on the Caribbean islands in the future? Justify your answer.

For parts c–e, we will be focusing on leg length in the different ecomorphs.

c. Scientists have found that animals with longer legs tend to be faster runners. But, having shorter legs can increase stability. Which ecomorphs have long legs? Which ecomorphs have short legs? Does this pattern make sense given the advantages of short *vs*. long legs?

d. *A. evermanni* is a Puerto Rican species that is part of the trunk-crown ecomorph and has short legs. *A. evermanni* shares a recent common ancestor with *A. cristatellus* (trunk-ground ecomorph) and *A. pulchellus* (grass-bush ecomorph), both of which have long legs. How did their common ancestor give rise to species with long legs AND species with short legs?

e. An individual lizard belonging to a trunk–ground species has much shorter than average legs. It survives and passes on its short-legged trait to its many offspring. Explain why this result is consistent with natural selection.

5. Study the the *Anolis* lizard phylogeny in Figure 2 of the Bite.

a. Find all of the species from Puerto Rico on the phylogeny. Do you think Puerto Rican anoles provide an example of **convergent evolution** (in which species independently evolve similar characteristics) or **divergent evolution** (in which an ancestral species diversifies into many different species)? Explain your answer.

b. Find the species that live on twigs and thin branches on the phylogeny. Do you think they are an example of convergent or divergent evolution? Explain your answer.

c. Think about the species *A. evermanni.* What selective pressures do you think contributed to this species evolving its particular phenotype? You may find it helpful to revisit the species cards and to consider its ecomorph.

d. *A. occultus* doesn't seem to be closely related to the other species on Puerto Rico. How do you think this species got there?

6. The modeling described in the Bite suggested that there might be some ecomorphs on Cuba that wouldn't be found in Puerto Rico. It turns out that this is true—there are some *Anolis* ecomorphs that only occur on Cuba. Why do you think Cuba has ecomorphs that other islands don't have? (*Hint:* Looking at the map in Figure 1 of the Bite might be helpful!)

7. What conclusions do you draw about evolutionary relationships from this activity? How do we know what we know about evolutionary relationships? What observations contribute to the most accurate depictions of evolutionary relationships?

_v2: formatting changes June 22, 2018