The primary focus of the Research in Ecology Program is to teach students how to do science. To this end, four different lecture components (Tuesdays (T) and Thursdays (R)) have been designed to "prime" students for their hands-on research experience in their faculty/grad student-led teams (Mondays (M), Wednesdays(W), and Fridays (F)).

1. **Ecology Lecture & Workshop – 8:15am – 10:30am, TR**
   Participants will receive instruction regarding the scientific method as well as in evolutionary theory and ecological principles. Each lecture will be followed by an interactive group activity that illustrates the day's topic.

2. **Scientific Writing Workshop – 10:30am – 11:30am, TR**
   Participants will be assigned in-class writing exercises to hone their skills in grammar and writing style, to assist them in developing their creativity, and in learning to write a scientific paper in standard format.

3. **Statistics Lecture and Workshop – 1:30pm – 2:30pm, TR**
   Participants will learn the basics of probability and statistics, including the concepts of mean, median, mode, standard deviation, variance, etc. They will learn about the different types of data (parametric, non-parametric), and how to appropriately apply sample statistical tests to these types of data (e.g., Chi Square, t-test).

4. **Computer Workshop – 2:30pm – 3:15pm, TR**
   Participants will use the computer lab in room 108 and be instructed in the proper use of Microsoft Word, Microsoft Excel (how to plot and analyze data), Microsoft Powerpoint, and how to use the internet to find scientifically useful information, such as to access peer-reviewed journals, find published source material in the library, etc. (And also to learn that web sites are NOT allowed as citations in scientific papers.)

**WRITING INSTRUCTOR DUTIES**

The Writing Instructor for Research in Ecology is charged with teaching the student participants the basic rules of grammar and writing style by assigning them in-class exercises to (1) assess their level of competence and (2) correct problems as they arise.

The instructor is free to use his/her own creativity in devising exercises that will adequately test students' abilities and allow assessment and instruction, as necessary. However, the following assignments are **required** in the writing component of the program.

1. **First Day: "What is a Scientist?"**
   Students should be assigned the task of (1) drawing a picture of their concept of what a "scientist" is, and (2) writing a short essay about what they think a scientist does. These should be corrected for grammar and style, but the main purpose is for us to determine whether the students have stereotypical ideas about what a scientist looks like (e.g., white male in a lab coat?) and does. (Please do not give any preamble that would alter these preconceptions before assigning the task. We would like to see what their uncolored impressions of a "scientist" are before and after they participate in science themselves.)

   This assignment will be followed near the end of the course (during the fifth or sixth week of the program) with the **same** assignment, so that we may see how the students impressions and preconceptions of "science" and "scientists" have changed.
2. How to Write a Scientific Paper in Standard Format

Students should be instructed in the significance and proper content of each of the main components of a scientific paper:

- abstract
- introduction
- materials and methods
- results
- discussion
- literature cited

...as well as the appropriate materials to include in each section. Appended to this document is a standard handout that we provide for our first year biology majors. The Writing Instructor should use this as a template, but is free to add or change minor aspects of it as s/he deems necessary, and provide a copy for each RiE participant. (Copying can be done by the staff in the Undergraduate Research Office.)

Since an inquiry-based, hypothesis-driven research project is at the core of the Research in Ecology experience, it is essential that students learn the proper format and construction of a scientific paper in the Writing Module of the program. Not only will they be required to write their research project in proper format, but they also will be designing a Power Point presentation (for the final symposium at the Graduation and Recognition Ceremony) that should be presented in this format.

This is one of the very first things the students must learn, as they will begin using this writing technique as early as the second week of the program.

3. Third Week: Scientific Paper on Caterpillar Growth and Development

One of the classroom projects that students will begin during the second week of the program (in Ecology Lecture/Workshop) is an inquiry-based, hypothesis-driven exercise in which they test the effect of one environmental variable on the development of caterpillars. Each group will design its own experiment, so there will be as many different papers in progress as there are teams.

The Caterpillar Research Papers may be written either longhand, or on the computers in room 108. If the latter is chosen, then all finished work should be stored in appropriate locations on the university server. Our Network Specialist and the Program Coordinator will provide instruction for this to the Writing Instructor for saving student work. The Writing Instructor is responsible for making sure students save their work in the proper location and don't lose it.

The Writing Instructor should save and/or back up all student work on a USB drive for added security and ease of transfer.

The Writing Instructor should guide the students through the construction of the research paper. On the day that the students design their experiment in Ecology Lecture (see Program Schedule for exact day), the Writing Instructor should begin helping the teams construct their paper. On the first day after the experiments are set up, the teams will be able to create an appropriate TITLE for their work, as well as write the MATERIALS AND METHODS section.

**TITLE**

The title should clearly explain what the team was testing. An appropriate title is something like, "The effect of temperature on the rate of caterpillar development", NOT "Our Caterpillar Project." The title can be written as soon as the team knows what they will be testing.
MATERIALS AND METHODS

The Materials and Methods section should contain a somewhat detailed explanation of how the students set up their organisms, the difference between the treatment and control, the parameter they are measuring, and the statistical test they will use to analyze their results. This can be written as soon as the experiments are set up and running.

INTRODUCTION

When the Methods sections are complete, the teams should begin working on their Introduction. This should include some background on the species being used (Vanessa cardui, the Painted Lady Butterfly) as well as why the environmental variable chosen is of interest. The Introduction should also include the null and alternative hypotheses for the experiment, as well as predicted results and a reason for the prediction. THE INTRODUCTION SHOULD NOT BE A RE-STATEMENT OF MATERIALS AND METHODS, which is a very common mistake. No materials or methods should be included in the Introduction.

RESULTS

The data collection phase of the caterpillar experiments usually is finished by the middle or end of the fourth week of the program. Once the data sets are complete, the Statistics Instructor will guide the students through appropriate analysis of their data, the Computer Instructor will guide students through the proper methods for graphing and presenting their data, and and the Results section can be started in Writing Workshop with the Writing Instructor.

Once the teams have their statistic and P-value, they should write the Results section. This should include a Table with their data (and the Table must have an appropriate title as well as a legend explaining what's IN the table, the units, etc.) There must also be a brief prose section in which the students present their findings, their statistic value, their P value, and then reject/fail to reject their hypotheses.

DISCUSSION

In this section, the teams should explain their results with logical reasons for what they saw. This is NOT merely a re-statement of the Results section. The key is proper explanation of their results, not just writing them over again in slightly different words. The discussion is the capstone of the project, and its most important section.

LITERATURE CITED

Any sources of information used in the research of the paper should be included. If web sites are used, they should be ONLY .edu or .gov sites. NO .com or .org sites are acceptable.

ABSTRACT

Though it's the first thing in the paper/on the poster, it's the last thing the teams write. This should be a brief explanation of all the other sections: Intro, Methods, Results and Discussion in a nutshell, with only one or two sentences to summarize each of those major sections.

The entire research paper on the caterpillar experiments should be completed no later than Thursday of the fifth (penultimate) week of the program. They should be done either in scientific paper format (MS Word), or as posters (PowerPoint) prepared as if for a scientific symposium, with all the proper sections and illustrations included.
4. Additional Writing Activities

The three required assignments outlined above will not likely take up every Writing Workshop period, and it is suggested that the Writing Instructor create a syllabus, if only for his/her own use, to provide a timeline for each component's completion. Workshop periods not scheduled with one of the above activities can be used at the Writing Instructor's discretion. In the past, Writing Instructors have engaged the students in such projects as:

a. Writing a poem or short essay from the point of view of a particular tree in the Gifford Arboretum (this would require a "field trip" outside into the arboretum, so students can each pick a tree or whatever.).

b. Writing a poem or short essay about some environmental issue.

c. Writing a poem or short essay about why they like science.

d. Insert your own creative idea here! Feel free to do something original!

5. Performance Art: Samples of Writing at the Graduation and Research Symposium

During the Graduation and Research Symposium on the very last day of the program (usually Sunday), we include one segment in which the students read selected works they have created during the Writing Workshops. The Writing Instructor generally selects these on the basis of excellence, and also will be in charge of creating the order in which the works are read. (In other words, The Writing Instructor is the "director" of this segment of the Graduation Program.) The segment usually lasts about 15 – 20 minutes.
A good scientist also must be a good writer. All the research of a lifetime is useless if the investigator cannot effectively communicate new findings to his or her colleagues.

The exact format of a scientific paper will vary, depending upon the exact journal in which the paper is published. However, most journals use some variation of a format including the following components: title, abstract, introduction, methods, results, discussion and literature cited. You will be using this format when you write a scientific paper on your Team Research Project, as well as the paper describing an experiment you will do on caterpillars and their development. This outline instructs you how to write each of the six components of a scientific paper. When you write your paper, you should label each component (except the title) as shown below.

**Title**

The title of your paper will be read by the most readers, and it is the title that often will determine whether the rest of your paper will be read. It should describe specifically the contents of your paper. Generally, the name of the organism being studied is also included. Under the title, list the names of all investigators in the research team, the date and your institutional affiliation (e.g., HHMI Research in Ecology 20XX.)

**Abstract**

The purpose of the abstract is to allow a reader to determine, with a very quick scan, what your report is about, how you did it and what you discovered. Although the abstract appears first, it is written last. In one double-spaced paragraph, offset from the rest of the paper, give a skeletal outline of your purpose (one sentence), methods, (one to two sentences), results (one to four sentences) and conclusions (one to two sentences). Do not cite literature references in the abstract.

The abstract is NOT merely an introductory statement. If you were actually to publish your paper, its abstract would appear in Biological Abstracts, a massive series of books containing nothing but the abstracts of scientific papers written in a given year. (The series is available in the reference area of the library, if you would like to see it.) An investigator searching for information on a particular subject can look up and read abstracts--rather than an entire paper--to determine whether a particular scientific study is relevant to his/her own work. If it is, s/he then can acquire the actual journal and the complete publication for a more detailed account of the study.

**Introduction**

This section can be written even before you begin your experiment. In one to several paragraphs, give specific background information on your project. Include a statement of purpose, the theory behind the experiment and what you are trying to demonstrate. Give background information on the species you are studying, if you are working on organisms.

When making a statement that is not common knowledge, you must cite the source of your information (see "literature cited" for instructions on the proper citation
format). Unless absolutely necessary, however, DO NOT USE DIRECT QUOTES! Instead, read, learn and *paraphrase* the knowledge.

The introduction is the proper place for you to state your null and alternative hypotheses. Include a summary of expected results (in terms of your hypothesis) and *why* you expect those results. If you have not mentioned predictions in your introduction, you cannot claim later "this was in agreement with my prediction."

**Methods (a.k.a. Materials and Methods)**

The purpose of your methods section is to enable a reader to duplicate your experiment exactly, and to test whether your results are reproducible. Using past tense (you are not writing a cookbook), you must describe all materials and procedures you used. **List concentrations, quantities, etc., of reagents in neat tables and refer to these tables in the text!** (Example: "Concentrations and amounts of enzyme and substrate used in Experiment #1 are listed in Table 1.") Do not describe the same procedure over and over for nearly identical experimental trials. Describe your general experimental procedure only once, then note any changes made in subsequent trials.

Caution! Don't get carried away with detail! It is *not* important that you used a #2 pencil to record your data in a spiral notebook on a slate table in a spacious laboratory. It *is* important that you were using *Vanessa cardui* as your study organism, and the precise temperatures, light regimens, etc. to which you subjected your organisms in your experiment. Also include the type of apparatus you used, and what statistical tests you performed on the data. Use your judgement and common sense! **Assume that your reader has some inkling of scientific procedures and knows good lab technique. DO NOT INCLUDE ANY DATA OR CONCLUSIONS IN THIS SECTION!!**

**Results**

Your results must be described in one to several *prose* paragraphs. *Never* give long lists of numbers in your prose text. List such results in neat tables or in clear figures. You MUST refer to every figure or table in the text. Example: "Increased reaction temperatures resulted in a higher rate of reaction (Figure 3)."

A *table* consists of neat columns of numbers or words. It should be referred to as "Table 1" (or 2, or 16, etc.) in your text and in its legend. The legend (prose explanation of the table) for a table should appear *above* the table.

A photograph, drawing, graph or other illustration is called a *figure*. It should be referred to as "Figure 1" (or 3 or 10, etc.) in your text and in its legend. The legend (prose explanation) for a figure should appear *beneath* the figure.

Do not alter your sacred data! Report exactly what happened in your experiment, even if it is not what you expected. You will have ample opportunity to explain deviations from the expected in the next section. **DO NOT INCLUDE ANY DISCUSSION OR CONCLUSIONS IN THIS SECTION!!**

**Discussion**

This is the main body of your paper and not merely a re-statement of your results. In your discussion, you must *analyze and explain* your results. Follow these simple guidelines to write a good discussion.

1. Link your results to your original hypotheses.
2. Do you accept or reject your null and alternative hypotheses? Why or why not?

3. Explain your experimental observations in specific terms. Describe what has happened in terms of molecular interaction, physics (kinetics), behavior, etc. DO NOT make statements such as: "The reaction was faster because it had a greater reaction rate." That's just redundant, and doesn't explain anything.

4. The world will not stop spinning if your results are not what you expected. Simply try to explain why your data show such unexpected results. Be logical and imaginative.

5. Discuss possible sources of error and how they might have affected your results.

6. Compare your results to those of similar experiments published elsewhere.

7. Draw overall conclusions--give summary statements.

This is your chance to show us your capacity for creative, scientific thought. Refer to literature and other published material on the subject, but more importantly, offer your own insights and ideas about why you observed your particular experimental results.

**Literature cited**

"Literature cited" is exactly that. **When you state a fact that is not common knowledge, you must cite the source of that information.** What source, you ask? Papers from scientific journals. A text book. Your instructor. (But NOT the internet!)

The precise citation format used varies among scientific journals. For our purposes, please cite references in the format in the examples shown below. Write (in parentheses immediately after the cited fact) the author's last name and the year of the source material's publication. For example, you may state

Reaction rate may vary depending upon the pH of the solutions (Campbell, et al, 2005). *(Note: "et al." is a Latin abbreviation meaning "and others." It is used only in the text reference when there are more than two authors. However, when listing the reference in your literature cited section, you must list every author's name--not "et al.")*

At the very end of your paper, after your discussion section, list references in alphabetical order in a section entitled "Literature Cited". **Include all citations mentioned in the text of your report, but DO NOT list a reference if you have not cited it in your report!** Use the format shown in the following examples.

**FOR A BOOK:**


**FOR A JOURNAL ARTICLE:**


**Do not cite "personal communication" references in Literature Cited.** If you include information you learned from your instructor during class, it should be cited where it appears in the text of your paper. For example: "Lemmings never jump off of cliffs during migration. The ones shown in that Disney film were actually herded off the cliff with flame throwers (D. Krempels, pers. comm.)."
Don’t make common mistakes!

1. **DO** use correct grammar and spelling.

2. **DO NOT** write in the second person. Use either first or third person. **RIGHT:** "The investigators grabbed a flask and heated it until it blew up." **WRONG:** "You grab a flask and you heat it until it blows up."

3. **DO NOT** write in present or future tense. Write in past tense, since you already have performed this experiment. Use the same tense throughout your paper.

4. **DO NOT** pad your prose with flabby pseudoexplanatory phrases such as “It is important to do this because...” or “It is a fact that...” This is just poor style.

5. **DO NOT** use subjective adjectives ("good result" “bad result” “clearly demonstrates” “extremely obvious” etc.). Let the reader judge.

6. **DO NOT** state that your purpose is "to learn all about the phenomenon of...." **It is NOT.** Your purpose **IS** "to test the effect of ....... on ............" You are writing a scientific report, not "What I did in school today."

7. **DO** write as though you had designed the experiment. Do not say, "We were required to..." or "The procedure required that we..." You are the scientist. You're in charge.

8. **DO** use your own words. Paraphrase sources ONLY when necessary. **Unless absolutely necessary, do not use direct quotes, even if placed in quotation marks (“ “).**

9. **DO NOT** use chatty prose. **RIGHT:** "The results did not support our prediction." **WRONG:** "The results kind of surprised me."

10. **DO** type your report and store it in the appropriate location, as instructed in the Computer Workshop. No handwritten reports will be accepted.

11. **DO NOT** wait 'til the last minute to **write** your report. Give yourself time to edit your work. Once you've finished your first draft, let it rest for a day or two, then **GO BACK AND READ IT AGAIN.**

12. And finally, please be sure you don’t make these mistakes (or others like them)
   a. It's means "it is." Its is the possessive form meaning "belonging to it."
   b. Data is the plural of datum. Data are; datum is.
   c. Usually, **effect** is a noun and **affect** is a verb. Know the difference, and how to use the words correctly.
   d. **Advise** is a verb ("to give advice"). **Advice** is a noun. Don't mix them up!

**IF YOU FOLLOW THESE RULES AND TAKE THE TIME TO LEARN GOOD GRAMMAR AND STYLE, YOU WILL BE WELL ON YOUR WAY TO A LONG AND HAPPY CAREER IN SCIENTIFIC WRITING.**