Homework - Week 8

Your homework this week will look at the two processes of *natural selection* and *artificial selection*. I suggest reviewing the last part of the online lecture notes before completing this assignment. For both parts of this homework assignment, you will look at data or evidence that illustrate whether natural and/or artificial selection is occurring.

The first part presents research from a scientist who investigated whether natural selection was leading to local adaptation in a particular plant. The second part (in a separate file) looks at how a plant population changes generation to generation through artificial selection. Because this file is large and can cause issues when uploading your answers, there is a separate document to turn in with your answers.

Part 1A. Natural Selection - Local Adaptation

<u>Research Background</u>: Doug is a biologist who studies plants from around the world. He often jokes that he chose to work with plants because he likes to take it easy. While animals rarely stay in the same place and are hard to catch, plants stay put and are always growing exactly where you planted them! Using plants allows Doug to do some pretty cool and challenging experiments. Doug and his research team carry out experiments with the plant species Mouse-ear Cress, or *Arabidopsis thaliana*. They like this species because it is easy to grow in both the lab and field. *Arabidopsis* is very small and lives for just one year. It grows across most of the globe across a wide range of latitudes and climates. *Arabidopsis* is also able to pollinate itself and produce many seeds, making it possible for researchers to grow many individuals to use in their experiments.

Doug wanted to study how *Arabidopsis* is able to survive in such a range of climates. Depending on where they live, each population faces its own challenges. For example, there are some populations of this species growing in very cold habitats, and some populations growing in very warm habitats. He thought that each of these populations would adapt to their local environments through **natural selection**. An *Arabidopsis* population growing in cold temperatures for many generations may evolve traits that increase survival and reproduction in cold temperatures. However, a population that lives in warm temperatures would not normally be exposed to cold temperatures, so the plants from that population would not be able to adapt to cold temperatures. The idea that populations of the same species have evolved as a result of certain aspects of their environment is called **local** adaptation.



Mouse-ear Cress, or Arabidopsis thaliana, growing in the field.



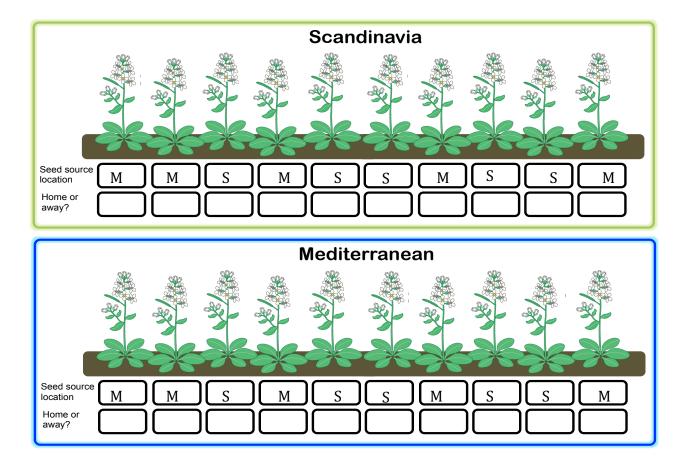


Doug, and two members of his team, setting up the reciprocal transplant experiment in Scandinavia.

To test whether *Arabidopsis* is locally adapted to its environment, Doug established a **reciprocal transplant experiment**. In this type of experiment, scientists collect seeds from plants in two different locations and then plant them back into the same location (home) and the other location (away). For example, seeds from population A would be planted back into location A (home), but also planted into location B (away). Seeds from population B would be planted back into location B (home), but also planted at location A (away). If populations A and B are locally adapted, this means that A will survive better than B in location A, and B will survive better than A in location B. Because each population would be adapted to the conditions from their original location, they would outperform the plants from away when they are at home ("home team advantage").

In this experiment, Doug collected many seeds from warm Mediterranean locations at low latitudes, and cold Scandinavian locations at high latitudes. He used these seeds to grow thousands of seedlings. Once these young plants were big enough, they were planted into a reciprocal transplant experiment. Seedlings from the Mediterranean location were planted alongside Scandinavian seedlings in a field plot in Scandinavia. Similarly, seedlings from the Scandinavian locations were planted alongside Mediterranean seedlings in a field plot in the Mediterranean. By planting both Mediterranean and Scandinavian seedlings in each field plot, Doug can compare the relative survival of each population in each location.

Below is a diagram of the research design. There are two field plots: one at a Scandinavian location and one at a Mediterranean location. There are 10 seedlings in each plot - 5 from the Mediterranean population (M) and 5 from the Scandinavian population (S). Think about whether each seedling is in its home or its original (away) location and which plants you think will survive in each field plot.



Doug made two local adaptation predictions:

- Scandinavian seedlings would survive better than Mediterranean seedlings at the Scandinavian field plot.
- Mediterranean seedlings would survive better than Scandinavian seedlings planted at the Mediterranean field plot.

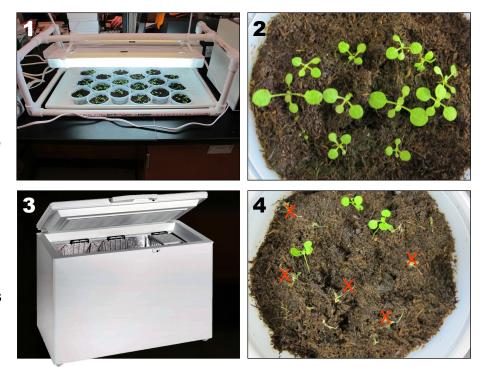
At this point, answer questions 1-4 on the answer sheet.

Part 1B. Natural Selection - Freeze tolerance

<u>Doug's next steps:</u> The data from Doug's reciprocal transplant experiment show that the *Arabidopsis* populations are locally adapted to their home locations. Now that Doug confirmed that populations were locally adapted, he wanted to know how it happened. What is different about the two habitats? What traits of *Arabidopsis* are different between these two populations? Doug now wanted to figure out the mechanism causing the patterns he observed.

Doug originally chose *Arabidopsis* populations in Scandinavia and the Mediterranean for his research on local adaptation because those two locations have very different climates. The populations may have adapted to have the highest survival and reproduction based on the climate of their home location. To deal with sudden freezes and cold winters in Scandinavia, plants may have adaptations to help them cope. Some plants are able to protect themselves from freezing temperatures by producing chemicals that act like **antifreeze**. These chemicals accumulate in their tissues to keep the water from turning into ice and forming crystals. Doug thought that the Scandinavian population might have evolved traits that would allow the plants to survive the colder conditions. However, the plants from the Mediterranean aren't normally exposed to cold temperatures, so they wouldn't have necessarily evolved freeze tolerance traits.

To see whether freeze tolerance was driving local adaptation, he set up an experiment to identify which plants survived after freezing. Doug again collected seeds from several different populations across Scandinavia and across the Mediterranean. He chose locations that had different latitudes because latitude affects how cold an area gets over the year. High latitudes (closer to the poles) are generally colder and low latitudes (closer to the equator) are generally warmer. Doug grew more seedlings for this experiment, and then, when they were a few days old, he put them in a freezer. Doug counted how many seedlings froze to death. and how many survived, and he used these numbers to calculate the percent survival for each population. To gain confidence in



Setup of Doug's freeze tolerance experiment. Seeds germinated (1) and grew up into seedlings (2). Seedlings were placed in a freezer (3), and Doug measured the percent of seedlings that survived, and how many froze to death (4).

his results, he did this experiment with three replicate genotypes per population.

Doug predicted that if freeze tolerance was a trait driving local adaptation, the seedlings originally from colder latitudes (Scandinavia) would have increased survival after the freeze. Seedlings

originally from lower latitudes would have decreased survival after the freeze because the populations would not have evolved tolerance to such cold temperatures.

Scientific Question: Are there differences in freeze tolerance between Scandinavian and Mediterranean populations of *Arabidopsis*?

Graph of results:

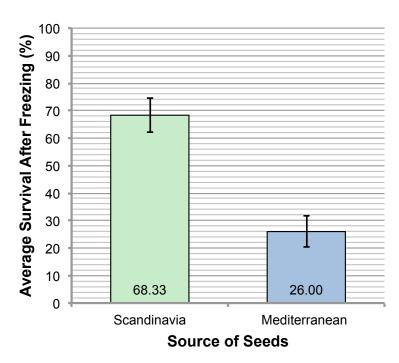


Figure 1. Average survival (+/- 1 standard error) of *Arabidopsis thaliana* seedlings after freezing. Seeds were from 4 different sites in Scandinavia and 4 different sites in the Mediterranean. Three trails were conducted with seeds from each site.

*Standard deviation (SD) tells us about the amount of variation in the data. A large SD means there is a lot of variation around the mean, while a small SD means the data points all fall very close to the mean. **Standard error (SE)** tells us how confident we are in our estimate of the mean, and depends on the number of replicates in an experiment and the SD. A large SE means we are not very confident, while a small SE means we are more confident.

At this point, answer questions 5-9, which start on page 2 of the answer sheet.