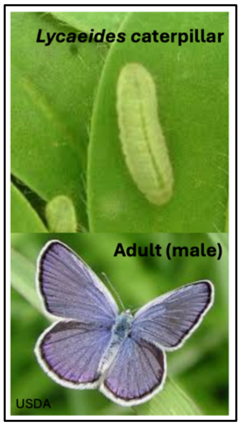
Name: Section: Group:

Hone: Getting to know the organisms for our class project
HONORS Week 7 of BIOL 1625, spring 2025

Objectives: In this lab, in collaboration with your group members, you will be able to: 1) learn background information and make observations, and 2) test the correlation between two variables.



Background information: Butterflies of the family Lycaenidae are commonly referred to as blues, hairstreaks, and coppers. The majority of species in the scientific family Lycaenidae have associations with ants that can be facultative or obligate and range from mutualism to parasitism. Lycaenid caterpillars (i.e., larvae in the Lycaenidae family) employ complex chemical and acoustic signals to manipulate ants (Pierce et al., 2002). In our project, we will focus on lycaenid caterpillars in the genus *Lycaeides* because your instructor and her collaborator (Zach Gompert) have been studying them for 20 years, and they are found in Logan, the Rocky Mountains, and beyond. A *Lycaeides* caterpillar and adult are pictured on the left.

Lycaeides caterpillars eat a variety of legumes native to the United States, like lupine, but are also able to eat relatively recently introduced alfalfa; however, alfalfa is not as nutritious for them. We know that ants are very important to the survival of *Lycaeides* caterpillars when they develop on alfalfa in the wild (Forister et al., 2011; Forister et al., 2020). But we do not know how abiotic and biotic factors affect the interaction between *Lycaeides* caterpillars and ants in general. We will work together to fill a gap in this knowledge. This week, we will make observations and gain necessary background information for creative and critical thinking next week. By the end of class, you will also have a better idea of the larger purpose of working with these organisms.

Pre-lab prep part 1: As you read this lab manual, look up any words you do not know and add their definitions to the margins of the lab manual.

Pre-lab prep part 2: Watch the short pre-lab video. In this video you will see a mutualistic relationship between the imperial blue butterfly caterpillars (*Jalmenus evagoras*) from Australia and a certain species of ant. As you watch, write down all the different caterpillar-ant interaction behaviors you see. These are all behaviors you could see in class this week.

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Pre-lab prep part 3: Next, read the relatively old but simple and interesting *Science* article found at the end of this lab manual (Pierce & Mead, 1981). As you read the article, record notes/answers to the questions below. The article is about caterpillars closely related to the ones we will use in our project. Another difference between our project and theirs is ours will be conducted in a lab, and they conducted a field experiment.

Notes about "Parasitoids as selective agents in the symbiosis between Lycaenid butterfly larvae and ants":

- Name of the butterfly family in which many members secrete substances that attract ants: ____________
- Genus and species name of the lycaenid butterfly larvae in this study: _______________________
- Ant behaviors mentioned in the article:

-
    -
    -
    -
- Caterpillar glands used to interact with ants:
    -
    -
    -
- Known parasitoids of *G. lygdamus*
    -
    -
- The authors' hypothesis: ____.

- Draw a picture of their experimental design here (both treatments):

- Was there a significant difference in the proportion of untended larvae attacked by parasitoids vs. tended larvae? __________________

- According to the article, is it possible that *G. lygdamus* is exploiting the ants that tend them? _________

Lab safety: Ants can bite and spray secretions onto intruders. We will transfer the ants gently with soft grip forceps. You are welcome to wear disposable gloves, a lab coat, and goggles to best protect yourself, but they are not required.

In-class instructions: The class activities described below are designed to help you get to know the caterpillars in the genus *Lycaeides* and ants in the family Formicidae. You will analyze the class's data in Activity #4. Each group member will fill out this manual to best get to know the study organisms. I will grade all lab manuals in a group collectively. **The answers need to be correct across all lab manuals within a group to receive full credit for Wk7-inclass** (20 pts total).

Supplies and equipment for Week 7:

- About 24 petri dishes each containing a **Northern Blue Butterfly (*Lycaeides idas*) caterpillar** on a sprig of alfalfa. These caterpillars come from eggs that were collected by Lauren and Zach Gompert from females from populations in or near Yellowstone and Grand Teton national parks in July 2024: Periodic Springs (PSP), Ski Lake (SKI), and Rendezvous Mountain (RNV). The eggs hibernated in a dark, cold growth chamber until 1/30/25 when they were placed in a light, warm growth chamber to break hibernation (a.k.a. diapause). They have been fed ~1 fresh leaf of alfalfa per day since, by the caterpillar-rearing team (Lauren, Brenna, Connor, Marissa & Bhagya). The information on their labels includes the population they came from, the year they were collected, the ID of the mom, and the ID of the offspring. For example, RNV-24-02-05 comes from population "RNV", collected in summer '24, from mom "02", and is mom's 5^{th} offspring.
- **Soft grip forceps, paint brushes, water, kimwipes** for gently transferring caterpillars and ants
- **Stereoscopes** for drawing characteristics, measuring caterpillar length, and observing behaviors
- **Rulers** for measuring caterpillar length

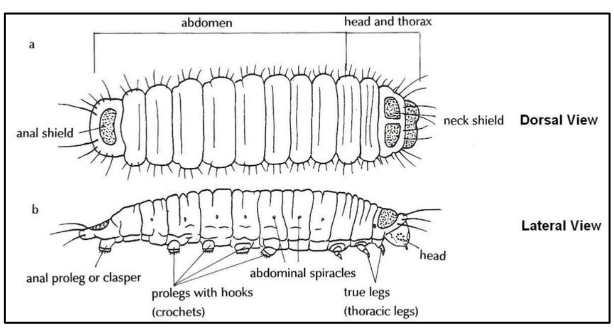
- **Balances** and **petri dishes** for weighing the caterpillars. These petri dishes have **insect-a-slip** on them to keep the insects from escaping.
- **Lab tape** and **sharpie** for labeling new petri dishes
- Ants collected from the Biology greenhouse: **Velvety Tree Ant (*Liometopum* sp.)**
- **Tally counters** for recording behavioral data
- Shared class google **data sheet**
- **Posit Cloud** HONORS Week 7 project
- The **original grant proposal** that helps fund our classroom research

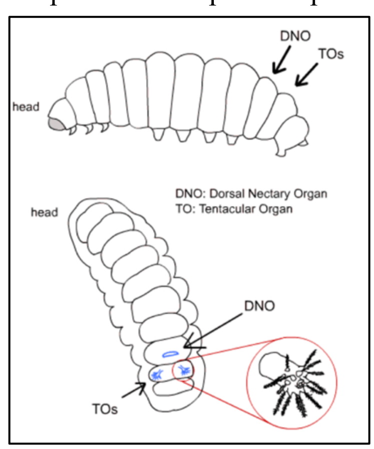
Table 1. My Week 7 data. Length and mass of each caterpillar (2 pts total) as well as recorded behaviors with an ant (1 pt total).

Caterpillar_ID	Length_mm	Mass_mg	Number of ant antennae touches in 5 min	Number of times ants bit caterpillar in 5 min	Number of times ant drank from nectary gland in 5 min	Number of times caterpillar tentacles extruded in 5 min

Activity #1: Measuring caterpillar length & Locating caterpillar glands used to interact with ants

- Each student will receive 1-2 caterpillars, each in their own petri dish labeled with their own unique ID.
- Obtain a Leica stereoscope for yourself. We will borrow from LSB 114 as needed.
- Open the petri dish lid to better find and see the caterpillar. Minimize disturbing the caterpillar.
- Is the caterpillar flat and straight? If not, wait to measure it until it is uncurled.
- Place a clear, flat ruler under the petri dish. Get a measurement of the length of each caterpillar you are assigned, from the top of the head to end of the anus, in millimeters (mm). Record your measurements in **Table 1**.
- Next, continue to keep the caterpillar in its dish. Only if needed, use the side of the paintbrush bristles or soft grip forceps to carefully orient the caterpillar so that its dorsal (back) is showing.
- Locate the head vs. the anal end. Count the 12 segments. Locate the abdominal spiracles on the sides of segments 4-10.
- Locate the DNO (i.e., Newcomer's gland), the TOs (i.e., tentacles). Caterpillars develop these special-ized organs for ant-tending by their third instar of development.





(Images from: https://www.researchgate.net/figure/8-Structure-of-larva-or-caterpillar-of-a-butterfly-of-the-family-Lycaenidae_fig7_290193055; http://eebweb.arizona.edu/animal_behavior/lycaenids/lycaen9.htm)

- Below, draw the dorsal side of your caterpillars. **Include and label**:

- The head (1 pt)
- The segments (and the correct number; 1 pt)
- The spiracles (and the correct placement; 1 pt)
- The two tentacles (and the correct placement; 1 pt)
- The Newcomer's gland (and the correct placement; 1 pt)

Caterpillar ID: ______________ **Caterpillar ID: _____________**

Magnification: ___________ Magnification: ___________

Activity #2. Weighing the caterpillars

To weigh individual caterpillars, a 0.01 mg analytical balance, at a minimum, is necessary.

With the help of an assistant, you will use a 0.01 mg analytical balance in the following way:

- If the balance is off, press the On button.
- Close the balance door. Press -O/T- to zero the balance. The more movement there is around the balance, the longer it will take to stabilize. The balance will beep (and the circle on the left side of the display will disappear) when it has stabilized.

- Open the balance door, place an empty petri dish on the balance, close the door and press -O/T- to tare the balance. Once it has stabilized, the balance will read 0.00 mg and "Net" appears in the display.
- Open the balance door, remove the petri dish, add one caterpillar to the petri dish, add it to the balance, and close the balance door. Once the balance has stabilized, record the mass in **Table 1**.
- Label the bottom of the new petri dish with the caterpillar ID with lab tape and sharpie.
- Repeat these steps for each caterpillar assigned to you (if applicable).
- Add a lid to the caterpillar's new petri dish and continue on to Activity #3.

Activity #3. Observing the diversity of ant behaviors, including nectar-drinking

Above: ant drinking from the nectary organ of a lycaenid larva.

Now you will explore the types of interactions seen between our caterpillars and ants. Possibilities include:

- Ant touching caterpillar with antennae
- Ant biting caterpillar (or carrying caterpillar in mandibles)
- Nectar gland droplet produced with ant drinking
- Tentacles being extruded, causing ant to lunge/run
- Other

Steps of Activity #3:

- Wear PPE, if you prefer.
- With soft grip forceps, gently add one ant to the top of the caterpillar. This way, the ant is aware of the caterpillar in the dish from the start. Place the lid on the dish.
- Place the lidded petri dish under the stereoscope and get the caterpillar in focus.
- Start a timer for 5 minutes and record your personal observations in **Table 1**.
- Repeat for each new petri dish/caterpillar (if applicable).

Activity #4. What is the correlation between caterpillar length and mass?

Bigger caterpillars might produce more nectar and thereby might attract more ant attention. We might want to account for this potential relationship in our upcoming class experiment. But which measure of caterpillar size should we use, length or mass? If these two variables are highly positively correlated, we would only need to measure one in our upcoming experiment.

Enter your data from Table 1 into the shared, editable class google spreadsheet (Canvas Week 7 page). Once the class datasheet is complete, you will download it as a csv file and upload it to this week's Posit Cloud "HONORS" project. Then, you'll work through the provided R script.

In the **scatterplot** you made in Posit Cloud, there is one point per individual caterpillar. Below, draw the scatterplot you made in Posit Cloud (1 pt), including clearly written axis labels (1 pt), and write a figure caption (1 pt) that describes the pattern or lack thereof (i.e., do the points trend from low to high on the y-axis as you look along x-axis?).

The **correlation coefficient**, a value between -1 and +1, tells you how strongly two variables are related to each other. The closer the coefficient is to 1, the more positively correlated the variables are, and the closer the coefficient is to -1, the more negatively correlated the variables are. And the closer the coefficient is to 0, the weaker the correlation is. As in Week 3, the **95% confidence interval (CI)** around the correlation coefficient helps describe the uncertainty in the correlation coefficient. If the interval includes 0, you will not know whether the correlation is positive or negative. List the correct data summaries below:

<u>Correlation coefficient</u> (1 pt):

<u>95% CI around the correlation coefficient</u> (1 pt):

Last, the **p-value of the correlation test** helps you test the following statistical hypotheses:

- Null hypothesis (H_0): the correlation coefficient is 0.
    - If your p-value is 0.05 or less, you reject the null hypothesis and support the alternative hypothesis.
    - If your p-value is above 0.05, you fail to reject the null hypothesis.
- Alternative hypothesis (H_A): the correlation coefficient is different from 0.

List the correct <u>p-value</u> (1 pt), and state correct <u>interpretation</u> here, regarding whether you reject or fail to reject the null hypothesis (1 pt):

Remember, if these two variables are highly positively correlated, you would only need to choose one for your project as a measure of size. Last, based directly on the results, would it be sound to use only one of these two measures of body size in our upcoming class experiment? Why or why not? (1 pt)

Activity #5. Learning about the project context. Next week you will receive guidance for writing a research proposal to fill a gap in our knowledge about how abiotic or biotic factors affect caterpillar-ant interactions. Your project fits into a larger research project that Zach Gompert has been leading for five years. Visit the link on the Week 7 page in Canvas to access the relevant parts of Zach's original National Science Foundation (NSF)-funded research proposal. Not only will this give you an example of what a funded research proposal looks like, it will provide some context for the experiment you will design next week. Zach will visit us at the start of class next week to help answer your questions about the bigger picture of our class project. The group Harmonizer should read the proposal out loud, and the Checker and Recorder should facilitate notetaking below. Then, as a group, come up with four questions you have about any of the information in the NSF proposal that Lauren and Zach can answer at the beginning of class next week (4 pts).

- The overall hypothesis of the NSF project is:

- The three objectives of the NSF project are (put a star next to the one we are involved in):

- Background about *Lycaeides* and their genomes:

- Background about CHCs. What does CHC stand for? Are CHCs at least somewhat heritable? What abiotic factors affect the CHCs? What do *Lycaeides* caterpillars use them for? What are the CHC-related tradeoffs?

- After reading the provided parts of Zach's NSF proposal, my group's four questions for Lauren and Zach are:

<u>Clean-up</u>:

- Return the ants from where you got them, using the soft grip forceps.
- Give Lauren your caterpillars and petri dishes.
- **If you borrowed a class laptop**: delete your personal files and empty the trash. Clean the laptop lightly with isopropyl alcohol and a provided cloth as instructed at the laptop cleaning station. Sign out on the cabinet sheet. Thank you!

<u>Useful references</u>:

Forister, M. L., Gompert, Z., Nice, C. C., Forister, G. W., & Fordyce, J. A. (2011). Ant association facilitates the evolution of diet breadth in a lycaenid butterfly. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1711), 1539-1547.

Forister, M. L., Philbin, C. S., Marion, Z. H., Buerkle, C. A., Dodson, C. D., Fordyce, J. A., Forister, G.W., Lebeis, S.L., Lucas, L.K., Nice, C.C, & Gompert, Z. (2020). Predicting patch occupancy reveals the complexity of host range expansion. *Science Advances*, *6*(48), eabc6852.

Pierce, N. E., & Mead, P. S. (1981). Parasitoids as selective agents in the symbiosis between Lycaenid butterfly larvae and ants. *Science*, 211(4487), 1185-1187.

Pierce, N. E., Braby, M. F., Heath, A., Lohman, D. J., Mathew, J., Rand, D. B., & Travassos, M. A. (2002). The ecology and evolution of ant association in the Lycaenidae (Lepidoptera). *Annual Review of Entomology*, *47*(1), 733-771.

Name: Group: Lab section:

Hone: Group research proposal draft
HONORS Week 8 of BIOL 1625, spring 2025

Objectives: By the end of this lab, you will be able to: 1) use your understanding of the entire process of hypothesis-driven science to design your own experiment, and 2) write a research proposal collaboratively.

Pre-lab prep: For the last three years, the BIOL 1625 Honors lab conducted an experiment they designed that filled a gap in our knowledge about abiotic or biotic factors that affect *Lycaeides* caterpillar – ant interactions. Now, watch the Week 8 pre-lab videos for quick overviews of the last three years' Honors Lab experiments. Take notes below. This year, we will come up with a different class experiment. You can either build on what we learned in previous years or go in a different direction. Read through the lab manual, then write down an idea you have for this year's experiment.

- Spring 2022 Honors lab research question:
  - Hypothesis and prediction:
  - Experimental design:
  - Results & interpretation:
  - Future directions:
- Spring 2023 Honors lab research question:
  - Hypothesis and prediction:
  - Experimental design:
  - Results & interpretation:
  - Future directions:

- Spring 2024 Honors lab research question:
    - Hypothesis and prediction:
    - Experimental design:
    - Results & interpretation:
    - Future directions:

- After watching the pre-lab videos and reading this lab manual, here is my project idea: (Say whether it builds off a previous year's experiment or goes in a new direction.)

In-class instructions: You are now a collaborator on an active National Science Foundation-(NSF) funded project, led by Zach Gompert and Lauren Lucas. Your job today is to propose a project that will contribute to what is known about abiotic or biotic factors that affect the interaction between *Lycaeides* caterpillars and ants. Work through the rest of this lab manual with your group members to brainstorm a project idea fully. Then, check in with Lauren before you start writing the draft of your group research proposal. Doing so will help prevent you spending a lot of time writing a proposal that will not be feasible. Last, use the online template to write a research proposal draft.

Lab safety: No PPE is required for this lab.

In-class methods **Step 1**. As a group, read aloud the following project guidelines. Add a check mark to each bullet point as you go. Doing so will help guarantee you do not spend a lot of time brainstorming a project that will not be feasible.

Project guidelines

- **Project timeline**:
    - Week 7: You became familiar with aspects of the caterpillars and ants.
    - Week 8: Your group designs an interesting and fact-based experiment for the entire class to carry out during the weeks after spring break. Completely explain and justify it in a written research proposal, as researchers do when they apply for project funding.
    - Week 9: You will incorporate feedback from Lauren, your peers, and a Science Writing Center tutor (optional) into the final draft of your research proposal and submit it to Lauren for funding consideration and grading. The self and peer evaluation re: collaboration skills will be available after class (due before class in Week 11).
    - Week 10: Spring break. Lauren will choose one project for the class will carry out and gather the

supplies needed to set up the experiment. The group research proposal that best meets the project requirements, is scientifically sound, and is interesting to a wide audience will be chosen.

- Week 11: You will start becoming an expert on the chosen class project and set up the experiment.
- Weeks 12: We will collect data for all replicates.
- Weeks 13: We will analyze and interpret the data.
- Week 14: We have an optional class session – come if you want one-on-one guidance on your research presentation. Individually, you will complete and submit a research presentation video (details to come) by 5pm Friday.
- Weeks 15-17: You will receive a grade and feedback on your individual research presentation.

- **Research question requirements**:
  - Your research question needs to follow the form: "How does X affect Y?"
  - You must decide what the independent (X) and dependent (Y) variables are. You have the following variables to choose from.

    - Independent variables:
      - *Lycaeides* caterpillar population (you will need to decide which *Lycaeides* we should use, regardless of whether you choose this as the independent variable). In summer 2024, eggs were collected from:

Pop. name	Location	Elevation (ft)	Ave. recorded rel. humidity 7/24 (%)	Estimate of long-term climate (- hotter/drier; + colder wetter)	Approx. median number of ants across sweep net samples in 2018 (+3rd quartile)
Hayden Valley (**HNV**)	44.678625, -110.50144	8050	28	1.4	0 (+2)
Blacktail Butte (**BTB**)	43.6382, -110.682	7300	30.7	-0.7	0 (+1)
Rendez-vous Moun-tain (**RNV**)	43.596383, -110.88473	9500	32.5	5.8	1 (+8)
Ski Lake (**SKI**)	43.509416, -110.9227	7900	29.95	1.9	0 (+2)
Periodic Springs (**PSP**)	42.7482611, -110.83985	7100	22.5	-3.4	1 (+2)

      - Caterpillar species
        - *Lycaeides* (see populations available above)
        - Painted lady caterpillars, *Vanessa cardui*, not known to interact with ants, ordered from Carolina Biological Supply Company
      - Caterpillar rearing condition:
        - Temperature. They can survive and develop between 24°C and 34°C. The default setting is 27°C.
        - Humidity. They can survive between ambient and 80% humidity.
        - Lighting conditions. The default is 14 hours light and 10 hours dark per day because this is about what they experience in the wild when eggs hatch.

- Duration of caterpillar-ant relationship
  - Ant introduced to caterpillar right before data collection.
  - Caterpillar reared with an ant for some time prior to data collection.
- Caterpillar nutrition (based on Forister et al., 2009)
  - Alfalfa with no flowers (less nutritious) vs. alfalfa with flowers (more nutritious). The default is no flowers because flowers can be in limited supply in the greenhouse this time of year (but we do have some).
- Ant species
  - A honeydew gatherer, the velvety tree ant (*Liometopum* sp.) collected from USU Biology greenhouse. We can get high numbers of these.
  - A honeydew gatherer, the pavement ant (*Tetramorium immigrans*) from our lab colonies. We have about 30 of these.
  - *Pogonomyrmex*, seed harvester <u>not</u> known to tend *Lycaeides* caterpillars, ordered from Carolina Biological Supply Company
- Ant nutrition
  - Diet, like temporarily depriving of food and water. Food we have available: crystalized honey, fish flakes, cat food, dried insects, fresh sowbugs
- *Lycaeides* caterpillar predator
  - Green lacewing larvae, ordered from Sounds Horticulture, Inc.
- Number of ants present
  - 1 ant per caterpillar
  - More than 1 ant per caterpillar

▪ <u>Dependent variables</u>. In Week 7, we talked about most of the following behaviors.
- Ant biting/carrying the caterpillar
- Ant touching caterpillar with antennae only to sense CHCs
- Ant receiving a reward (honeydew) from the caterpillar
- Ant running due to caterpillar tentacle alarm
- Caterpillar survival in the presence of a predator for some amount of time (fitness)

- **Classroom research laboratory constraints**:
  - Your class will be provided about 100 Lycaeides caterpillars total so that the sample size is high, to be split among the experimental treatments.
  - Data analysis. You'll propose to calculate summary statistics, visualize your results, and perform a statistical test. We will probably need to perform a linear regression, so that we can account for caterpillar size, as larger caterpillars might be more attractive to ants.
  - Lauren, Marissa, Brenna, Connor, Natalie, and Zach will care for the animals outside of class time.

<u>**Step 2**</u>**.** As a group, brainstorm a project.

1) Share with your group the project idea you wrote down pre-lab.

2) Compare group members' ideas. Are there overlapping ideas or an idea that arises as the most interesting?

3) Now, design a research question. Remember to follow the research question requirements (above).

Introduction/Research question:

- *2022 example: How does supplemental ant food affect caterpillar-ant interactions?*

4) What is already known about the topic of your research question? Conduct a scientific literature search (peer-reviewed articles) using Google Scholar or Scopus. Include your findings (with citations) below. Note: Visit **Appendix A** at the end of the lab manual for a reminder from BIOL 1615 about scientific articles and citing sources in APA format, as well as helpful links on the **Canvas Week 8 page**.

Introduction/Background information:

- *2022 example: Social insect foragers, like ants, must take into account the varying nutritional needs of different colony members and the inventory of food currently available to the colony when searching for food (called nutrient compensatory foraging).* Lee Cassill, D., & Tschinkel, W. R. (1999). Regulation of diet in the fire ant, *Solenopsis invicta*. *Journal of Insect Behavior*, *12*(3), 307-328.

5) Now, use inductive reasoning to design your hypothesis. This means you will use your observations from last week's lab and from the literature search you just conducted to write your hypothesis. Remember, a scientific hypothesis describes a biological mechanism; it explains why you would see a certain outcome of an experiment.

Introduction/Overall hypothesis:

- *2022 example: We hypothesize that nutrient compensatory foraging affects how ants interact with caterpillars.*

6) Now you will use deductive reasoning to design your experiment. This means you'll start with your hypothesis and logically design one experiment of many possible experiments that will test your hypothesis. Start by drawing a visual of your experimental design that includes the independent variable(s), the dependent variable(s), and replication (at least 30 replicates per treatment):

Methods/List of supplies and equipment needed:

Methods/Steps the class would follow to perform the experiment:

- *2022 example: Ants will be fed 10% sugar water until 24 hours before the experiment. A day before the experiment, half of the ants will be switched to a water-only diet (i.e., nutrient deprived treatment), while the other half will remain on a 10% sugar water diet (e.g., supplemental sugar treatment). We will conduct the experiment March 22, 2022, between 10:30am-1:15pm in BIOL 1625-001. First, ants will be chilled in a refrigerator to aid in the transfer to petri dishes. Each ant will be placed in a petri dish that contains a small handful of soil that covers half of the petri dish. Ants will be given at least five minutes to acclimate to the petri dish. Next, a caterpillar will be added to the dish, to the non-soil side. Each data collector will use a stereoscope to focus on the Newcomer's organ on the caterpillar. For 10 minutes, the data collector will record the number of times the ant: 1) accepts honeydew from the caterpillar, and 2) touches the caterpillar with antennae.*

Methods/Data analysis that fits our data (data summaries, graph, and statistical test(s)):

- *2022 example: We will visualize the raw data by making a scatterplot of caterpillar weight (x) versus ant interactions (y) with different colors for each treatment. We will use a linear regression to test whether the ant diet treatments affect ant interactions with* Lycaeides *caterpillars, while accounting for caterpillar weight. We will report the caterpillar weight, treatment, and interaction effects, their standard errors (SEs), and the p-values.*

7) Now write down your prediction that is in alignment with the overall hypothesis and experimental design, as well as the possible outcomes (null and alternative statistical hypotheses).

Potential outcomes/Prediction:

- *2022 example: We predict that ants with supplemental food (sugar) will be less interested in caterpillars (touch and accept honeydew less) when compared to ants temporarily deprived of all nutrients but water.*

Potential outcomes/Statistical hypotheses:

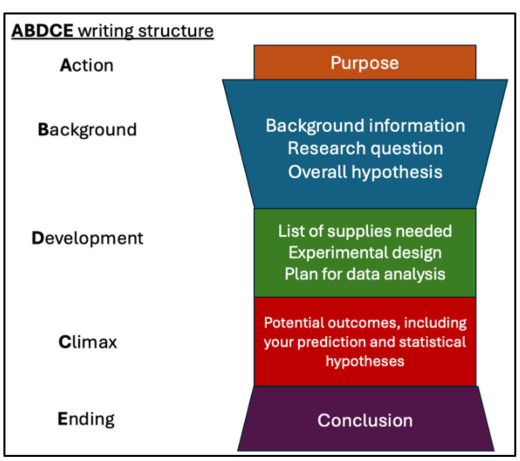
Step 3. Ask Lauren to come to your table to talk through what you wrote down during Step 2. She might have suggestions to consider before moving forward. Write the considerations below.

Step 4. Writing a research proposal will expose you to the process scientists go through to obtain funding for their own research projects. Picture your audience is biologists that have been charged to read your proposal to decide whether a federal agency, the National Science Foundation (NSF), should use government money to fund your project. The purpose of the NSF is to promote the progress of science, particularly basic or fundamental science. The proposal you will write with your group will cover all the information necessary to plan a successful experiment. But you must also write concisely, as your audience is busy and not very patient. Shoot for 3-4 pages total.

Read aloud the following group research proposal sections you need to write. Add a check mark to each bullet point as you go -- doing so will help guarantee you will write a good first draft and receive meaningful feedback before submitting your final draft next week.

Group research proposal document guidelines (adapted from Schimel, 2012)

Your proposal needs to include the following components, using **the ABDCE writing structure** (see visual on the left) you learned about in Week 2:



○ **Introduction**. Write two paragraphs. First, you need to grab your reader's attention quickly. What gap in the scientific community's knowledge are you proposing to fill, and why is that important? Follow this attention-grabber with what is currently known from the scientific literature that is relevant to the knowledge gap, in order to justify the project's purpose. You must cite sources for all facts you mention, within the text as well as in a References section, in APA format. Second, clearly lay out the research question and the overall hypothesis your project would test.

○ **Methods: Experimental design**. First, you must list all supplies and equipment you would need to perform your experiment. Then, using complete sentences, you'll explain how your methods will answer your research question. Provide a detailed description of how you would set up and conduct your experiment such that biologists not taking this course could use it to replicate your experiment. You must define your independent and dependent variables and explain how you will keep other variables that are not important to your study consistent across treatments. Mention your sample size (number of replicates per treatment) in your description. If there are challenges (limitations), explain how you will get around them.

- **Methods: Data analysis**. This section must describe how you will analyze the collected data. It must include details about the appropriate data summaries, graph, and statistical test(s) for your particular data.
- **Potential outcomes**. In this section, include your prediction that is in alignment with your overall hypothesis and experimental design. Explain the statistical hypotheses, null and alternative, and what it would mean for your overall hypothesis if you fail to reject or reject the null hypothesis.
- **Conclusion**. Without repeating your "attention grabber" at the beginning of your proposal, write a brief resolution paragraph that encapsulates the proposal, reiterates the big issue and explains how the components work together to address it – make the final pitch for why the proposal should be funded. At this point in your proposal, your reader will be thinking about how the pieces fit together, whether the experiment will work, whether this will really solve the problem. This is your last opportunity to convince your reviewer.
- **References**. In alphabetical order, cite all sources you referenced in the proposal using APA citation guidelines.

<u>**Wk8-inclass assignment**</u>: Group research proposal draft (13 pts). You are now ready to use all your brainstorming notes and the research proposal template (via link on the Canvas Week 8 page) to complete a draft of all sections of the research proposal. The quality will not be assessed until you submit the final group research proposal next week; at that point its quality will be assessed with the final grading rubric (see **Appendix B**). However, the more effort you put in now, the more meaningful feedback you will receive about its quality from your instructor. Your instructor will provide timely feedback to help you make improvements on your research proposal. Save your document as a pdf and upload it to Canvas. You will receive credit for completing a draft of each of:

- Introduction: purpose ("attention grabber") (1 pt)
- Introduction: relevant background information (1 pt)
- Introduction: research question (1 pt)
- Introduction: overall hypothesis (1 pt)
- Methods: experimental design: list of supplies and equipment (1 pt)
- Methods: experimental design: complete sentences about variables, replication, steps (1 pt)
- Methods: data analysis: data summaries, graph, statistical test (1 pt)
- Potential outcomes: prediction (1 pt)
- Potential outcomes: statistical hypotheses and how they relate to the overall hypothesis (1 pt)
- Brief conclusion / resolution (1 pt)
- Cited sources within the text in APA format (1 pt)
- Cited sources in the Reference section in APA format (1 pt)
- Headers for each major section of the proposal (1 pt)

Appendix A: Scientific articles and citing sources in APA format

Scientific articles are complete descriptions of new scientific research written by experts in the field. Scientific articles are the final step in the scientific process as they disseminate results. Dissemination is important because it keeps scientists in check and allows for a replication of scientific work. These articles are published in journals and are the way scholars communicate their findings with each other and the public. You probably have textbooks and a whole list of assigned readings for your other courses. Which might make you ask yourself, "ugh, why do I have to read complicated scientific articles on top of this?" Scientific articles are: current, contain data, peer-reviewed, and relevant.

In Biology, a great option for finding scientific articles is **Google Scholar**. It's easy to search, just like Google. Here are some helpful tips:

- Condense your topic into a concise group of keywords. Throughout the search process, try switching up your keywords to see how it affects your search results.
- You can sort search results by relevance or the date of publication.
- If you find a useful article for your needs, click on the "Related articles" link for more useful articles. You can also try the "Cited by" option.
- You'll have access to the full text if you see the "Full-Text @ Utah State" link to the right of the search result.
- For the useful articles you find, click on the " link for a draft of the APA citation for your report. You will likely need to edit parts of it to make it fully in APA format.

But **how should you read a scientific article** once you have one that sounds relevant to your project? This can be tricky because scientific articles are often long and full of complicated procedures and terminology. There is a way to read scientific articles efficiently. You might also find it helpful to have a dictionary at the ready to look up terminology you are unfamiliar with.

- Step 1. Read the discussion section. This section summarizes important results and gives conclusions based on the data. It also mentions how the results fit into the context of the field.
- Step 2. Read the introduction section. This will briefly explain the background of the research and why it was conducted.
- Step 3. Read the results section. Pay close attention to the tables and graphs. These are quick summaries of the findings of the study (the data the authors collected and the sample sizes they used).
- Step 4. Read the methods section. This tells you how the authors approached answering their research questions.

Cite the sources you use information from to write your introduction. Whenever you summarize or paraphrase information that is not your own, you need to give credit to the source of the information, both in the text and in a References section towards the end of your report. In Biology, sources are cited in a certain way to aid the reader. We will use APA citation guidelines. Below you will see an example of citing a peer-reviewed article with three or more authors. See the link in Canvas for APA citation guidelines for all types of sources.

Example in-text citation in APA format, first at the end of a sentence, and next at the beginning:
….(Nguyen et al., 2019).
Nguyen et al. (2019) suggest...

Example reference section citation in APA format:
Nguyen, T., Carnevale, J. J., Scholer, A. A., Miele, D. B., & Fujita, K. (2019). Metamotivational knowledge of the role of high-level and low-level construal in goal-relevant task performance. *Journal of Personality and Social Psychology*, *117*(5), 879-899. http://dx.doi.org/10.1037/pspa0000166

Appendix B: Grading rubric for the final group research proposal.

Your final group research proposal will be graded using a published, validated grading rubric for scientific lab reports (Timmerman et al., 2011). You should see this grading rubric again in other science courses at USU. We do not expect you to write a research proposal at the "expert" level in this introductory biology course, but your future instructors will. Thus, you will receive full credit on this assignment by meeting at least the "intermediate" level criteria for all sections of the research proposal. See below for the rubric.

Criteria	Not addressed	Novice	Intermediate	Expert
Introduction: Accuracy and relevance				
Content knowledge is accurate, relevant and provides appropriate background for reader including defining critical terms.	• Background information is missing or contains major inaccuracies. • Background information is accurate, but irrelevant or too disjointed to make relevance clear • Primary literature references are absent or irrelevant.	• Background omits information or contains inaccuracies which detract from the major point of the paper. • Background information is overly narrow or overly general (only partially relevant). • Primary literature references, if present, are inadequately explained.	• Background information may contain minor omissions or inaccuracies that do not detract from the major point of the paper. • Background information has the appropriate level of specificity to provide relevant context. • Primary literature reference(s) are relevant and adequately explained.	• Background information is completely accurate • Background information has the appropriate level of specificity to provide concise and useful context to aid the reader's understanding. • Primary literature references are relevant, adequately explained, and indicate a reasonable literature search.
Introduction: Context				
Demonstrates a clear understanding of the big picture; What is the research question and why is this question important/ interesting in the field of biology? What is the hypothesis to be tested?	• The importance of the question is not addressed. • How the question relates within the broader context is not addressed. • A hypothesis is lacking or not testable. No prediction is given.	• The writer provides a generic or vague rationale for the importance of the research question. • The writer provides vague or generic references to the broader context. • The hypothesis is testable, but not relevant or clear. Prediction is vague or inaccurate.	• The writer provides one explanation of why others would find the topic interesting. • The writer provides some relevant context for the research question. • The hypothesis is clear, testable and related to the research question. A logical prediction stemming from the hypothesis is articulated.	• The writer provides a clear sense of why this knowledge may be of interest to a broad audience • The writer describes the current gaps in our understanding of this field and explains how this research will help fill those gaps • The hypothesis is clear, creative or novel, testable and related to the research question. The prediction from the hypothesis is articulated; it is logical and easy to follow.

Criteria	Not addressed	Novice	Intermediate	Expert
Methods: Experimental design				
Methods are likely to produce salient and fruitful results (tests the hypothesis posed.) Variables and appropriate replication are present and explained. Methods are:	• inappropriate • poorly explained / indecipherable	• somewhat appropriate • somewhat clearly explained	• mostly appropriate • mostly clearly	• appropriate • clearly explained
Methods: Data analysis				
Data and analyses are comprehensive and relevant.	• No plans for data collection are included or the proposed data are too incomplete or haphazard to provide a reasonable basis for testing the hypothesis.	• Some necessary data are missing or inaccurate. • Analyses are not described or only include descriptive summary statistics.	• Proposed data are relevant, accurate and complete with any gaps being minor. • Data analysis includes summaries, graphing, and inferential statistics. • Data analysis tests the proposed hypothesis.	• Proposed data are relevant, accurate and comprehensive. • Data analysis is comprehensive. • Data analysis includes summaries, graphing, and inferential statistics. • Analyses are particularly appropriate for testing the proposed hypothesis.

Criteria	Not addressed	Novice	Intermediate	Expert
Potential outcomes				
A logical chain of reasoning from hypothesis to data to interpretation is clearly and persuasively explained.	• Connections between hypothesis, data and interpretation are non-existent, limited, vague or otherwise insufficient to allow reasonable evaluation of their merit.	• Connections between hypothesis, data and interpretations are present but weak.	• A reasonable and clear chain of logic from hypothesis to data to interpretations is made.	• Connections between hypothesis, data, and interpretations are comprehensive and persuasive.
Conclusion				
A brief resolution paragraph that encapsulates the proposal and convinces the reader the proposal should be funded.	• The purpose from the very beginning of the proposal is "plagiarized".	• The ending leaves the reader questioning whether the experiment will work or fill the gap.	• The reader is left with some doubt as to whether the experiment will work or fill the gap.	• The ending of the proposal ties all the parts of the proposal together and is persuasive
References				
Relevant and reasonably complete discussion of how this research project relates to others' work in the field (scientific context provided). <u>Primary literature is defined as:</u> - peer reviewed - reports original data - authors are the people who collected the data.	• Facts do not come with citations. • Primary literature reference(s) are not included.	• Primary literature reference(s) are limited • Citations are at least partially correctly formatted. Note that proper format includes a one-to-one correspondence between in-text and end of text references (no references at end that are not in text and vice versa) as well as APA citation style.	• Primary literature reference(s) are more extensive. • Primary literature reference(s) are used primarily to provide background information and context. • Citations are mostly correctly formatted.	• Primary literature references indicate an extensive literature search was performed. • Primary literature references frame the question in the introduction by indicating the gaps in current knowledge of the field. • Primary literature references are properly and accurately cited.

Criteria	Not addressed	Novice	Intermediate	Expert
Writing quality				
Grammar, word usage and organization facilitate the reader's understanding of the paper.	• Grammar and spelling errors detract from the meaning of the paper. • Word usage is frequently confused or incorrect. • Subheadings are not used or poorly used. • Information is presented in a haphazard way.	• Grammar and spelling mistakes do not hinder the meaning of the paper. • General word usage is appropriate, although use of technical language may have occasional mistakes. • Subheadings are used and aid the reader somewhat. • There is some evidence of an organizational strategy though it may have gaps or repetitions.	• Grammar and spelling have few mistakes. • Word usage is accurate and aids the reader's understanding. • Distinct sections of the paper are delineated by informative subheadings. • A clear organizational strategy is present with a logical progression of ideas.	• Correct grammar and spelling. • Word usage facilitates reader's understanding. • Informative subheadings significantly aid reader's understanding. • A clear organizational strategy is present with a logical progression of ideas. • There is evidence of an active planning for presenting information; this paper is easier to read than most.

Name: Group: Lab section:

Hone: review panel

Honors Week 9 of BIOL 1625, spring 2025

Image of National Science Foundation (NSF) proposal review panel (from nsf.gov).

Instructions & objectives: You will be able to: 1) provide feedback to a peer group, 2) incorporate feedback, and 3) finalize your group research proposal.

Pre-lab prep: Last semester in BIOL 1615, we thought about peer review in the context of publishing a scientific article. This semester, we are going to conduct a peer review in the context of a NSF review panel. Scientists need money to make discoveries and answer research questions. When a scientist starts a job at a university, they are usually given some research money to help them get started on their research, but then they're expected to apply for and be rewarded money from a government or private funding source. Thus, academic scientists spend a lot of their time writing research proposals to apply for grant money. Most proposals that are written and submitted do not end up getting funded. Now watch the short pre-lab video via the Canvas Week 9 page and take notes below:

Additional background information and food for thought: In 1950, President Harry Truman created the National Science Foundation (NSF), charging it with developing a national policy for the promotion of basic research. For the next five and a half decades, the federal funding tap flowed with gradually increasing velocity, with a few marked leaps that coincided with perceived threats to the national security or economic angst. In 1957, for example, the year before the USSR launched Sputnik, the NSF budget was $40 million. In 1959, it was $134 million, and by 1968, Cold War concerns had shot it up to nearly $500 million. Other bursts attended the gas crisis of the 1970s, President Ronald Reagan's "Star Wars" Strategic Defense Initiative in 1983, a continuing concern about the health of baby boomers in the 1990s, and the 9/11 terrorist attack on the World Trade Center in 2001 (Jahnke, 2015).

Who are the favorite children of federal funders? From 1970 to 2012, spending in constant dollars on the social sciences remained essentially flat (and relatively minuscule), while money for the environmental sciences, other life sciences, and physical sciences increased slightly. Since 1990 math and computer science's budgets have more than doubled, and engineering's almost doubled. But the big winner has been the National Institutes of Health (NIH) whose biomedical science funding leaped from less than $10 billion in 1990 to about $30 billion in 2008, before dipping nearly $5 billion by 2014 (Jahnke, 2015).

Some legislators wonder why the government should pay for so much university research, and why it cannot be funded by industry. Industry is focused on applied research that will result in the development of products with immediate commercial application. But fundamental or basic research is needed in order to create the knowledge base that leads to more applied research. For example, in the area of medicine, specific treatments for many diseases cannot be developed until we know much more about the basic cellular and molecular changes involved in the development of the disease. Social science research has also played an extremely important role in addressing national security challenges. In a similar vein, scholarship in the humanities is critical to creating a broadly educated workforce and our ability to engage with other areas of the world. Another argument: the internet itself, without which there would be no Google, was developed with funds from the Department of Defense's DARPA (Defense Advanced Research Projects Agency) and the NSF, and it was based on research conducted at MIT, UCLA, and other academic laboratories (Jahnke, 2015).

Regardless of the difficulty of receiving federal funding for research today, all scientists go through a process to apply for money to fund their research projects. Government agencies like the NSF award grants on a competitive basis. In selecting proposals to be financially supported, NSF is assisted by reviewers who are scientists in related disciplines. These reviewers are drawn primarily from two- and four-year colleges and universities. A proportion of proposals submitted to NSF are considered by panels of peer reviewers. The purpose of the review is to provide NSF with a written critique and an individual rating from each reviewer as well as a summary analysis by the panel. Each panelist writes their own review for all proposals assigned to the panel. Reviewers are asked to provide a detailed evaluation of both the merits and the shortcomings of each proposal and to provide a rating:

<u>Key to rating (NSF, 2018)</u>:
Poor: Proposal has serious deficiencies
Fair: Proposal lacking in one or more critical aspects; key issues need to be addressed
Good: A quality proposal, worthy of support
Very good: High quality proposal; should be supported if possible
Excellent: Outstanding proposal in all respects; deserves highest priority of support

The panel then convenes as a group to discuss the proposals. This gives each reviewer the benefit of an informed discussion upon which to base a decision. Following these discussions, panelists complete their individual review, and one panel member writes a summary of the discussion for each proposal. Reviews are used by NSF Program Directors to inform funding decisions. At the end of the review process, the principal investigator (proposal writer) is sent the written verbatim reviews with the reviewers' names and affiliations omitted. Reviews are forwarded whether the proposal is funded or not. All reviews are confidential. NSF releases abstracts and other information about funded proposals only (NSF, 2018).

Today, you will write comments about a peer group's research proposal to help them maximize success on the group research proposal assignment. It is important to give firm but friendly feedback and deliver it in an effective way. Here are four pieces of advice for doing so (Padula, 2015):

1) Try to avoid being tired when conducting your peer review.
2) List the positives and the negatives and keep sarcastic comments to yourself.
3) Give concrete examples and advice. No one likes to be told "this is unclear" or "this is great" without getting the context they need to understand why.
4) Don't be afraid to seek support. If you're not sure if the project is pitched in the best manner, don't hesitate to read outside sources or recommend the peer seeks guidance from the GTA.

<u>Methods</u>: We will conduct a mock NSF review panel in class. There is only enough funding to support one project per class. You will follow the steps below to help your GTA think about which group's proposal should be funded. Your GTA will consider your reviews and several other factors and make a final decision during Week 8.

Name: Group: Lab section:

Step 1) First, your group will be given about 20 minutes to incorporate comments from your GTA (and Science Writing Center tutor(s), if applicable) into your group research proposal draft.

Step 2) Before class, your GTA manually assigned your group's facilitator a peer group's proposal for your group to review. It is the facilitator who will upload your group's updated proposal draft as a pdf. Facilitator, now upload the pdf to the Canvas assignment "**Wk9-inclass**". Facilitator, then click on the link re: your assigned peer and refresh the page until you receive the other group's proposal to read. After waiting a few minutes, you can let your GTA know if you haven't received it and they will help you. Facilitator: next, download the received pdf and share it with your group members so that each group member can read the pdf on their own computer.

Step 3) Each group member will then read the other group's proposal. Do not edit or comment on the electronic copy; instead, on paper (below), chose the appropriate score for each rubric category and make notes while doing so. These notes will help you and your group members craft your consensus written feedback to your peer group.

Important notes:

- Your scores will not affect the group's grade in this course; instead, your feedback will help the group make their final edits.
- You will not be penalized for not being in the "expert" category on the final draft of your research proposal.
- Reference the project/proposal guidelines in the Week 6 lab manual, the proposal template, and the Purdue OWL: APA website as needed.

Personal review for the other group's research proposal

Reviewer's Name & Group #: ____________________ Reviewing for Group #: ___________

1. Introduction – Accuracy and relevance: Is the background information relevant to understanding the research question? Are all facts supported by citations?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
Introduction: Accuracy and relevance				
Content knowledge is accurate, relevant and provides appropriate background for reader including defining critical terms.	• Background information is missing or contains major inaccuracies. • Background information is accurate, but irrelevant or too disjointed to make relevance clear • Primary literature references are absent or irrelevant.	• Background omits information or contains inaccuracies which detract from the major point of the paper. • Background information is overly narrow or overly general (only partially relevant). • Primary literature references, if present, are inadequately explained.	• Background information may contain minor omissions or inaccuracies that do not detract from the major point of the paper. • Background information has the appropriate level of specificity to provide relevant context. • Primary literature reference(s) are relevant and adequately explained.	• Background information is completely accurate • Background information has the appropriate level of specificity to provide concise and useful context to aid the reader's understanding. • Primary literature references are relevant, adequately explained, and indicate a reasonable literature search.

Strength:

Weakness:

Name: Group: Lab section:

2. Introduction -- Context: Will the project fill a gap in our knowledge? Is the project worthwhile? Are the hypothesis and prediction distinguished properly?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
Introduction: Context				
Demonstrates a clear understanding of the big picture; What is the research question and why is this question important/ interesting in the field of biology? What is the hypothesis to be tested?	• The importance of the question is not addressed. • How the question relates within the broader context is not addressed. • A hypothesis is lacking or not testable. No prediction is given.	• The writer provides a generic or vague rationale for the importance of the research question. • The writer provides vague or generic references to the broader context. • The hypothesis is testable, but not relevant or clear. Prediction is vague or inaccurate.	• The writer provides one explanation of why others would find the topic interesting. • The writer provides some relevant context for the research question. • The hypothesis is clear, testable and related to the research question. A logical prediction stemming from the hypothesis is articulated.	• The writer provides a clear sense of why this knowledge may be of interest to a broad audience • The writer describes the current gaps in our understanding of this field and explains how this research will help fill those gaps • The hypothesis is clear, creative or novel, testable and related to the research question. The prediction from the hypothesis is articulated; it is logical and easy to follow.

Strength:

Weakness:

3. Methods: Experimental design: Is the plan for carrying out the proposed experiment well-reasoned, well-organized, detailed enough, and based on a sound rationale? Are independent and dependent variables correctly defined? Is the sample size (replication) at least 24 per treatment? Are all supplies listed, enough supplies for the whole class to carry about the experiment?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
Methods: Experimental design				
Methods are likely to produce salient and fruitful results (tests the hypothesis posed.) Variables and appropriate replication are present and explained. Methods are:	• inappropriate • poorly explained / indecipherable	• somewhat appropriate • somewhat clearly explained	• mostly appropriate • mostly clearly	• appropriate • clearly explained

Strength:

Weakness:

Name: Group: Lab section:

4. Methods: Data analysis: Do they explain how they will summarize, graph, and use a statistical test on the data? Does the statistical test proposed match the type of data they are collecting?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
Methods: Data analysis				
Data and analyses are comprehensive and relevant.	• No plans for data collection are included or the proposed data are too incomplete or haphazard to provide a reasonable basis for testing the hypothesis.	• Some necessary data are missing or inaccurate. • Analyses are not described or only include descriptive summary statistics.	• Proposed data are relevant, accurate and complete with any gaps being minor. • Data analysis includes summaries, graphing, and inferential statistics. • Data analysis tests the proposed hypothesis.	• Proposed data are relevant, accurate and comprehensive. • Data analysis is comprehensive. • Data analysis includes summaries, graphing, and inferential statistics. • Analyses are particularly appropriate for testing the proposed hypothesis.

Strength:

Weakness:

5. Potential outcomes: Is the prediction as well as null and alternative hypotheses described? Are the statistical outcomes tied back to the overall hypothesis?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
Potential outcomes				
A logical chain of reasoning from hypothesis to data to interpretation is clearly and persuasively explained.	• Connections between hypothesis, data and interpretation are non-existent, limited, vague or otherwise insufficient to allow reasonable evaluation of their merit.	• Connections between hypothesis, data and interpretations are present but weak.	• A reasonable and clear chain of logic from hypothesis to data to interpretations is made.	• Connections between hypothesis, data, and interpretations are comprehensive and persuasive.

Strength:

Weakness:

6. Brief conclusion / resolution: Do they justify the purpose of the project in different words than in the beginning of the proposal? Do they tie the whole proposal together? Are they convincing or persuasive?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
Conclusion				
A brief resolution paragraph that encapsulates the proposal and convinces the reader the proposal should be funded.	• The purpose from the very beginning of the proposal is "plagiarized".	• The ending leaves the reader questioning whether the experiment will work or fill the gap.	• The reader is left with some doubt as to whether the experiment will work or fill the gap.	• The ending of the proposal ties all the parts of the proposal together and is persuasive

Strength:

Weakness:

7. References: Is APA format used correctly in the text and in the references section? Are the Reference section citations listed alphabetically? Is there a one-to-one match between in-text and Reference citations?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
References				
Relevant and reasonably complete discussion of how this research project relates to others' work in the field (scientific context provided). Primary literature is defined as: - peer reviewed - reports original data - authors are the people who collected the data.	• Facts do not come with citations. • Primary literature reference(s) are not included.	• Primary literature reference(s) are limited • Citations are at least partially correctly formatted. Note that proper format includes a one-to-one correspondence between in-text and end of text references (no references at end that are not in text and vice versa) as well as APA citation style.	• Primary literature reference(s) are more extensive. • Primary literature reference(s) are used primarily to provide background information and context. • Citations are mostly correctly formatted.	• Primary literature references indicate an extensive literature search was performed. • Primary literature references frame the question in the introduction by indicating the gaps in current knowledge of the field. • Primary literature references are properly and accurately cited

Strength:

Weakness:

8. Writing quality: Is the proposal clearly written and easy to follow?

Circle one:

Criteria	Not addressed	Novice	Intermediate	Expert
Writing quality				
Grammar, word usage and organization facilitate the reader's understanding of the paper.	• Grammar and spelling errors detract from the meaning of the paper. • Word usage is frequently confused or incorrect. • Subheadings are not used or poorly used. • Information is presented in a haphazard way.	• Grammar and spelling mistakes do not hinder the meaning of the paper. • General word usage is appropriate, although use of technical language may have occasional mistakes. • Subheadings are used and aid the reader somewhat. • There is some evidence of an organizational strategy though it may have gaps or repetitions.	• Grammar and spelling have few mistakes. • Word usage is accurate and aids the reader's understanding. • Distinct sections of the paper are delineated by informative subheadings. • A clear organizational strategy is present with a logical progression of ideas.	• Correct grammar and spelling. • Word usage facilitates reader's understanding. • Informative subheadings significantly aid reader's understanding. • A clear organizational strategy is present with a logical progression of ideas. There is evidence of an active planning for presenting information; this paper is easier to read than most.

Strength:

Weakness:

Final decision for funding, circle one:

Poor **Fair** **Good** **Very Good** **Excellent**

Key to rating (NSF, 2018):

Poor: Proposal has serious deficiencies

Fair: Proposal lacking in one or more critical aspects; key issues need to be addressed

Good: A quality proposal, worthy of support

Very good: High quality proposal; should be supported if possible
Excellent: Outstanding proposal in all respects; deserves highest priority of support

Step 4) When all group members are done reading and making notes, come to a group consensus about the top three strengths of the proposal with justifications (3 pts), top three weaknesses of the proposal, written as constructive criticism (3 pts), and a final decision for funding (1 pt). It is this page of the facilitator's lab manual that ultimately will be graded by your GTA for your group's "**Wk9-inclass**" score. **To receive full credit, all feedback you leave must be effective (refer back to pg 3) and in complete sentences**.

Our group's consensus review

Our section # and group #: ____________________

for the proposal written by group #: ______________________

Strengths (3 pts):

1)

2)

3)

Constructive criticism (3 pts):

1)

2)

3)

Final decision for funding, circle one (1 pt):

Poor **Fair** **Good** **Very Good** **Excellent**

Key to rating (NSF, 2018):
Poor: Proposal has serious deficiencies
Fair: Proposal lacking in one or more critical aspects; key issues need to be addressed
Good: A quality proposal, worthy of support
Very good: High quality proposal; should be supported if possible
Excellent: Outstanding proposal in all respects; deserves highest priority of support

In-class assignment (7 pts). Next, you will summarize your positive feedback on the board to advocate for the project and to help the class see all the possible projects. Then, facilitator, give your assigned peer group this page of the lab manual so that they can incorporate your comments into the final draft of your proposal. Last, make sure this page gets turned into your GTA before you leave, for grading.

References:
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NSF (2018). Proposal & award policies & procedures guide. Retrieved from https://www.nsf.gov/pubs/policydocs/pappg18_1/pappg_3.jsp

Name: Lab section:

Hone: Start class experiment

HONORS Week 11 of BIOL 1625, spring 2025

Objectives: You will be able to: 1) articulate the background information for your class project, and 2) start setting up a well-designed experiment.

Pre-lab prep part 1: Recall your scientific communications training in Week 2. Look back at the study guide you filled out for that week. What do your notes say about the difference in the way to communicate in a scientific article versus a research presentation?

Reminder: As with scientific papers, the purpose of oral presentations at a scientific conference is to share your research with other scientists. The presenter must convince the audience that the research presented is important, valid, and relevant to them. Thus, oral presentations—like papers—must emphasize both the motivation for the work and the outcome of it, and they must present enough evidence to establish the validity of this outcome. In general, papers differ from presentations in that they can be forwarded in unpredictable ways and may be read many years from now, so they should be lasting and largely self-contained. Papers can be read in any order and at the reader's own pace, whereas presentations impose both the sequence and the rhythm of content on their audience. Presentations can therefore be harder to follow and should be more selective in what they contain. Presentations should focus on getting a main message across in theorem-proof fashion (Scitable, 2004). It may not be necessary to present everything that was done in the order it was done. Instead, the main message should be presented early and then show the evidence to support it.

Pre-lab prep part 2: Learn about your last major assignment in this course, the individual research presentation, worth 20% of your grade:

Overview and purpose of the individual research presentation assignment: Towards the beginning of class during **Week 11**, you will get to know the research proposal for the class project. As a class, you will get the project started. By the end of class, you will make a draft of the first few slides of your individual research presentation (title and introduction/background information). In **Week 12**, your class will carry out the rest of the experiment and collect data. You will make a draft of the next part of your presentation (methods). In **Week 13**, we will analyze the data, interpret the results, and finish the draft of your presentation (data analysis, results, conclusion, acknowledgements). During **Week 14**, by 5pm Friday, you will record and submit your individual research presentation to Canvas. We will have an optional class session that week for one-on-one guidance. Your presentation will be akin to a "lightening talk" oral presentation that researchers give at conferences. Some research conference presentations are about 15 minutes long, and some presentations are a quick 5 minutes long; the quick ones are called "lightening talks". You will be giving a recorded video lightening talk.

Individual research presentation requirements

A general rule of thumb is to have one presentation slide per minute of your talk, but you can have more as long as extra slides are presented quickly but clearly, like the title slide and the acknowledgements slide. Devote at least one slide to each of the following:

1. Title of project, your name, lab section number.
2. Introduction: The most relevant background information. Cite sources properly in APA format here.
3. Introduction: research question, overall hypothesis, and purpose.
4. Experimental design methods (treatments, dependent variable(s), replication, prediction).
5. Data analysis methods and results (data summaries, graph, statistical hypotheses & test).
6. Conclusion (interpretation based directly on the results – a connection to overall hypothesis; limitations; what you would do next).
7. Acknowledgements: thank others who contributed to the project and funding sources.

- Avoid busy slides (Fleming, 2018). Prevent wandering minds during your presentation by providing images and the most relevant words on your slides that paint a picture of your project. Interact with your slides by pointing out the parts of your images or graphs that you want your audience to notice.

- Incorporate the feedback you receive along the way from your instructor on the draft of your presentation slides into your final presentation. Your instructor will be watching for this. You will make a draft of slides 1-3 in Week 11. You will make a draft of slide 4 in Week 12. You will make a draft of slides 5-7 in Week 13.

- Speak with your audience in mind. Specifically for the Honors Lab, your audience is the National Science Foundation (NSF) and next year's Honors Lab. Assume NSF does not know about our study system. One or two of the clearest presentations will be included in Zach's annual report to NSF and shared in Canvas with next year's Honors students.

- Your presentation should be 5 minutes long, give or take 30 seconds. Your score will be docked for going over or under this limit. Plan on spending about a minute per slide (i.e., a minute for each of slides 2-6 above). Practicing your presentation several times before your presentation will help ensure your presentation is within the time limit. Memorize key sentences within your speaker notes instead of memorizing all of your notes or reading from them word for word.

- You will use the KalturaCapture software to record both your face, your voice, and your presentation slides using your laptop or a USU computer. You will need to use a USU computer if the software doesn't work on your laptop. Your score will be docked if your audience can't hear your voice, see your face, or see your slides.
    - Here's a tutorial for how to install KalturaCapture: https://www.usu.edu/academic-support/technology/kaltura-capture-installation
    - Here's a tutorial for how to record your face and computer screen: https://www.usu.edu/academic-support/technology/kaltura/record-a-presentation-from-your-computer

- You need to submit your individual research presentation video by the end of your scheduled class session during Week 15. Come to (optional) class for last-minute guidance from your GTA that week. You will embed your video in the assignment textbox.
    - Here's a tutorial for how to embed your video recording in the Canvas assignment textbox: https://www.usu.edu/academic-support/technology/kaltura-submit-video-for-assignment
    - Practice this process of recording with the fake assignment: "KalturaCapture video practice"

Pre-lab prep part 3: Now watch the pre-lab video. This is an example presentation by Lauren, followed by a brief explanation of how the presentation meets your assignment requirements. It is about *Lycaeides* but not caterpillar-ant interactions. Apply what you see in this presentation to planning for your own presentation – this is an important leap to take as a student in this course. The data analysis you see in this example presentation will remind you of the analyses we did in Week 3. After watching the pre-lab video, jot down ideas about what would make your research presentation clear, easy to follow, and receive at least an "intermediate" score on the final grading rubric (**Appendix A**):

-
-
-
-
-

<u>In-class instructions</u>: Step 1. Your instructor will share with you the research proposal for your class's experiment. As you go over this together, make notes about the following aspects of the project. You will use your notes and the proposal when working on the Wk11-inclass assignment.

<u>My class's experiment</u>

<u>Research question</u>:

<u>Background information necessary to set-up the hypothesis</u>:

<u>Overall hypothesis</u>:

<u>Purpose of the project</u>:

<u>Draw a diagram of the experimental design that mentions the independent variables (treatments), dependent variable(s), and replication</u>:

<u>Prediction that is in alignment with the overall hypothesis and experimental design</u>:

Your instructor will share with you the spreadsheet your class will use for data collection. <u>Draw what the data sheet should look like to store the data to be collected</u>:

Your instructor will share with you a folder for storing photos of the class's experiment for use in your research presentation. What images do you think will be useful for helping your audience understand the main message of your project?

Step 2. Your class will set-up an aspect of the experiment. Your instructor will explain the plan. Everyone will be assigned a role for participation. My role in setting up the project is:

Step 3. Wk11-inclass assignment. This is an individual assignment, not a group assignment. Use google slides to make a draft of the following slides for your individual research presentation. Include speaker notes to remind yourself of important details to say aloud during the presentation.

The quality will not be assessed until you submit your final individual research presentation in Week 14, and its quality will be assessed with the final grading rubric (see **Appendix A**). However, the more effort you put in now, the more meaningful feedback you will receive about its quality from your instructor. Your instructor will provide timely feedback. Save your google slides as a **.pptx file** (not a .pdf file) and upload it to Canvas.

You will receive credit for completing a draft of each of the following (6 pts total):

1) Title slide: Title of project & your name and lab section number (1 pt) with speaker notes (1 pt)

2) First introduction slide: Relevant background information with sources cited in APA format (1 pt) with speaker notes (1 pt)

3) Second introduction slide: Research question, overall hypothesis, and purpose (1 pt) with speaker notes (1 pt)

References:

Fleming, F. (2018). How to give a great scientific talk. Retrieved from https://www.nature.com/articles/d41586-018-07780-5

Scitable. (2014). Oral presentation structure. Retrieved from https://www.nature.com/scitable/topicpage/oral-presentation-structure-13900387.

Appendix A. BIOL 1625 Individual Research Presentation final grading rubric.

Criteria	Ratings			
1a.2: Introduction - Accuracy and relevance Content knowledge is accurate, relevant and provides appropriate background for reader including defining critical terms.	**Expert: Background information is completely accurate. Background information has the appropriate level of specificity to provide concise and useful context to aid the reader's understanding. Primary literature references are relevant, adequately explained, and indicate a reasonable literature search.**	**Intermediate: Background information may contain minor omissions or inaccuracies that do not detract from the major point of the paper. Background information has the appropriate level of specificity to provide relevant context. Primary literature references are relevant and adequately explained.**	**Novice: Background omits information or contains inaccuracies which detract from the major point of the paper. Background information is overly narrow or overly general (only partially relevant). Primary literature references, if present, are inadequately explained.**	**Not addressed: Background information is missing or contains major inaccuracies. Background information is accurate, but irrelevant or too disjointed to make relevance clear. Primary literature references are absent or irrelevant.**
1a.1: Introduction - Context Demonstrates a clear understanding of the big picture: What is the research question and why is this question important/ interesting in the field of biology?	**Expert: The writer provides a clear sense of why this knowledge may be of interest to a broad audience. The writer describes the current gaps in our understanding of this field and explains how this research will help fill those gaps.**	**Intermediate: The writer provides one explanation of why others would find the topic interesting. The writer provides some relevant context for the research question.**	**Novice: The writer provides a generic or vague rationale for the importance of the research question. The writer provides vague or generic references to the broader context.**	**Not addressed: The importance of the question is not addressed. How the question relates within the broader context is not addressed.**
1a.3: Methods Methods are likely to produce salient and fruitful results	**Expert: Methods are appropriate and clearly explained.**	**Intermediate: Methods are mostly appropriate and mostly clearly explained.**	**Novice: Methods are somewhat appropriate and somewhat clearly explained.**	**Not addressed: Methods are inappropriate or poorly explained/indecipherable.**
1a.4: Results Data are summarized in a logical format. Tables and figures are appropriate.	**Expert: Presentation of data contains no mistakes. Uses a format which highlights relationships between the data points or other relevant aspects of the data. The presentation may be elegant, novel, or otherwise allow unusual insight into data. Visual representations have informative, concise and complete captions.**	**Intermediate: Presentation of data contains only minor mistakes that do not interfere with the reader's understanding and the meaning is clear. Figure/table formats are appropriate for data type and include captions that are at least somewhat useful.**	**Novice: Presentation of data contains some errors in or omissions of labels, scales, units etc., but the reader is able to derive some relevant meaning from the presented data. The visual representation is technically correct but inappropriate format prevents the reader from deriving meaning or using it. Captions are missing or inadequate.**	**Not addressed: Labels or units are missing, which prevent the reader from being able to derive any useful information from the presented data. Presentation of data is in an inappropriate format. Captions are confusing or indecipherable.**
1a.5: Discussion - Conclusion Conclusion is clearly and logically drawn from data provided. Conflicting data, if present, are adequately addressed.	**Shows Mastery: Conclusions are completely justified by data. Conclusions address and logically refute or explain conflicting data. Synthesis of data in conclusion may generate new insights.**	**Intermediate: Conclusions are clearly and logically drawn from and bounded by the data; presented with no gaps in logic. Conclusions attempt to discuss or explain conflicting or missing data.**	**Novice: Conclusions have some direct basis in the data, but may contain some gaps in logic or data or are overly broad. Conflicting or missing data are poorly addressed**	**Not addressed: Conclusions have little or no basis in data provided. Connections between data and conclusion are non- existent, limited, vague or otherwise insufficient to allow reasonable evaluation of their merit. Conflicting data are not addressed.**
1a.6: Discussion - Limitations Limitations of the data and/or project design and corresponding implications discussed.	**Expert: Limitations are presented as factors modifying the author's conclusions. Conclusions take these limitations into account.**	**Intermediate: Limitations are relevant, but not addressed in a comprehensive way. Conclusions fail to address or overstep the bounds indicated by the limitations.**	**Novice: Limitations are discussed in a trivial way (e.g. "human error" is the major limitation invoked).**	**Limitations are not addressed.**

1a.7: Discussion - Implications Implications of research: Paper gives a clear indication of the implications and direction of the research in the future.	**Expert: Future directions and implications of this research are salient, plausible and insightful. Future directions and implications of this research suggest work that would fill knowledge gaps and move the field forward.**	**Intermediate: Future directions and implications of this research are useful, but indicate incomplete knowledge of the field (suggest research that has already been done or is improbable with current methodologies). Future directions and implications of this research suggest a fruitful line of research, but lack detail to indicate motivations for or implications of the future research.**	**Novice: Future directions and implications of this research are vague, implausible (not possible with current technologies or methodologies), trivial or off topic**	**Future directions and implications of this research are not addressed.**
1a.8: References Relevant and reasonably complete discussion of how this research project relates to others' work in the field (scientific context provided). Primary literature is defined as: peer reviewed reports original data authors are the people who collected the data	**Expert: Primary literature references indicate an extensive literature search was performed. Primary literature references frame the question in the introduction by indicating the gaps in current knowledge of the field. Primary literature references are properly and accurately cited.**	**Intermediate: Primary literature references are more extensive. Literature cited is predominantly (> 90%) primary literatures. Primary literature references are used primarily to provide background information and context for conclusions.**	**Novice: Primary literature references are limited. References to the textbook, lab manual, or websites may occur. Citations are at least partially correctly formatted. Note that proper format includes a one-to-one correspondence between in-text and end of text references (no references at end that are not in text and vice versa) as well as APA citation style.**	**Not addressed: Primary literature references are not included.**
3b.2: Clear choice of language	**Expert: Language is used at the appropriate level of understanding for the audience; it is unambiguous and concise; terminology is clearly defined.**	**Intermediate: Language chosen is often used at the appropriate level of understanding, but there are occasional uses of language that is too technical, and some terminology is not defined.**	**Novice: Language chosen vacillates between everyday language and technical language causing some confusion; terminology is not defined.**	**Not addressed: Language chosen is inappropriate for the audience; terminology is not defined; explanations are ambiguous and confusing.**
3b.3: Skill of Presentation Technical use of media, tactical use of media, use of mental images to support explanation	**Expert: Use of media clearly aids audience understanding of the explanation. Draws from a variety of media: whiteboard, PPT, humor, gestures, demonstrations. Presents clear, powerful images that are familiar to audience and stick in audience's minds so they can refer back to them.**	**Intermediate: Use of media provides some structure and assistance to the audience in aiding understanding but there are clear areas for improvement.**	**Novice: Media are used to a limited extent and/or are of limited utility to audience in comprehending the presentation.**	**Not addressed: No use of media OR use of media distracts from the presentation and confuses audience understanding.**

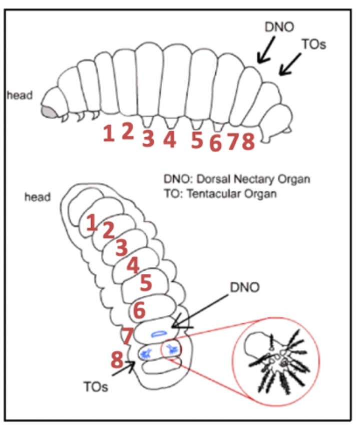
Name: Lab section:

Hone: class experiment data collection
HONORS Week 12 of BIOL 1625, spring 2025

Objectives: You will be able to: 1) ethically and consistently collect data for our class project, and 2) articulate the experimental design.

Pre-lab prep part 1: To prepare for class this week, think about the general question: what kind of data do I need to collect to answer a specific research question? This week's pre-lab quiz will have you think about a few scenarios to test your knowledge about the data that is appropriate for a particular research question.
Look back and reflect on the weeks of this semester during which we collected data to answer a specific question and write your notes below:

- In Week 3, we asked "How does initial habitat preference compare between sow bugs and millipedes?" We collected data on:
- In Week 4, we asked "How do drugs affect heart rate?" We collected data on:
- In Weeks 5-6, we asked "How is the rate of evolution of multicellularity affected by relying on de novo vs. standing variation?" We collected data on:
- In Week 7, we asked "What is the correlation between caterpillar length and mass?" We collected data on:



Pre-lab prep part 2: Before collecting data in class this week, we need to remind ourselves of some things we learned in Week 7, the week we got to know *Lycaeides idas* caterpillars and ants for the first time. Watch the pre-lab video for a quick reminder of what's included in the caterpillar IDs and what the caterpillars look like. Refer back to Week 7 for reminders about: 1) what the different ant behaviors look like (Week 7 pre-lab video), and 2) how to locate the important caterpillar organs for ant attendance. See the figure on the left for a quick reminder of the latter. I've labeled the non-head and non-thorax segments. DNO stands for Dorsal Nectary Organ, another name for the Newcomer's organ. TOs stands for Tentacular Organ, another name for the caterpillar's tentacles.

Pre-lab prep part 3: Our research question is "How is *Lycaeides* honeydew secretion and caterpillar survival affected by ant group size?" In class last week, we focused on the background information of the class research proposal. At the beginning of class this week, we will make sure we are all on the same page about the experimental design. Re-read the methods section of the class research proposal (see link on the Week 12 Canvas page). Draw a diagram of our experimental design here:

In-class data collection. We will discuss the steps of the experiment before we begin data collection to help ensure we all collect data ethically and consistently. While we have hypotheses and predictions for this project, we must collect the data without bias (including when individuals do not act as we expect).

1. Plan on collecting data for at least two caterpillars for each treatment (four caterpillars total). Work on one caterpillar at a time. In **Table 1** below, record the ID for a caterpillar you are responsible for. Also record the treatment to which the caterpillar ID was assigned, in **Table 1** below.

2. Get a stereoscope ready. Without touching the caterpillar, get the caterpillar in focus at a magnification that allows you to see the entire caterpillar and the Newcomer's organ and tentacles in good detail. This way your stereoscope is more ready for data collection. Ask for help with microscope focusing well before data collection, if needed.

3. Label the bottom of a new petri dish that's lined with fluon with the caterpillar ID, using labeling tape and a sharpie. Then, with the aid of an experienced caterpillar handler, record the mass (mg) of the caterpillar in **Table 1**. Your caterpillar should now be in the new dish.

4. Get ready to start a 2-minute timer. Visit one ant container and add the correct number of ants from the one container to the top of the caterpillar – doing so will help ensure the ant(s) knows the caterpillar is there. Let them acclimate for two minutes. During this time, get ready for data collection. Under the microscope, make sure the ants are moving properly and are not damaged. Then, get the caterpillar in focus at a magnification that allows you to see the entire caterpillar and the Newcomer's organ and tentacles in good detail.

5. After the 2 minutes, start a timer for 5 minutes. Look through the stereoscope continuously for 5 minutes. During the 5 minutes, record data in **Table 1**: the number of times the ant receives honeydew from the Newcomer's organ, and the number of times each tentacle protrudes.

6. After 5 minutes of data collection, add a predator to the dish, on the opposite side of the dish from the caterpillar. **Record the current time on the lab tape so that you have a record of this, since it will be 30 minutes from this time that you will record caterpillar survival.** Set a 1-minute timer for acclimation. While you wait, look at the predator under the microscope to make sure it is moving properly and is not damaged. Then, quickly get the caterpillar in focus.

7. Start a timer for 5 minutes. Look through the stereoscope continuously for 5 minutes. During the 5 minutes with the predator, record data in **Table 2**: the number of times the ant receives honeydew from the Newcomer's organ, the number of times each tentacle protrudes, and the number of times the predator bites the caterpillar. Set the dish aside for now.

8. When it has been 30 minutes from the time you recorded on the lab tape, record caterpillar survival (yes or no) by looking under the microscope for caterpillar movement. If the caterpillar is not moving, does it move when you gently prod it with the soft grip forceps? If so, it is not dead. Do you see a combination of puncture wounds from the predator and no caterpillar movement? If so, it is likely dead.

<u>Table 1</u>: Caterpillar-ant interactions for 5 minutes <u>with no predator</u>. Record data on the blank data sheet provided below. You will share your data with your instructor after data collection.

Caterpillar ID	**Treatment: 1 ant or 3 ants**	**Mass (mg)**	**Ant honeydew acceptances**	**Caterpillar tentacles firing**	**Notes**
Example: PSP-24-24-11	*3 ants*	*12.14*	*0*	*0*	*The ants did sense the caterpillar with antennae*

<u>Table 2</u>: Caterpillar-ant-<u>predator</u> interactions for 5 minutes and survival after 30 minutes. Record data on the blank data sheet provided below. You will share your data with your instructor after data collection.

Caterpillar ID	Ant honeydew acceptances	Caterpillar tentacles firing	Predator bites caterpillar	Caterpillar survival after 30 minutes (Y/N)	Notes
Example: PSP-24-24-11	*1*	*0*	*1*	*Y*	*The predator was a relatively small one*

9. We will do data entry towards the end of class. Before you leave, please give Lauren your paper lab manual – she'll save all lab manuals as back-up copies of the raw data.

In-class assignment (2 pts). This is an individual assignment, not a group assignment. Use google slides to make a draft of the following slide for your individual research presentation. Include speaker notes to remind yourself of important details to say aloud during the presentation.

4) Experimental design slide: treatments, dependent variable(s), replication, prediction (1 pt)
with speaker notes (1 pt)

The quality will not be assessed until you submit your final individual research presentation in Week 14, and its quality will be assessed with the final grading rubric (see **Appendix A in lab manual for Week 11**). However, the more effort you put in now, the more meaningful feedback you will receive about its quality from your instructor. Your instructor will provide timely feedback. Save your google slides as a **.pptx file** (not a .pdf file) and upload it to Canvas.

Hone: Class experiment data analysis
Honors Week 13 of BIOL 1625, spring 2025

Objectives: You will be able to: 1) analyze the data collected with the appropriate analysis, and 2) articulate the data analysis, results, and conclusions.

Pre-lab prep: This week's pre-lab quiz will have you think back on previous statistics we've performed this semester and have you think ahead to the data analysis we will perform this week. Reflect on the weeks of this semester during which we analyzed data, then prepare for this week's analysis by reading the rest of the lab manual. In summary:

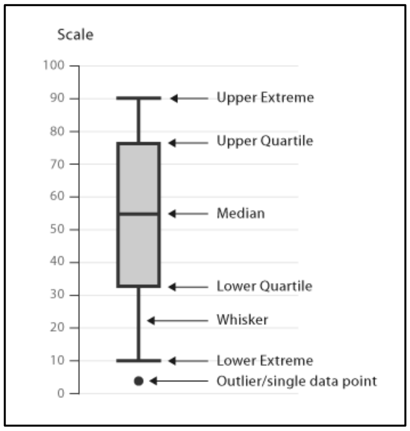
- In Week 3, we analyzed the proportion of sowbugs and millipedes that preferred the moist habitat vs. dry by calculating **point estimates** and **95% CI**s (confidence intervals) for each species' preference and making a **barplot** with these numbers. We performed a test called a **1-sample proportion test** to see if each preference was different from 0.5 and a **2-sample test for equality of proportions** to see if the two preferences were different from each other.
- In Week 4, we analyzed the number of *Daphnia* heartbeats in 15 seconds after exposure to caffeine or spring water by calculating **means** and **SE**s (standard errors) for each treatment and making a **barplot** with these numbers. We performed a **two sample t-test** (because we had different *Daphnia* in each treatment; if each *Daphnia* experienced both treatments, we would have used a **paired t-test**) to test for a significant difference between treatment means.
- In Week 6, we analyzed the relationship between the average number of yeast cells per cluster and both time (transfers) and treatments (different levels of initial genetic variation) by graphing a **scatterplot with best-fit lines** for each treatment to compare their rates of evolution. We performed a **linear regression** to determine whether the interaction between transfer and treatment had a signification effect (different from 0) on the average number of cells per yeast cluster, and we reported the interaction **coefficient, SE, and p-value**, as well as the **R^2 value** for the entire model.
- In Week 7, we analyzed the correlation between caterpillar length and mass by making a **scatterplot** with these two variables and calculating a **correlation coefficient** and **95% CI**. We performed a **correlation test** to see whether the correlation coefficient was different from 0.

Background information about this week's data analysis:

First, here is a reminder of **all of our variables**. A longer description is on the left, with how it shows up in our data sheet / R on the right:

Longer description	Shorter description
The population the caterpillar originally came from: PSP or RNV	"Pop"
The species of ant we ended up using (Lauren will explain this in class): velvety or pavement	"ant"
Our main independent variable: 1ant vs. 3ant	"Treatment"
Caterpillar mass measured in mg	"Mass_mg"
Without predator: the number of times the ant receives honeydew from the Newcomer's organ	"Honeydew.acceptances"
Without predator: the number of times each tentacle protrudes	"Tentacle.eversions"
With predator: the number of times the ant receives honeydew from the Newcomer's organ	"Predator_honeydew.acceptance"
With predator: the number of times each tentacle protrudes	"Predator.tentacle.eversions"
With predator: the number of times the predator bites the caterpillar	"Predator.bites"
Caterpillar survival after 30 minutes with the predator: 1 = yes; 0 = no	"Caterpillar.survival"

Visualizing the patterns in the data. We will make **scatterplots** when caterpillar mass is involved, because caterpillar mass is a continuous variable. We will make **barplots** when looking at the average proportion of caterpillar survival. We will also use a new kind of plot this week, the **boxplot**. A boxplot will help us visualize how much variation is between our treatments versus within the treatments. For each box of the boxplot, there are several components (see the figure on the left): 1) the middle of the box is the median, the middle value of the data set; 2) the bottom of the box is the lower quartile, the median of the lower half of the dataset; 3) the top of the box is the upper quartile, the median of the upper half of the dataset, 4) the minimum is the lower line drawn from the box, and it is the lowest data point in the data set excluding any outliers, and 5) the maximum is the upper line drawn from the box, and it is the highest point of the dataset excluding any outliers. The lines are also called “whiskers”. Outliers are plotted as individual points beyond the whiskers.



As you may remember from Week 6, a **linear model or regression** is an approach for modeling the relationship between a dependent variable and your independent variables. In our case, performing a linear regression will tell us how confident we can be in saying that there are significant differences in caterpillar-ant-predator behavior among caterpillar populations (RNV, PSP), by caterpillar mass (this is a continuous variable), and between our treatments (1 ant vs. 3 ants).

The regression line is the line that minimizes the sum of squared deviations of prediction. The general equation for a line is:

$$\mathbf{y = mx + b}$$

- y is the dependent variable
- m is the slope
- x is the independent variable
- b is the intercept with the y-axis

The **p-values** you will get are essentially a comparison between the **coefficient** (the constant that represents the rate of change of one variable as a function of changes in the other) and the **standard error** (a measure of the accuracy of predictions). If a coefficient plus or minus its standard error (SE) overlaps 0, it will not have a significant effect on the relationship between your variables. Note: If the coefficient plus or minus its SE excludes 0, the p-value may but will not necessarily be at or less than 0.05. If we get a p-value <u>above</u> 0.05, the correct interpretation is that we did not detect an effect; the incorrect interpretation is: there wasn't an effect. In other words, for a non-significant p-value, you are not confident there was an effect; you shouldn’t say that you are confident there wasn't an effect. If we get a p-value <u>at or below</u> 0.05, we can reject that the coefficient is 0 and say there was a significant effect.

You will also record an **R^2 value** for the linear regression, a key output of a regression analysis. It is the proportion of the variance in the dependent variable that is predictable from all the independent variables in your model, and thereby it describes your overall linear model. How well did the model explain our data? The higher the R^2 value, the more your independent variables are explaining the dependent variable. The p-value associated with the R^2 value helps you see whether the R^2 value is different from 0. In biological datasets, even a R^2 value of 0.10 (or 10%) is a modest (decent) amount of variance explained by the coefficients in a model.

<u>In-class data analysis methods</u>:
1. Lauren and Zach already assessed the dataset for outliers. Data for one replicate was removed due to the confirmed death of the ant early in the trial. We weren't able to clearly justify other outliers, so no other data points were removed.
2. Access this week's Posit Cloud project via the Week 13 Canvas page.
3. We will follow the R script together as a class. We will focus on the analyses that yield significant results, but you will have the means to look at the trends in the other variables afterwards.

First, let's see how caterpillar population affected caterpillar mass (mg). Here we treat caterpillar mass as a dependent variable. For this linear regression, the equation is:

$$\mathbf{y = B_1 + B_2x_{RNV}}$$

- This is encoded as: 0 = PSP and 1 = RNV
  - The expected value for PSP is B_1
- The expected value for RNV is $B_1 + B_2$

Describe the boxplot pattern:

Linear regression output & interpretation. Dependent variable: Caterpillar mass

Effect	Coefficient (Estimate)	Standard Error	P-value	Interpretation
Intercept (expected mean mass for PSP)				
Population (RNV relative to PSP)				

Multiple R-squared value and overall p-value for the linear model:

Second, we will look at the effect of population and mass on honeydew acceptance (with a predator). For this linear regression, the equation is:

$$\mathbf{y = B_1 + B_2x_{RNV} + B_3x_{mass} + B_4x_{RNV}x_{mass}}$$

- This is encoded as: 0 = PSP and 1 = RNV
  - The intercept for PSP is B_1
  - The intercept for RNV is $B_1 + B_2$
- For x_{mass}, caterpillar mass is a continuous variable
- The slope for PSP is B_3: the change in y for every 1 mg change in x_{mass}
  - The slope for RNV is $B_3 + B_4$

Describe the scatterplot pattern:

Linear regression output & interpretation. Dependent variable: Honeydew acceptance (with predator)

Effect	Coefficient (Estimate)	Standard Error	P-value	Interpretation
Intercept (expected honeydew acceptance for PSP when mass is 0 mg)				
Population (RNV relative to PSP)				
Caterpillar mass (mg)				
RNV's slope relative to PSP				

Multiple R-squared value and overall p-value for the linear model:

Third, we will look at the effect of population and mass on predator bites. For this linear regression, the equation is the same as above, but with a different independent (y) variable:

$$\mathbf{y = B_1 + B_2 x_{RNV} + B_3 x_{mass} + B_4 x_{RNV} x_{mass}}$$

- This is encoded as: 0 = PSP and 1 = RNV
  - The intercept for PSP is B_1
  - The intercept for RNV is $B_1 + B_2$
- For x_{mass}, caterpillar mass is a continuous variable
- The slope for PSP is B_3: the change in y for every 1 mg change in x_{mass}
  - The slope for RNV is $B_3 + B_4$

Describe the scatterplot pattern:

Linear regression output & interpretation. Dependent variable: Predator bites

Effect	Coefficient (Estimate)	Standard Error	P-value	Interpretation
Intercept (expected predator bites for PSP when mass is 0 mg)				
Population (RNV relative to PSP)				
Caterpillar mass (mg)				
RNV's slope relative to PSP				

Multiple R-squared value and overall p-value for the linear model:

Forth, we visualize caterpillar survival by population.

Describe the boxplot pattern:

Fifth, we will look at the effect of ant number on honeydew acceptance (without predator). For this linear regression, the equation is:

$$\mathbf{y = B_1 + B_2 x_{3ant}}$$

- The expected value for 1ant is B_1
- The expected value for 3ant is $B_1 + B_2$

Describe the boxplot pattern when ant species are pooled:

Describe the boxplot pattern when ant species are separated:

Means across treatments and ant species. Dependent variable: Honeydew acceptance (no predator).

Treatment	Pavement ant	Velvety tree ant
1 ant		
3 ants		

Linear regression output & interpretation. Dependent variable: Honeydew acceptance (no predator)

Effect	Coefficient (Estimate)	Standard Error	P-value	Interpretation
Intercept (1ant mean)				
Treatment (3ant mean relative to 1ant)				

Multiple R-squared value and overall p-value for the linear model:

Sixth, we will look at the effect of ant number on honeydew acceptance (with predator). For this linear regression, the equation is like the last one:

$$y = B_1 + B_2x_{3ant}$$

- The expected value for 1ant is B_1
- The expected value for 3ant is $B_1 + B_2$

Describe the boxplot pattern when ant species are pooled:

Describe the boxplot pattern when ant species are separated:

Means across treatments and ant species. Dependent variable: Honeydew acceptance (with predator).

Treatment	Pavement ant	Velvety tree ant
1 ant		
3 ants		

Linear regression output & interpretation. Dependent variable: Honeydew acceptance (with predator)

Effect	Coefficient (Estimate)	Standard Error	P-value	Interpretation
Intercept (1ant mean)				
Treatment (3ant mean relative to 1ant)				

Multiple R-squared value and overall p-value for the linear model:

Seventh, you can explore other patterns on your own, like how caterpillar population, mass, or treatment affects tentacle eversions. Edit the code you have available to do this. Results:

<u>In-class conclusions</u>: Here are some things to think about when drawing overall conclusions.

- What did we learn about how population affects caterpillar mass?
- What did we learn about how population and caterpillar mass affect the dependent variables? For which dependent variables did we detect significant effects and which do we not have support for?
- What did we learn about how ant group size affects the dependent variables? For which dependent variables did we detect significant effects and which do we not have support for?
    - What do the tentacle eversions mean exactly?
    - How do our results compare to Axen & Pierce (1998)?
    - Do our findings support the original hypotheses:
        - Lycaenid caterpillars increase honeydew secretion until they reach the number of ants needed to defend them from predators
        - Ants in a group sense nest-mate chemicals, which prompts aggressive behaviors to defend valuable food.
- If we had more time to work on this together, what would be a logical next step or steps to take for this particular project?
- Last, reevaluate the purpose of our experiment: "If we find significant differences in caterpillar-ant interactions among treatments, this will make ant-communication CHCs a good trait for our larger study on how fluctuating selection affects the genome." How did we contribute to the larger study on fluctuating selection's effect on genomes?

<u>In-class assignment</u> (8 pts). This is an individual assignment. Continue to use google slides to make a draft of the following slides for your individual research presentation. Include speaker notes to remind yourself of important details to say aloud during the presentation. The quality will not be assessed until you submit your final presentation in Week 13, and its quality will be assessed with the final grading rubric (see **Appendix A in Week 10 lab manual**). However, the more effort you put in now, the more meaningful feedback you will receive about its quality. Save your google slides as a **.pptx file** (not a .pdf file) and upload it to Canvas.

4) Experimental design slide: treatments, dependent variable(s), replication, prediction (1 pt) with speaker notes (1 pt)
5) Data analysis methods and results slide: graphs, relevant coefficients/SEs/p-values, R^2 values (1 pt) with speaker notes (1 pt)
6) Conclusion slide: interpretation of results, connection back to hypotheses and purpose, limitation, future direction (1 pt) with speaker notes (1 pt)
7) Acknowledgments slide: thank all contributors (1 pt) with speaker notes (1 pt)