HOW TO USE THIS RESOURCE

Show the following figures and caption to your students. The accompanying Student Handout provides space below the caption for Observations, Notes, and Questions and space next to the "Background Information" for Big Ideas, Notes, and Questions. The "Interpreting the Figures" and "Discussion Questions" sections provide additional information and suggested questions that you can use to prompt student thinking, increase engagement, or guide a class discussion about the characteristics of the figures and what they show.

Figure 1:

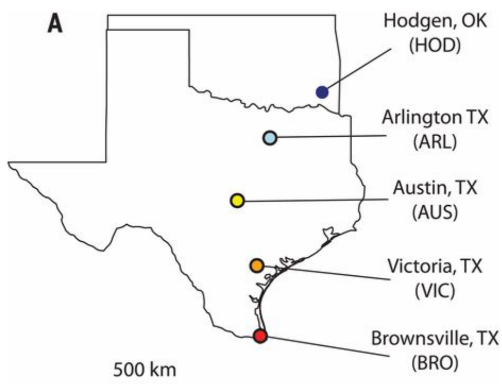
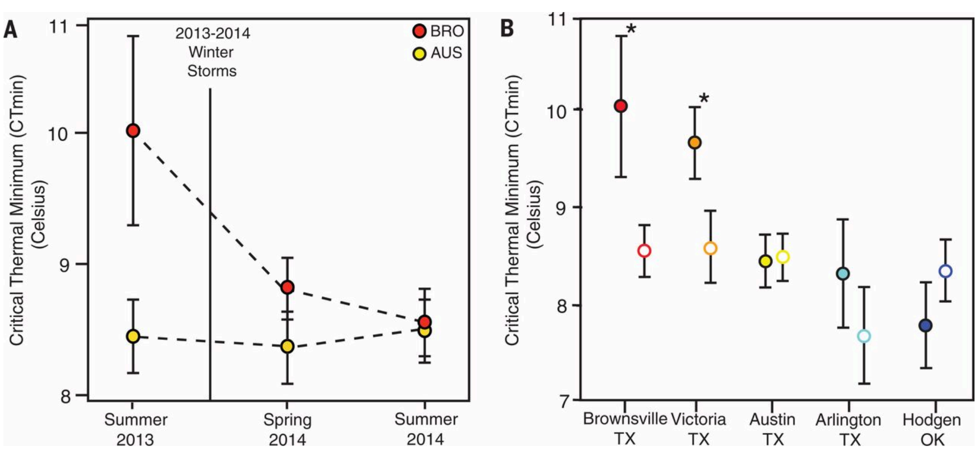


Figure 2:



Caption: *Figure 1A shows the locations of the five anole lizard populations in the study. Figure 2A shows the mean CT_{min} (critical thermal minimum, the temperature at which lizards lose their coordination) over time for two of the populations. Figure 2B compares the mean CT_{min} values for all five populations in the summers of 2013 (closed circles) and 2014 (open circles). Asterisks indicate that the CT_{min} for a population was significantly lower in 2014. Error bars represent the standard error of the mean (SEM).*

BACKGROUND INFORMATION

Extreme climate events, such as droughts or storms, can drive evolutionary changes in populations. One such event was the winter storms of 2013 to 2014 in the southern United States, which caused some of the area's coldest temperatures in the last 15 years. Scientists investigated how these extremely cold temperatures affected local populations of anole lizards. These lizards' ability to tolerate cold is an inherited trait. The scientists thought that the extremely cold winter could cause natural selection on this trait.

The scientists studied five anole lizard populations in different locations: four in Texas and one in Oklahoma. In the past, the southern locations usually had warmer, milder winters than the northern ones. Before the winter storms, the scientists sampled lizards from each population. They determined how well these lizards could tolerate cold by measuring their critical thermal minimum (CT_{min}), the temperature at which the lizards lost their coordination. (A lizard with a lower CT_{min} may be better able to move when it is cold.) After the winter storms, the scientists sampled the surviving lizards from each population. They compared the mean CT_{min} values of the samples taken *before* the storms (from the initial populations) to those of the samples taken *after* the storms (from the winter survivors).

INTERPRETING THE FIGURES

Figure 1A shows that the five populations of anoles (*Anolis carolinensis*) in the study were located along a latitudinal transect. The scientists had previously found that cold tolerance in this species varies with latitude (the anoles located farther north, where winters are typically colder, have greater cold tolerance), and that this variation may have a genetic component. They hypothesized that the extreme cold snap during the winter of 2013 to 2014 selected for more cold-tolerant lizards, and that selection depended on how much cold stress the lizards experienced.

Figure 2A compares two of the five populations: the southernmost population in Brownsville, Texas (abbreviated BRO), and a more northern population in Austin, Texas (abbreviated AUS). This figure shows the cold tolerance of each population, as represented by the critical thermal minimum (CT_{min}), at three different time points:

1. **Summer 2013**: At this point, the BRO population had a significantly higher CT_{min}, indicating a lower cold tolerance, than the AUS population did. During the following winter, minimum daily temperatures dropped throughout the study area. The BRO population experienced considerably more cold stress than the AUS population did, as there were many more days with temperatures below the BRO CT_{min} (see Figure 1c in the original paper for more data).
2. **Spring 2014**: By this point, the CT_{min} of the BRO population had significantly decreased, indicating increased cold tolerance. The CT_{min} of the AUS population, on the other hand, did not change significantly.
3. **Summer 2014:** The CT_{min} of the BRO population remained low, suggesting that its decrease was due to evolutionary change through natural selection rather than phenotypic plasticity (the same genotype producing different phenotypes based on environmental conditions). The BRO and AUS error bars also overlap at this point, suggesting that the two populations had become statistically similar with regard to cold tolerance.

A common misconception is that evolution involves individual organisms changing over time, so it is important to note that the lizards sampled after the cold snap were most likely *not* the same lizards that were sampled before. The figures reflect comparisons between individuals from the initial populations and individuals that survived the winter storms, not comparisons of the same individuals over time.

Figure 2B compares the cold tolerance of all five populations in summer 2013 (before the cold snap) and summer 2014 (after the cold snap). As shown, only the two southernmost populations, BRO and VIC, experienced a significant increase in cold tolerance (decrease in CT_{min}). The other, more northern populations did not change significantly, presumably because they were already adapted to harsher winters. The overlapping error bars for the populations after the cold snap suggest that all five populations ultimately become more similar with regard to cold tolerance.

As discussed in the original paper, the scientists also analyzed gene expression profiles for the populations in the study. They found that the southernmost population, BRO, had significant differences in 14 genomic regions before and after the cold snap. The BRO lizards sampled *after* the cold snap (the winter storm survivors) had gene expression levels more similar to those of the northernmost population, HOD, than the BRO lizards sampled *before* the cold snap (the initial population) did. (The gene expression profiles of the non-BRO populations did not change as much, suggesting that those populations were less affected by the winter storms.) In addition, some of the same genomic regions that differed between the BRO winter storm survivors and the initial BRO population also differed between the BRO and HOD lizards. These results suggest that winter storms and latitudinal variation in winter cold (i.e., colder winters farther north) may have similar effects on anole populations.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

Figure 2A:

- Graph type: Line graph
- *X*-axis: Sampling times for the populations. Summer 2013 is before the cold snap, and spring 2014 and summer 2014 are after the cold snap.
- *Y*-axis: Mean critical thermal minimum (CT_{min}) in Celsius for each population, which is used as a measure of cold tolerance. The error bars indicate the standard error of the mean (SEM).
- Legend: Populations are color-coded by location, as shown on the map (Figure 1A).

Figure 2B:

- Graph type: Scatter plot
- *X*-axis: Locations of the populations, listed southernmost to northernmost from left to right
- *Y*-axis: Mean critical thermal minimum (CT_{min}) in Celsius for each population, which is used as a measure of cold tolerance. The error bars indicate the standard error of the mean (SEM).
- Asterisks: Indicate populations for which CT_{min} was significantly lower after the cold snap
- Legend: Populations are color-coded by location, as shown on the map (Figure 1A). Closed circles represent measurements from summer 2013 (before the cold snap), and open circles represent measurements from summer 2014 (after the cold snap).

DISCUSSION QUESTIONS

- Consider the locations of the five populations on the map (Figure 1A). What might have been some of the differences among the lizards in these populations *before* the winter of 2013 to 2014?
- Explain in your own words what a critical thermal minimum (CT_{min}) is. Why do you think the scientists used CT_{min} to measure the cold tolerance of the lizards? Can you think of other measurements that the scientists could have used instead?
- Do you think that the individual lizards that the scientists sampled *before* the winter storms are the same individuals that the scientists sampled *after* the storms? Why or why not?
- How did the BRO and AUS populations differ in summer 2013, before the winter storms? Use evidence from Figure 2A to support your answer.
- Describe how the winter storms affected the BRO and AUS populations. Use the summer 2013 and spring 2014 data points from Figure 2A to support your answer.
- Overall, how did the BRO and AUS populations change from summer 2013 to summer 2014? Use evidence from Figure 2A to support your answer.
- Evaluate the claim that the CT_{min} values of the BRO and AUS populations became less statistically different over time. Use evidence from Figure 2A to support your answer.
- Compare the five populations in Figure 2B. Which populations had significantly different CT_{min} values before and after the winter storms of 2013 to 2014? Use the error bars to explain your answer.
- Why do you think the five populations differed as shown in Figure 2B?
- If the winter storms of 2013 to 2014 were a rare event that does not occur again, what do you predict might happen to the CT_{min} values of these populations over time?

- The scientists determined that cold tolerance is an inherited trait in anole lizards. What kinds of genes or gene functions might affect a lizard's cold tolerance?
- The scientists hypothesized that the extremely cold winter led to natural selection on some of the lizard populations. Do the data support this hypothesis? Explain your answer.
- Are there any other explanations besides natural selection for the results in the figures? If so, what additional data would you need to determine whether natural selection actually took place?
- Can you think of other examples of extreme climate events that might lead to natural selection? What do you predict the effects of natural selection would be in those cases? How might you test your predictions?
- Many extreme climate events are likely to become more frequent and severe due to climate change. Based on this information and the figure you discussed, how do you think climate change may affect the survival and distribution of different species? What other data might be useful for answering this question?

KEY TERMS

Anolis, cold tolerance, error bar, extreme climate event, line graph, lizard, map, polar vortex, scatter plot, standard error of the mean (SEM)

SOURCE

Figures 1a and 2 from:

Campbell-Staton, S. C., Z. A. Cheviron, N. Rochette, J. Catchen, J. B. Losos, and S. V. Edwards. "Winter storms drive rapid phenotypic, regulatory, and genomic shifts in the green anole lizard." *Science* 357, 6350 (2017): 495–498. https://doi.org/10.1126/science.aam5512.

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