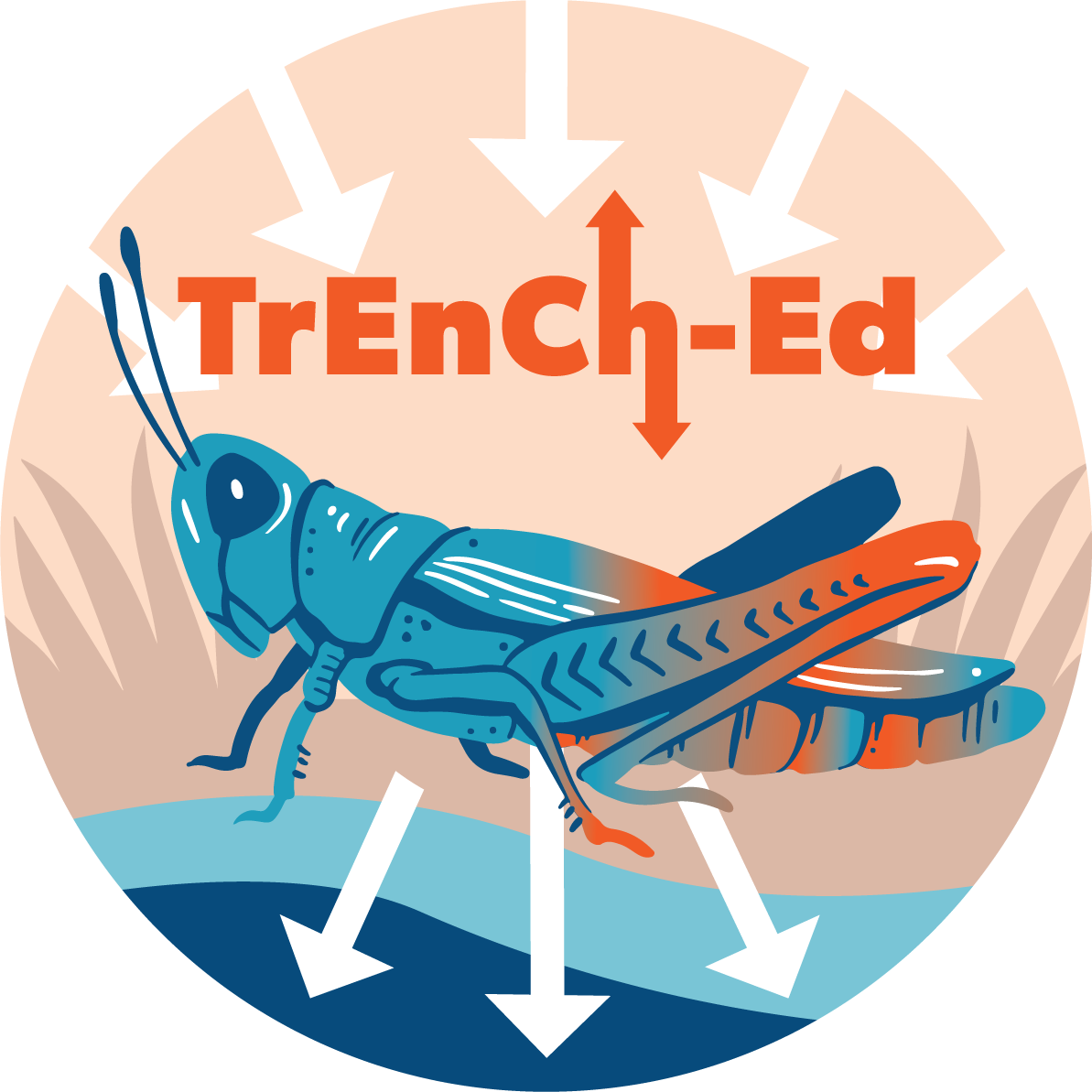
# Butterfly Museum Specimens

Morphological Responses to Climate Change: A Case Study

## [Link to the visualization](https://huckley.shinyapps.io/butterflies/)

## [Link to TrEnCh-Ed](https://trench-ed.github.io/#)

## Objectives

* Analyze case study data to create an explanation about how climate might influence species such as the *Colias* butterflies.
* Understand how thermoregulatory traits (e.g., coloration, size) influence how organisms interact with their environment.
* Examine how climate change can drive changes in thermoregulatory traits

## Core concepts -- *BioCore*

* Physiology: Evolution
* Ecology & Evolutionary Biology: Evolution
* Ecology & Evolutionary Biology: Information Flow
* Physiology: Structure Function
* Ecology & Evolutionary Biology: Structure Function
* Ecology & Evolutionary Biology: Transformation of Energy and Matter
* Physiology: Systems

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## Background

Read the introduction to the visualization and answer these background questions below.

### Museum specimens hold clues to organisms’ physical changes

1. What response to recent climate change did researchers document in many species?
2. What do they think are the two reasons for this response?

### Warmth is life or death for *Colias* butterflies

1. What is the habitat of the *Colias* butterflies?
2. Define thermoregulation:
3. How do *Colias* butterflies thermoregulate?

### Pulling data out of specimen drawers

1. Where were the *Colias* butterflies found in this study?

### Taking trait measurements

1. Summarize how MacLean measured the three morphological traits.
2. In the next and final set of questions, you will be analyzing variables about the *Colias* butterflies. Give a definition of each of the following measurements and how they were collected using information given in the reading.
   1. Seasonal temperature:
   2. Pupal temperature:
   3. Wing melanism:
   4. Forewing length:
   5. Setae length:

## Questions

In this exercise, you will be able to create graphical representations using multiple variables. You will be attempting to evaluate a graph and then will be able to make changes according to your hypotheses. Try to answer some of the following questions by changing the data you plot. For each question, consider whether you see the same patterns at all three sites, or if different populations respond differently. Recall how each population occupies a different elevational range. How might this affect their responses? Click the hint buttons for some help.

1. Change the y-axis to represent the seasonal temperature. Using the graph have spring and summer temperatures increased over the years? If so, at which sites?
2. Change the y-axis to measure the forewing length. Has forewing length decreased over the years? If so, at which sites?
3. Have butterfly wings lightened over the years?
4. Using the visualizations, have forewings or setae length changed over the years?
5. How do spring and summer temperatures affect the day of year when butterflies reach adulthood? Explain why this may occur.
6. Plot spring and summer temperatures against pupal temperatures and explain the relationship.
7. Now instead of spring and summer temperatures in Q5, how do pupal temperatures affect the day of year when butterflies reach adulthood? Is this what you would expect from Q5 and Q6? What explains this complexity?

## **Analysis**

It is difficult to predict how individual populations will behave in the face of change. It is important that data are collected to allow for testing of both simple and complex hypotheses to help forecast responses to climate change.

Using the visualization in the section “Exploring butterfly morphological data”, create and test your own hypothesis. Don’t make changes until you have a prediction!

Fill out the following sections:

* What is your prediction/hypothesis?
* What is your chosen x-axis variable?
* What is your chosen y-axis variable?

Run your test using the visualization.

* What did you observe?
* Was your hypothesis correct? Explain.