Florida lizards evolve rapidly after the invasion of a competitor

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In this activity students analyze excerpts from a scientific article, which describes a set of experiments conducted on a population to test for an evolutionary change. Students are guided through the article by a set of questions, which they answer individually or discuss in pairs.

4.1 Aims

- To enable the students read and learn from a primary scientific source.
- To point out that evolutionary change may happen quickly.
- To enhance the understanding of a scientific work and experimental design.
- To discuss the problem of invasive species.
- To emphasize the importance of evolutionary biology for natural protection.

4.2 Structure

- Students work individually or in pairs on the reading assignment (30–45 min).
- Discussion with the whole class (30–45 min).

4.3 Materials

- Student sheets

4.4 Procedure

1. Students work individually or in pairs on the reading activity.
2. The teacher discusses the study described by the passage with the class and reviews the students' answers.

References

- Stuart, Y. E., T. S. Campbell, P. A. Hohenlohe, R. G. Reynolds, L. J. Revell, and J. B. Losos. 2014. "Rapid Evolution of a Native Species Following Invasion by a Congener." Science 346 (6208), 463-466. Article used and modified with the authors' agreement.
- Picture 1 A: Euku `https://commons.wikimedia.org/wiki/File:Male_Anolis_carolinensis.jpg`, "Male Anolis carolinensis" `https://creativecommons.org/licenses/by-sa/3.0/legalcode`
- Picture 1 B: Charlesjsharp `https://commons.wikimedia.org/wiki/File:Cuban_brown_anole_(Anolis_sagrei_sagrei)_juvenile.JPG`, `https://creativecommons.org/licenses/by-sa/4.0/legalcode`

Florida lizards evolve rapidly after the invasion of a competitor

Though it is generally assumed that evolution only occurs slowly and gradually, in recent years, biologists begun to suggest that evolutionary change may also occur on a time scale observable by humans. One of the causes of rapid evolution may be a negative interaction between closely related species, which creates strong selective pressure on the species involved.

(A) (B)

Figure 1: Two anolis species: A) *Anolis carolinensis* and B) *Anolis sagrei sagrei*.

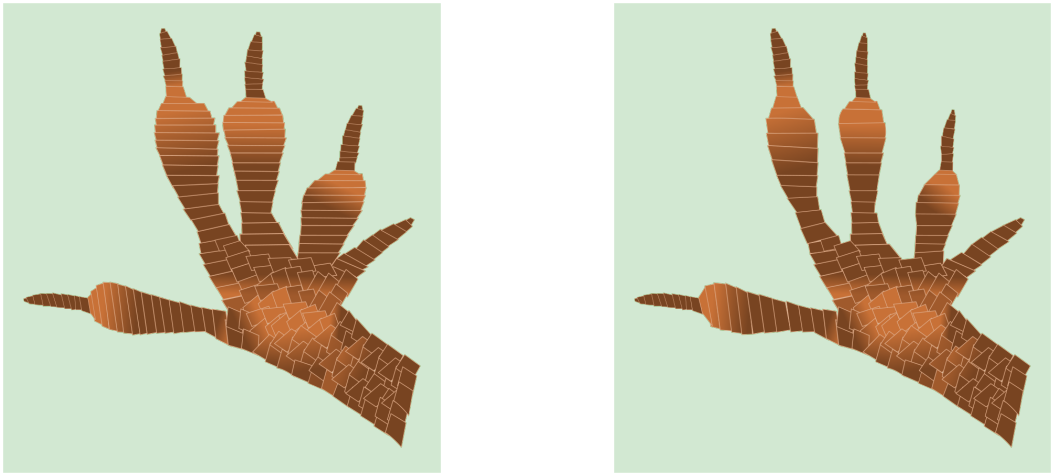

Figure 2: *Intraspecific variability in toe width and the number of lameles in* Anolis carolinensis.

Question 1: *What do you think "a time scale observable by humans" would be? What is the shortest amount of time in which an evolutionary change could occur?*

An opportunity to study the evolutionary consequences of such a negative interaction was provided by the invasion of the Cuban brown anole lizard, *Anolis sagrei*, onto the islands of the coast of Florida (the Florida Keys), where *Anolis carolinensis* is the sole native anole. The diet and habitat requirements of these two species overlap, so when they co-occur, competition for both space and food is a significant factor. What is more, individuals of these two species have been observed to interact agonistically. Scientists found that after the invasion of *Anolis sagrei*, introduced from Cuba, the native lizard *Anolis carolinensis* moved to higher perches. In response to perching higher in the trees, *Anolis carolinensis* adaptively evolved larger toepads, better at gripping the thinner, smoother branches found higher up.

What did the scientists actually do to find this out? Let Yoel Stuart, the leader of the research group from Harvard University, tell us:

> "Typical of solitary anoles, *A. carolinensis* habitat use spans from the ground to the tree crowns. However, where *A. carolinensis* and *A. sagrei* co-occur elsewhere, *A. carolinensis* perches higher than *A. sagrei*. Thus, we used an introduction experiment to test a prediction that competitive interactions with *A. sagrei* should drive an increase in *A. carolinensis* perch height."

Question 2: *Suggest an experiment to test the prediction, that "competitive interactions with* A. sagrei *would drive an increase in* A. carolinensis *perch height". What would you manipulate in your experiment? What would you measure?*

> "In early May 1995, we chose six islands that contained resident populations of *A. carolinensis* and collected pre-introduction perch height data from undisturbed lizards. Later that month, we introduced small populations of *A. sagrei* to three treatment islands, leaving three control islands containing only *A. carolinensis*. From May to August 1995–1998, we measured perch heights for both species. The *A. sagrei* populations grew rapidly and by August 1995, *A. carolinensis* on treatment islands already showed a significant perch height increase relative to controls, which was maintained through the study."

Question 3: *How was your suggested experiment similar to the experiment actually done by Yoel Stuart's group? How long did this part of the research take?*

Question 4: *What happened to the population of* A. sagrei *introduced to the islands? What did the* A. carolinensis *individuals do in response to the introduction of* A. sagrei*?*

> "We next predicted that this arboreal shift by *A. carolinensis* would drive the evolution of larger toepads with more lamellae (adhesive, setae-laden, subdigital scales). Toepad area and lamellae number correlate positively with perch height among anole species, and larger and better developed toepads improve clinging ability, permitting anoles to better grasp unstable, narrow, and smooth arboreal perches."

Question 5: *Suggest a reason for the expectations of the authors, that the "arboreal shift by* A. carolinensis *would drive the evolution of larger toepads".*

> "We tested the prediction in 2010 on a set of islands partially overlapping those used in 1995–1998. We surveyed 30 islands and found that *A. sagrei* had colonized all but five. We compared *A. carolinensis* populations on these five islands without the invader (hereafter "un-invaded") to *A. carolinensis* populations on six islands that, on the basis of 1994 surveys, were colonized by *A. sagrei* sometime between 1995 and 2010 (hereafter "invaded"). From May to August 2010, we measured perch height for undisturbed lizards and found that, as in the 1995 introduction experiment, *A. carolinensis* perch height was significantly higher on invaded islands. We then tested whether the perch height shift had driven toepad evolution by measuring toepad area and lamellae number of the fourth toe of each hind leg for every *A. carolinensis* captured. We found that *A. carolinensis* on invaded islands indeed had larger toepads and more lamellae."

Question 6: *What exactly did the scientists measure on each of the captured* A. carolinensis*? How long after the introduction of* A. sagrei *were these measurements taken?*

> "We tested several alternative processes (other than evolution caused by changed perch height—editor's note) that could have generated the observed divergence."

Question 7: *Suggest an alternative reason (other than evolutionary change caused by competition) that could explain the larger toepads and more lamellae found in* A. carolinensis *living in islands inhabited also by* A. sagrei*.*

> "First, we used a common garden experiment to investigate possible posthatching, developmental responses to physical challenges imposed by arboreality during growth (i.e., phenotypic plasticity). We took gravid *A. carolinensis* females from four invaded and four un-invaded islands in July 2011, collected their eggs in the laboratory, and raised the offspring in identical conditions. The effect of *A. sagrei* invasion on *A. carolinensis* toepad characteristics persisted in the common garden suggesting genetically based divergence in nature."

Question 8: *What do the researchers mean by saying that "the effect of* A. sagrei *invasion on* A. carolinensis *toepad characteristics persisted in the common garden"? What did they find out?*

> "Second, observed divergence in *A. carolinensis* could have arisen through nonrandom migration of individuals with large toepads among invaded islands, instead of arising independently on each island. Thus, we tested whether relatedness among *A. carolinensis* populations is independent of *A. sagrei* invasion. We genotyped 379 *A.*

> *carolinensis* individuals from four un-invaded and five invaded islands. Individuals from the same island were closely related, and islands were largely genetically independent. We found no evidence that population relatedness in *A. carolinensis* was correlated with whether an island had been colonized by *A. sagrei* or with distance between islands, suggesting that gene flow is relatively limited."

Question 9: *The scientists say that they genotyped the* A. carolinensis *individuals and found out that "individuals from the same island were closely related, and islands were largely genetically independent". What kind of data did the scientists obtain from genotyping the lizards? How did they use the data to determine which individuals were related and which were independent?*

The authors conclude by saying that their study, apart from describing an evolutionary change observed in real time, also demonstrates the relevance of evolutionary biology to contemporary environmental issues.

Question 10: *How quickly did the described evolutionary change happen? Was it more or less than your initial suggestion?*

Question 11: *For the purpose of this study, scientists introduced a species into a new environment, where it had not been living before. Can you suggest some possible negative consequences of this procedure?*

Question 12: *What changes would you expect to occur in the populations of* A. carolinensis *on the invaded islands if the populations of* A. sagrei *were removed from these islands?*