# The College of New Jersey

# Department of Biology

# Research Paper Style Manual

**2021 – 2022**

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## WHY RESEARCH PAPERS?

Peer-reviewed research papers are the primary way in which new scientific knowledge is documented and communicated. This "primary literature" forms the foundation for future research and for the synthesis and communication of science in all other forms. As you learn to write an effective research paper, you are essentially learning how to write a primary scientific research paper, which requires the following three fundamental skills highlighted below:

- **Accurate reporting**
- **Effective communication**
- **Insightful interpretation and analysis of results in the context of other research**

## THE GOALS OF THE *STYLE MANUAL*

This *Style Manual* is intended to provide formatting instructions, as well as appropriate content and organization, for each part of the research paper and is to be used as the standard throughout the entire four-year Biology Curriculum. In addition, you can use this *Style Manual* as a companion to *reading* primary literature. One of the best ways to become a better writer is to become a more attentive reader. The *Style Manual* has the following three goals:

### *1. Establish common formatting guidelines – "Why should I follow instructions?"*

It is essential for you to realize that accurate reporting and effective communication is improved when your paper organizes information in a very specific and predictable manner. As such, each scientific journal requires authors to follow an exceedingly detailed list of formatting instructions, which are generally similar (although not identical) among journals. Failure to follow all instructions precisely results in rejection of a submitted paper.

Why are the instructions so exceedingly specific and inflexible? Reading a primary paper involves assimilating and evaluating substantial technical detail, which is easier to accomplish when that information is organized predictably. Here is a useful analogy: when you walk into an unfamiliar airport, regardless of what state or country you are in, you can rely on a certain set of organizational standards to help you find your way around. At some point early after you enter, you will encounter a board with departure and arrival times, as well as gate listings. Beyond those, you can find ticket counters. Beyond those, security lines, then departure gates, etc. That common organization aids your ability to navigate an unfamiliar airport, just as common formatting aids in navigation through a research paper. Thus, the take home message is the following:

> **FOLLOW INSTRUCTIONS.** They are neither arbitrary, nor negotiable. This point cannot be overemphasized, and the Biology Faculty have agreed that failure to accurately follow basic formatting instructions could justify an assignment being returned without review (with potential late penalties), just as in a professional setting.

***2. Explain the specific requirements for each research paper section***

For every scientific paper, you have three major objectives. First, you must identify your purpose (*i.e*., the question you are trying to answer and your hypothesized answer to that question. Next, you must clearly and accurately describe the procedures that were followed and the results that were obtained. Finally, you must place these results in perspective by relating them to the current state of knowledge and interpreting their significance in light of your original hypothesis. The structure of the entire report should look like the following:

- **Title Page**
- **Abstract**
- **Introduction**
- **Methods**
- **Results**
- **Discussion**
- **Literature Cited**
- **Tables** (with headings)
- **Figures** (with legends, which are detailed captions)

The *Style Manual* will treat each of these sub-sections separately because they require distinct approaches to writing, as well as distinct information content.

## TITLE PAGE

Include the title of your paper, your name, the course name, and the instructor's name. The title of your paper should reflect its scientific content, and not the nature of the assignment. E.g., "*PitX1* Mutations and the Evolution of Pelvic Reduction in Threespine Stickleback Fish " is more appropriate than "Lab Report 1" or "Fishy PCR." Also, do not put images or decorations on your title page.

## ABSTRACT

The abstract is a brief (usually < 250 words), one paragraph synopsis of your entire research project. It should be a stand-alone entity from which a reader can elucidate all of the main points of your research, thus allowing them to determine whether reading the paper will be useful for them. Think of your abstract as providing one or two sentences that summarize each of the subsequent main sections of your paper. Thus, it is often easiest to write your abstract after the rest of the paper is completed. Specifically, your abstract should clearly and concisely answer the following questions:

1) What is the problem, or knowledge gap that you are trying to fill?
2) What is the specific purpose of your research in light of that knowledge gap?
3) What specific hypothesis or hypotheses did you test?
5) Briefly, what was your general methodological strategy for testing that hypothesis?
6) What were your main results?
7) What are the implications of these results?

## INTRODUCTION

Your introduction provides broad context for your research (what is the "big picture?"), identifies the question you are trying to answer, your specific hypotheses, and briefly outlines your methodological rationale for testing those hypotheses. An effective introduction is written in the active voice, and leads the reader from broad to specific information, presenting a convincing argument that the research is important and that the approach employed is sound. A good introduction should cover the following:

***Broad Context***

- Describe the general question, problem or gap in our knowledge, and explain why it is important to consider.
- Describe the contributions of other studies to addressing this question/problem. What is the current state of knowledge on the subject, and what new knowledge is required? Refer to the *Literature Cited* section, below, for how to properly cite information from other sources.
- Describe your specific goal, which should be to fill one or more of the knowledge gaps you have just identified.

***Study System/Organisms***

- If the purpose of your investigation is to learn about a specific biological entity (e.g., a particular organ, organism, ecosystem, etc.) because it is important in and of itself, then your presentation of broad context, above, will have already provided necessary background, and you can proceed to describing your hypotheses and strategy.

- On the other hand, if you are interested in investigating a general biological process (e.g., oogenesis, transcription in eukaryotes, optimal foraging by animals), then you must explain and justify the model system you have chosen to consider. Your model might be a traditional one such as *Drosophila* or yeast, or a less traditional model such as birds or deciduous trees. If others have used this system in a similar way, you should cite a few of these other studies to support your claim that the system is useful.

***Specific Hypotheses and Predictions***

- Explain your specific hypotheses and predictions. Your hypothesis is what you think the answer to your question is. Your prediction is what you expect your data to show if your hypothesis turns out to be correct. For example, consider an experiment in which you set up bird feeders, some of which are stationed near simulated predators:

    - ❖ *Question*: How do nearby predators affect the foraging behavior of their prey?
    - ❖ *Hypothesis*: Animals avoid eating in areas where predation risk is high, instead preferring less risky foraging patches.
    - ❖ *Prediction*: Birds will eat significantly less birdseed from feeders near a fake owl than from feeders without a fake owl.

  Notice how the hypothesis *explains* the behavior of animals. Hypotheses are proposed explanations for natural phenomena. Also notice that the prediction refers very specifically to the data you expect to collect, if your hypothesis is correct. A scientific prediction is a statement that must be true if your hypothesis is true. Note that in some cases the research is experimental by design, as in this example, while in others it may be an observational and descriptive study, without any experimental manipulations. In either case you will have a general question, specific hypothesis, and prediction.

- After describing your hypotheses and predictions, give a brief summary of your methodological strategy for testing these hypotheses. This summary helps prepare the reader to evaluate the detailed Methods section, as described below.

- At the end of the Introduction, some authors choose to reveal the main findings of their research, thus helping the reader interpret the forthcoming results in light of those conclusions. Other authors wait until the Results and Discussion to first reveal the outcome of their investigation. Check with your professor for their preference.

## METHODS

It is essential to accurately and effectively communicate your procedures so that other scientists can evaluate the validity of your data collection and analytical methods, compare your results to those of other researchers, and repeat your experiment if they so desire. In paragraph form, the methods section should clearly describe the following:

- The study site (if experiments were not carried out in the lab, *i.e*., for an ecological study)
- The source and maintenance of your organisms or special materials
- The study design. For an experimental study, include the setup, treatment and response variables; for an observational study describe the units of study, their locations, and any relevant characteristics (for example, maple seedlings located along transects from the forest edge to the forest interior, located in four second-growth forest stands on the TCNJ campus, etc.)
- The procedures you used to collect your data (but omit descriptions of common-sense techniques—refer to the primary literature for a sense of essential details)
- Sample sizes
- Quantities of all reagents, with concentrations specified as well (*e.g*., 5 ml of a 5M NaCl solution. If you just write 5 ml of NaCl, the quantity is meaningless.)
- The analytical approaches you used to evaluate your hypotheses. Be sure to describe the analyses in the same order that they appear (or are mentioned) in your results section, which helps the reader understand your project in a logical and organized format. Be sure that you have organized the methods (and therefore results) so that you explain the experiments in a logical flow – and therefore NOT necessarily in actual chronological order (*e.g*., if you first performed a PCR, and then collected embryos for staining, and then ran the PCR reactions on the gel, you would NOT write your methods/results that way; instead you would describe how you did the PCR and ran the samples on a gel, and THEN you would introduce the next part of the experiment, where you collected embryos for staining). Also, any analysis that is mentioned in the methods must have results, and it follows that these results should be discussed.

While you should avoid giving specific or lengthy details of procedures, you should provide enough details to allow another person to understand exactly what you did. If your methods match, or are a modified version of what has been done in another study, it is appropriate to briefly describe your procedures, and then direct your reader to the other relevant source for more detail. **Never include a description of every step or a list of materials/supplies used**.

For more complicated projects, it is often helpful to divide the methods into sub-sections with descriptive headings. This approach can help delineate different types of methods (*e.g.*, collection and care of animals, experimental design, data collection, analyses, etc.)

The methods section should be written in past tense (i.e., “100 g of mushrooms were homogenized in 200 ml of cold water.”). Do not write the methods in the imperative (*i.e.*, do not say “Homogenize the spinach in cold buffer solution,” as if you were giving instructions). While the active voice should be used throughout the rest of the research paper, the Methods section tends to use the passive voice more extensively because you should make the procedures, not the investigator, the main subject. For example, “Samples were collected…” However, it is acceptable to occasionally identify yourself as the subject ("I measured…" or "We collected…"), so long as this form is not overused.

## RESULTS

The goal of the results is to clearly and concisely describe your analytical results, supported by relevant statistical information and figures and/or tables. To do this, state the biological result, and then in parentheses provide the relevant statistics (statistic with degrees of freedom as a subscript, *P* value, figure and/or table reference if applicable). State your results in simple, declarative statements of what your analyses revealed. *E.g.*:

> "Standard length differed among lakes, with North Rolly Lake having much larger fish than those in the other three lakes ($F_{2, 57} = 9.65$, $P = 0.012$, Fig. 4)."

Alternatively, if you have a number of similar statistics to report, you can report them collectively in a table, instead of parenthetically in the text. *E.g.*:

> "Standard lengths differed among each of the six pairs of lakes, with the deeper lakes always having the larger fish then their neighboring shallow lake (Table 1)."

Statistical information should only be reported once to avoid redundancy. **Never report the same information in both the paragraph and in a table, nor in both a table and a figure.** Readers will be confused if they see the same information multiple times.

***Additional guidelines for the results section:***

- This section is written in past tense, and you should avoid making the investigators the subject of any sentence. In other words, eliminate all uses of phrases like "We found that…." *E.g.*,

    - ❖ <u>Worst</u>: "We found that photosynthetic rates differed between the two types of plants ($F_{1,64} = 2.35$, $P = 0.032$, Fig. 1)."
    - ❖ <u>Better</u>: "Photosynthetic rates differed between the two types of plants ($F_{1,64} = 2.35$, $P = 0.032$, Fig. 1)."
    - ❖ <u>Best</u>: "*Arabidopsis* strain A had a higher mean photosynthetic rate than strain B ($F_{1,64} = 2.35$, $P = 0.032$, Fig. 1)."

  This last example is best because it not only makes the result, rather than the investigator, the subject of the sentence, but it also specifically states what the nature of the difference was between the two strains. That is, not only were the two strains different, but strain A had a higher photosynthetic rate than strain B.

- ***Do*** use simple, declarative statements that clearly state the outcome of each analysis. Each of these statements should end with a parenthetical report of statistics and/or a reference to figures or tables.
- ***Do not*** report means as being different if the statistical analysis indicates that the means are not significantly different. For example, ***do not write a statement like*** "Group A was

larger, on average, than Group B, but the difference was not significant." In this case, you would simply state that the group means are not different. If *P* is close to 0.05, then you might say that there is a non-significant trend towards a group difference.

- ***Do not*** include information from references in this section. The Results are all about what you found in the present study. Leave the synthesis of other research for the Discussion.
- ***Do not*** evaluate or interpret the results in this section. Report only what you found; hold all discussion of the meaning of the results for the discussion section.
- ***Do not*** describe every step of your statistical analyses. Scientists understand all about null hypotheses, rejection rules for *P* values, and so forth.
- Report any *P* value less than 0.001 as "$P < 0.001$" because *P* cannot = 0.000. If $P >$ 0.001, report the exact value as in the examples above.
- ***Do not*** provide a complete list or table of raw data.
- ***Do*** refer in the text to each figure or table you include in your paper, and number them in the order in which they are referred to in the text. Number tables and figures separately beginning with 1 (*e.g.*, Table 1, Table 2, Fig. 1, Fig. 2, etc.).
- Although they are referred to in the Results, **place all figures and tables after the Literature Cited**. While it might seem unusual, this placement avoids annoying conflicts in word processing programs between text and images that can disrupt formatting. More information on formatting figures and tables will appear below.
- Avoid making a table/figure the subject of a sentence. For example, "Amylase activity was highest in the 35$^{o}$C treatment (Fig. 1)" is preferred over "Fig. 1 shows that…"

## DISCUSSION

The discussion is the place for you to explain your results in plain language, interpreting them both in the context of your original hypotheses and of previously published work. Your results are also likely to point to new avenues of research, which you might choose to propose here.

Do not simply restate the results in the discussion; instead discuss the key findings and their biological significance. The organizational structure of a good discussion is a mirror image of that presented in the introduction. Now, your narrative will proceed from specific interpretations of your results in light of your hypotheses, all the way to implications for the broad context with which you began your introduction. To construct a well-written discussion you should do the following:

***Interpret the results of your analyses in light of your questions/hypothesis***

- Reiterate your main findings in plain language (i.e., describe the main outcome(s) of your analyses). Use the active voice to make your narrative engaging.
- Discuss whether these results support or refute your hypotheses
- Discuss whether your results are consistent with what others have found, if similar experiments/studies exist. If they are consistent, then you can be more confident that your results represent a general principle, and aren't specific to the limited conditions of your

experiment. If they are not consistent, propose some explanations for the discrepancies. ***Do not* simply attribute unexpected results to human error**—generate and discuss alternate hypotheses to explain your results. If our initial hypotheses were always correct, then we would never bother running any experiments.

- Discuss any limitations or shortcomings to your approach, and how you might remedy them in future studies.

***Discuss remaining/newly open questions***

- Often, some or all of your results might contradict your expectations or lead to more questions that might be the subject of further experiment. Discuss any such situations, and suggest ways to possibly clarify the issues with further work. It is important to remember that you tested your particular hypothesis over a very limited set of conditions and probably in a single species—thus, you cannot generalize to all species and all conditions. The best you can do is draw conclusions from your own limited experiment or observational study and then relate it to the findings of others. In other words, where should your research go from here?
- If others have completed similar studies and your results contradict theirs, you might discuss why you think the results differ.

***Summary/Conclusion/Broader Implications***

- There is considerable latitude here, but a common formula is to briefly (probably 1-2 sentences, unless it was a complex study) summarize your findings again in light of your broad question, and then discuss the general relevance of the work and question. In many ways, you are reiterating the points you made in the beginning of your introduction, but now you have actually tested your hypothesis so hopefully you have new insights into what we know about the topic.

## LITERATURE CITED

***Formatting In-Text Citations***

The references contained within a scientific paper are the framework for the paper, and without them, the paper is incomplete, and is in fact an example of plagiarism. **Whenever you write anything that is not an original thought, you must include a reference to the source in parentheses in the body of the paper.** We will follow the citation and literature cited format used in the journal *Ecology* (author date), which is fairly standard for scientific journals, but know that each journal has its own formatting guidelines. The essential point is for you to follow the specified instructions **exactly**, so that readers of a particular journal know where you found information. List multiple citations contained within the same parentheses in chronological order by year, and alphabetically within year:

- **For a single author:** Several genes, such as x, y, and z, are activated in the organizer region of *Xenopus* embryos (Smith 1982).
- **When two authors are present:** Several genes, such as x, y, and z, are activated in the organizer region of *Xenopus* embryos (Smith and Jones 1982).

- **For three or more authors:** Several genes, such as x, y, and z, are activated in the organizer region of *Xenopus* embryos (Smith et al. 1982). Note that "et al." is not italicized, as is the case in many other journals.
- **For multiple citations:** Several genes, such as x, y, and z, are activated in the organizer region of *Xenopus* embryos (Smith et al. 1982, Adams 1987, Tyler et al. 1987, Park 2009).
- **For citations in which you have already identified the authors' names in the sentence:** If you may have already identified the author(s) by name in the text of a sentence, you only need to write the date of the publication in parentheses. For example: "In a study investigating coat color evolution in wild mice, Domingues et al. (2012) found that a single genetic difference was responsible for divergence in coloration between mainland mice, and their descendants on barrier islands."
- **For a book:** Several genes, such as x, y, and z, are activated in the organizer region of *Xenopus* embryos (Smith et al. 1982).

### *Finding and Organizing Sources*

To find valuable reference material, be sure to look on the library web site (or Google Scholar) [http://www.tcnj.edu/~library/research/index.html]. You may use any biological reference index that you are comfortable using. Cite only peer reviewed primary literature, or scientific secondary literature (review papers, textbooks). Lecture notes and websites are not appropriate (although they may be helpful starting points for your research). It is also helpful to look through the Literature Cited of a paper related to your research.

You are **encouraged** to learn to use a **reference management software package** to help you organize your references, and to build citation lists within your paper. For example, *Refworks* is a free reference management system available through the TCNJ Library that will automatically create reference lists for you as you cite references within your paper. See the following website for information and simple tutorials, or ask a librarian for help:

http://www.tcnj.edu/~library/research/name/RefWorks.html

Other paid (*e.g.,* Endnote, Papers) and free (*e.g.,* Mendeley, Zotero) reference management applications are available to you as well.

### *Formatting the Literature Cited*

In the literature cited, list all of the references that you have cited, and only the references you have cited. Journals vary widely on the exact format for references, so we will adhere to a relatively common format that is also used by the journal *Ecology*. Citations should be listed alphabetically by the last name of each first author. Note that in the journal *Ecology,* journal titles are never abbreviated, nor are journal titles or book titles italicized (as is common in many other journals).

**Journal articles (traditional page numbers present)**

Author(s). Year. Article title with sentence case capitalization. Journal Title Capitalized Volume:pages.

Johnson, P. T. J., D. E. Stanton, E. R. Preu, K. J. Forshay, and S. R. Carpenter. 2006. Dining on disease: how interactions between infection and environment affect predation risk. Ecology 87:1973–1980.

Note that the first author is listed last name, initials but that the remaining authors are listed with their initials preceeding their last name.

Where consecutive papers have the same exact authors and years, then designate them "a" and "b." *E.g.*,

Ostfeld, R. S. and F. Keesing. 2000*a*. The function of biodiversity in the ecology of vector-borne zoonotic diseases. Canadian Journal of Zoology 78:2061–2078.

Ostfeld, R. S. and F. Keesing. 2000*b*. Biodiversity and disease risk: The case of Lyme disease. Conservation Biology 14:722–728.

Where consecutive papers have the same first author, but different additional authors, alphabetize them by the second author. *E.g.*,

Foster, S. A. and J. A. Baker. 2004. Evolution in parallel: new insights from a classic system. Trends in Ecology & Evolution 19:456-459.

Foster, S. and S. Ploch. 1990. Determinants of variation in antipredator behavior of territorial male threespine stickleback in the wild. Ethology 84:281-294.

**Journal articles (online only, with traditional page numbers absent)**
Many online-only journals do not use traditional page numbers, but instead give each article a unique identifier. Follow the same formatting rules as above, but replace the page numbers with the electronic page number or numbers listed, as well as the unique "digital object identifier" that accompanies the article.

Snider, D. L. and S. M. Horner. 2021. RNA modification of an RNA modifier prevents self-RNA sensing. PLoS Biology 19: e3001342. https://doi.org/10.1371/journal.pbio.3001342

**Books with an author (i.e., not an edited volume)**
Author(s). Year. Book title with sentence case capitalization. Publisher, Place.

Clark, J. S. 2007. Models for ecological data. Princeton University Press, Princeton.

**Chapter from an edited book**
Author(s). Year. Chapter title with sentence case capitalization. Pages x-y *in* Editors Names, editors. Book title with sentence case capitalization. Publisher, Place.

Schlichting, C. D. 2004. The role of phenotypic plasticity in diversification. Pages 191-200 *in* T. J. DeWitt and S. M. Scheiner, editors. Phenotypic plasticity: functional and conceptual approaches. Oxford University Press, New York.

**Thesis**

Author. Year. Thesis title with sentence case capitalization. Thesis Type. Institution, Place.

Wund, M. A. 2005. Learning in the development of phenotypically plastic bat echolocation. Ph.D. Thesis. The University of Michigan, Ann Arbor, MI.

## TABLES

Tables generally should report summary-level data, such as means ± standard deviations, test statistics, and possibly *P* values, rather than all of your raw data. A long list of all your individual observations will mean much less than a few concise, easy-to-read tables or figures that bring out the main findings of your study. When data is repeated for every row of the table, omit the data and refer to it in the table heading. Tables should have a brief, but descriptive heading. *E.g.*,

Table 1. Body size parameters (mean ± sd) of stickleback fish in four Alaskan lakes.

| **Population** | ***N*** | **Length (mm)** | **Mass (g)** |
|---|---|---|---|
| Beverly Lake | 32 | 34.7 ± 2.0 | 1.6 ± 0.1 |
| Long Lake | 30 | 36.4 ± 2.2 | 1.8 ± 0.1 |
| Whale Lake | 31 | 31.2 ± 2.6 | 0.9 ± 0.1 |
| Willow Lake | 34 | 33.1 ± 2.4 | 1.2 ± 0.1 |

Table 2. Results from four analyses of variance comparing characteristics among four populations of stickleback fish.

| **Character** | ***F*** | **d.f.** | ***P*** |
|---|---|---|---|
| Length | 2.324 | 1, 123 | 0.046 |
| Mass | 2.564 | 1, 120 | 0.039 |
| Pelvic Spine Length | 1.126 | 1, 120 | 0.064 |
| Dorsal Spine Length | 1.157 | 1, 122 | 0.122 |

## FIGURES

When presenting data, graphs are often far more informative than tables, so you need to practice deciding when to use one or the other in your research paper. This decision may involve presenting the data several ways and picking the most informative format. Use a figure (graph, gel image, map, etc.) when information lends itself to good visual representation. Most figures depict data and are therefore associated with the Results, but figures can also effectively communicate methodologies (*e.g.*, a diagram illustrating some sort of technique, or a map indicating a study plot) or conceptual models. Whichever the case, aim for simple, elegant figures in order to clearly present your information. It is important to choose the appropriate type of graph to represent the appropriate type of data (*e.g.*, histograms for distributions of observations among categories, scatter plots to show the relationship between two variables, line graphs to show the repeated observations of the same sample over time). While it is not appropriate to report the same data in both a figure and a table, or in the main text and a table, information can be repeated between the main text and a figure legend (*e.g.*, sample sizes).

Figures should be constructed with *intention*, meaning that every choice of color and detail should be made to convey some important piece of information. For example, there is no need to use 3-D bars in a histogram if there is no z-axis. Only use different symbols if those symbols represent different entities. Stylistic embellishments for no other purpose can only lead to confusion. Clearly label all axes with what was measured, and the units of measurement. Bar graphs should only be used to represent categorical data or percentages. Scatterplots are used to relate two continuous variables to one another, and point means +/- error bars should be used to represent means of continuous data.

Figure legends are written in paragraph form, and should explain each relevant element of the figure so that the reader knows how to interpret what they see. For example, in a graph depicting some aspect of your results, explain what was measured and how the symbols on the graph represent those measurements (e.g., identify points as means, identify what types of error bars were used, and indicate sample sizes). **Note:** Some journals encourage authors to include the results of statistical tests in figure legends, while many others consider it redundant with the text of the Results. Consult your professor to determine their particular preference. The examples below contain essential information that should be included in figure legends.

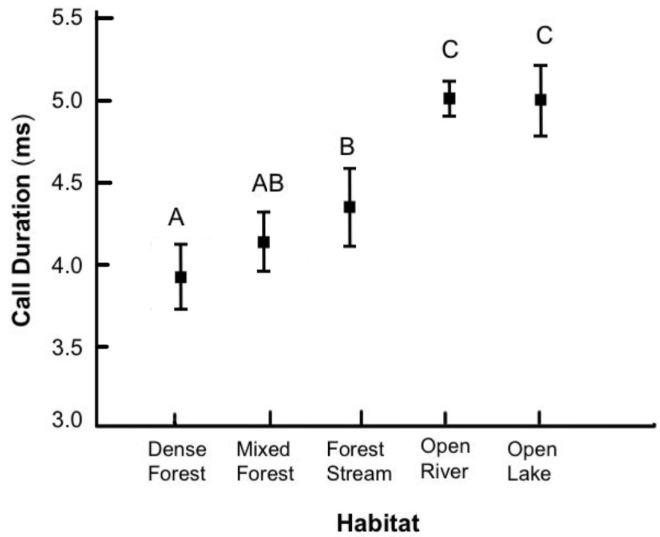


Figure 1. Durations of echolocation calls produced by little brown bats *(Myotis lucifugus*) at five sites that differed in structural complexity. Points are means +/- SEM. Means with the same letter are not significantly different ($P > 0.05$) as determined by Tukey's HSD *post hoc* tests. $N$ = 80 (Dense Forest), 37 (Open River), 34 (Forest Stream), 141 (Open River) and 46 (Open Lake).

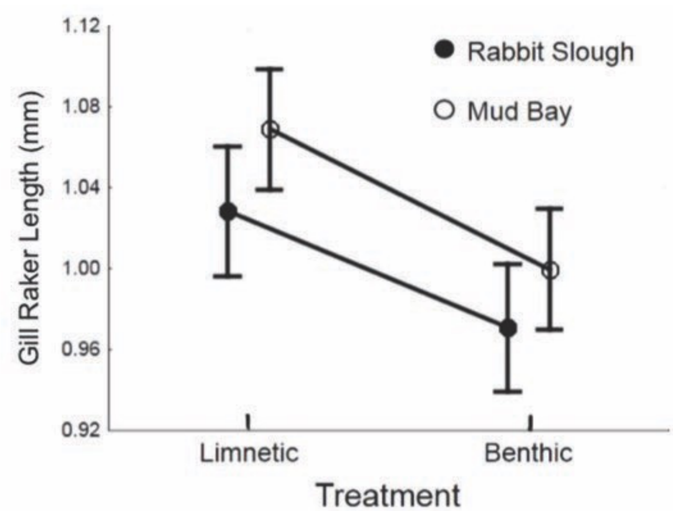


Figure 2. Differences in mean gill raker length between two populations of stickleback fish reared in limnetic versus benthic conditions. Values are means $\pm$ 95% C.I. $N = 45$ for all population x treatment groups.

**Note:** The use of **connector lines** in figure 2 is typical in an "interaction plot" and helps visually illustrate which sets of points in alternative treatments are linked in some way (in this case linked by population). There are no connector lines in figure 1 because the different habitats represented are all independent of one another.

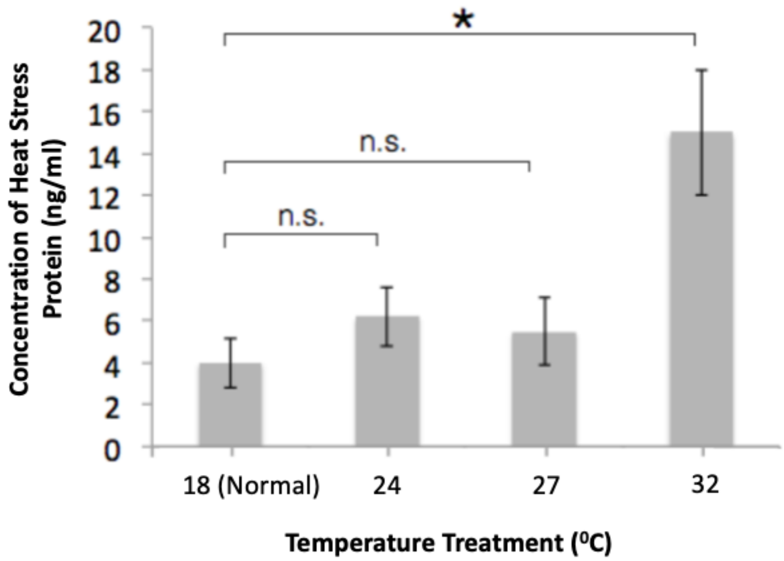


Figure 3. Concentration of Heat Stress Protein in plasma of in *Sesarma* crabs in different temperatures. Mean concentration of heat stress protein in plasma from 15 crabs is shown. (* $P<0.05$; n.s.= not significant, based upon two-tailed *t*-tests). Error bars show standard deviation.

**Note:** Figure 3 depicts differences in group means as bar graphs, rather than as means plots as shown in Figures 1 and 2. Some disciplines or journals prefer bars to represent means, while others restrict bar plots to only represent the accumulation of some quantity (i.e., the y-axis is a percentage, or count data that accumulates from zero up to the top of the bar). Check with your professor to see if they have a preference. Also note the alternative, yet equally valid, way of showing statistically similar groups, as compared to the use of letters in Figure 1."

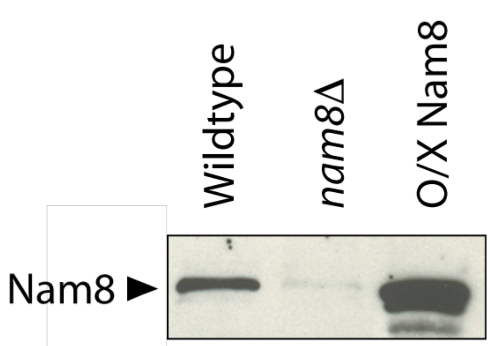


Figure 4. Abundance of Nam8 protein in various strains of *Saccharomyces cerevisiae* as determined by Western blot. *S. cerevisiae* extract (50 μg total protein) was separated by 10% SDS-PAGE and blots were probed with α-Nam8 antibodies. Extracts shown are from wildtype *S. cerevisiae*, a strain lacking the *NAM8* gene (*nam8*Δ), and a strain that overexpresses the *NAM8* gene (O/X Nam8). The position of the Nam8 protein is indicated by an arrowhead.

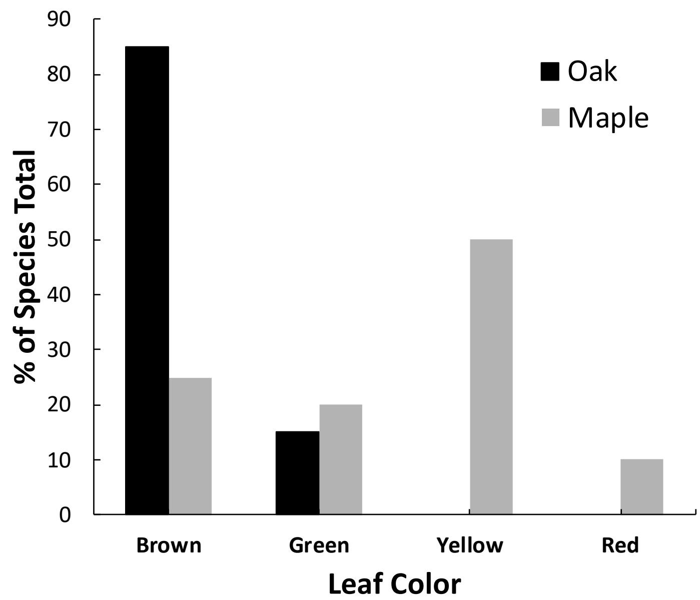


Figure 5. Percent of leaves in each color category, distinguished by species. Leaves were collected in a 10m x 10m plot in a suburban woodlot on the campus of The College of New Jersey. Oak: $N = 360$; Maple: $N = 400$.

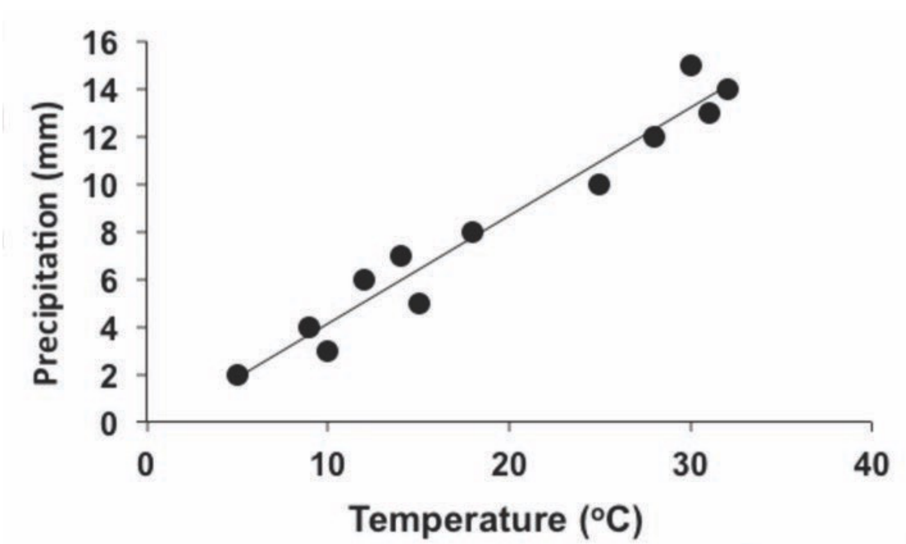


Figure 6. The relationship between average annual precipitation and average annual temperature for 12 cities in North America. Averages were calculated from 2000-2016. Data were obtained from the US National Weather Service. See Methods for identities of the cities.

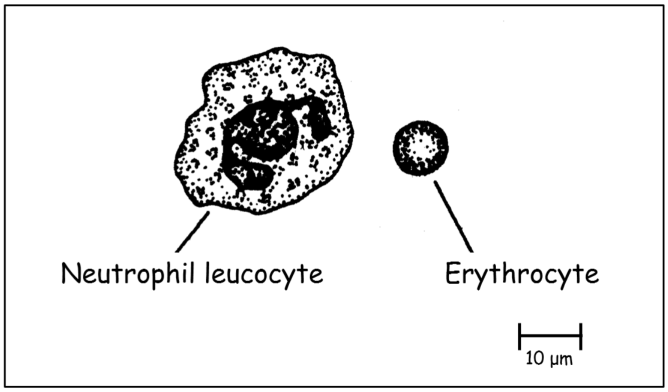


Figure 7. Human blood cells. Blood smear stained with Wright's stain.

**Note**: This format can be used for either micrographs or drawings. Never draw the circular field of view seen through the microscope ocular (eye piece). The size of objects is indicated by including a scale bar, which typically is placed in the lower right-hand corner of the figure. NEVER include in the figure legend the magnification of the image or the power of the objective lens used. When labelling details, use simple straight lines, not arrows.

## SCIENTIFIC WRITING, GRAMMAR, AND PARAGRAPH STRUCTURE

For all research papers, you should be able to utilize a style of writing, called *scientific writing*. This style is a form of technical communication that is designed to relay information that can be interpreted the same way by multiple readers and/or observers. The goal is to report your findings and conclusions clearly, and with as few words as necessary. Your audience (usually other scientists) is not interested in flowery prose; they want to know your findings. You should try to convey relevant information so that all readers of the report will understand your conclusions.

Proper grammar is also very important to achieve clarity and understanding. For this endeavor, your writing should be in complete sentences and easily understood. It should conform to the conventions of standard written English (sentence form, grammar, spelling, etc.). Your ideas will have little impact if they are not communicated well. Remember that scientific terminology very often has precise meaning. Be certain you choose your words and punctuation correctly and wisely. The worst mistake in science is allowing a misinterpretation of results due to lack of clarity (that includes poor grammar)!

Paragraph structure is as important to good writing as sentence structure and grammar. Make sure to break your ideas into individual paragraphs. Each paragraph should follow a single idea or theme, and should flow logically into the next. The opening sentence is the most important sentence of your paragraphs, as it is the "theme" of the paragraph. The opening sentence should be a statement regarding what the paragraph is going to describe. The following sentences should develop the theme or support the argument presented in the opening sentence.

## ADDITIONAL GUIDELINES FOR WRITING YOUR RESEARCH PAPER

1. Italicize the genus and species name (when you are handwriting genus and species name, underline them, instead). Spell out genus the first time it is used; thereafter, abbreviate it using just the first letter. *E.g.*:

    *Drosophila melanogaster*
    *Danio rerio*
    *Crotalis horridus*
    *Orconectes rusticus* (first time)
    *O. rusticus* (after the first time, but never to begin a sentence)

2. Common names should not be capitalized unless their name includes a proper noun. *E.g.*:

    black-capped chickadee
    white-tailed deer
    Bonaparte's gull
    Thompson's gazelle

3. Taxonomic names (e.g., species, genus, phylum, etc.) are singular nouns. *E.g.:*

   *Incorrect:* "*Danio rerio* are an important model of vertebrate development."
   *Correct:* "*Danio rerio* is an important model of vertebrate development."
   *Incorrect:* "Echinodermata are one of three deuterostome phyla."
   *Correct:* "Echinodermata is one of three deuterostome phyla."

4. Present all measurements as an Arabic numeral followed by an *abbreviation* of the units. Do not write out the number or the units. The only instance in which you should write out the number is if it is the first word of a sentence.

   *Incorrect:* “The trees were ten meters apart.”
   *Correct:* “The trees were 10 m apart.”
   *Correct:* “Fifty-six trees were measured.”

5. When writing numbers, you should spell out every number that starts a sentence. In addition, spell out all numbers one through nine, unless the number is a measurement. For numbers greater than ten, you can write the number. *E.g.*,

   *Incorrect:* “57 birds were included in the analysis.”
   *Correct:* “Fifty-seven birds were included in the analysis.”
   *Incorrect:* “We used 5 temperature conditions.”
   *Correct:* “We used five temperature conditions.”
   *Correct:* “Out of 63 birds captured, 57 were included in the analysis.”

6. Number all pages except for the title page.

7. **Consult with your individual professor regarding preferred font sizes, line spacing, margins and line justification.** If not otherwise instructed, use the following default formatting: the text should be double-spaced, other than the abstract, literature cited, or legends, which should be single-spaced. Use 11- or 12-point type. Margins should be set to 1” for top, bottom and sides of the page.

8. **Avoid direct quotes**. In most cases you should paraphrase (and then cite) the reference. You should use direct quotes only if a reference says something in an unusual way or if a statement is so contrary to current understanding that you want to prove that you did not misunderstand the original text.

   - **A Tip on Paraphrasing and Avoiding Plagiarism:** When you collect information from a source, take paraphrased notes using bulleted points and incomplete sentences (i.e., copy the idea, but not the verbatim text). Then, when you write your paper, turn your own notes into complete sentences and parenthetically cite the original source. Now your writing is two steps removed from the original text--you will have captured the idea, but in your own words. If you do feel the need to write a direct quote in your notes, place quotation marks around the quote. That way when you use your notes to write the paper two weeks later, you will not mistake a direct quote for your own language, inadvertently plagiarizing the source. This technique not only helps avoid plagiarism, but also encourages you to think about the essence of a concept, rather than the specific phrasing used to convey it.

## COMMON WORD USAGE ERRORS TO AVOID

**Based on/Based off**

The correct phrase is "based on." Although one's comments may be "off base" (*i.e.*, mistaken or inappropriate), the expression "based off" is NEVER grammatically correct. The expression "based on" is derived from the phrase "on the basis of."

*Based on the data collected, we concluded that nitrogen was the limiting nutrient.*

**Compliment/Complement**

To "compliment" means to give praise, whereas to "complement" means to be compatible.

**Compose/Comprise**

The word "compose" is synonymous with "make" or "make up" and usually is followed by the word "of". The word "comprise" is synonymous with "is made up of" and is never followed by the word "of".

*A full lab section typically is composed of 24 students.*
*Twenty four students typically comprise a full lab section.*

**Data**

The word "data" always is **<u>plural</u>**, and therefore **<u>requires a plural verb</u>**.

<u>Correct</u>: *The data were compared for each of the species.*
<u>Incorrect</u>: *The data is compared for each of the species*

**Effect/Affect**

"Effect" is a noun; "affect" is a verb.

*The effect of temperature on enzyme activity was examined.*
*Temperature affected the activity of the enzyme.*

**Fewer/Less**

"Fewer" is used for things that can be counted. "Less" is used for individual groups referred to as a unit. (Hint: If you use a plural verb, then it should be "fewer"; if you use a singular verb, use "less".)

*There were fewer data points. Less information was collected.*

**If/Whether**

The word "if" is used in a conditional construction; it is (or could be) used with "then". The word "whether" is used in discriminating constructions; it is (or could be) used with "or not".

*If the average value for the controls is greater than zero, one must subtract it from the average value for the treatment. (If the average value for the controls is greater than zero, then one must subtract it from the average value for the treatment.*

*The purpose of the experiment was to determine whether temperature affected growth rates. (The purpose of the experiment was to determine whether or not temperature affected growth rates.)*

**Imply/Infer**

The word "imply" means "to suggest", whereas "infer" means "to conclude".

*The significant interaction between time of day and foraging activity implies (suggests) that birds view afternoon foraging as costly.*

*From these results, we can infer (conclude) that birds avoid areas with high predation risk.*

**Its/It's**

Use "its" as the possessive form of "it." Use "it's" as the contraction of "it is." But do not use contractions in formal scientific writing.

**Lose/Loose**

"Lose" is the opposite of "find." "Loose" is the opposite of "tight."

**Sex/Gender**

In Biology, when referring to males and females, always use the word "sex" instead of "gender." "Sex" reflects biological distinctions between males and females in all dioecious species, or between male and female organs in monoecious species. In contrast, "gender" is a concept that integrates biological, social and cultural differences, and which applies only to humans.

**Significant**

The word "significant" has a special meaning in science. It is used **only** when one uses (or implies the use of) "statistically" with it. Otherwise, one should use other words such as "substantially".

*The mean value was significantly higher ($p < 0.05$) in freshwater than in marine species of algae.*

**Than/Then**

Use "than" when comparing things.

*Boulders weigh more than pebbles.*

Use "then" when referring to chronology.

*First we baked cookies, then we ate them.*

**Vial/Vile**

A "vial" is a vessel. To be "vile" is to be repugnant or morally reprehensible.

*We opened a drawer and found some dirty Drosophila jars from last year's Genetics course. Those vials were vile!*

**Which/That**

This pair of words causes trouble for a great number of people. "That" is used when describing a subset of a group; "which" is used to further describe the group with modifiers that apply to all members of the group. "Which" is followed by a comma, "that" is not.

Correct: *Cardinals, which prefer sunflower seeds, commonly visited the feeders.*
Correct: *Cardinals that prefer sunflower seeds commonly visited the feeders.*
Incorrect: *Cardinals which prefer sunflower seeds commonly visited the feeders.*

## SUGGESTED RESOURCES FOR SCIENTIFIC WRITING

Hofman, A. H. 2009. *Scientific Writing and Communication: Papers, Proposals and Presentations*. Oxford University Press, Oxford.

Katz, M. J. 2009. *From Research to Manuscript: a Guide to Scientific Writing* ($2^{nd}$ Ed.). Springer, New York.

Matthews, J. R., J. M. Bowen and R. W. Matthews. 2005. *Successful Scientific Writing: A Step by Step Guide for Biological and Medical Sciences.* Cambridge University Press, Cambridge.

## ABBREVIATED FORMATTING CHECKLIST

The following checklist will help you to quickly assess whether your research paper complies with the basic specifications laid out in the *Style Manual*.

| **Section** | **Yes?** | **No?** | **Refer to page(s):** |
|---|---|---|---|
| **Whole Document** | | | |
| Title Page Present | | | 5 |
| Abstract Present | | | 5 |
| Intro Present | | | 5-6 |
| Methods Present | | | 7-8 |
| Results Present | | | 8-9 |
| Discussion Present | | | 9-10 |
| Literature Cited Present | | | 10-12 |
| Tables Present (if applicable) | | | 13 |
| Figures Present (if applicable) | | | 13-17 |
| Page numbering, margins, fonts, spacing | | | 19 |
| All scientific names italicized and capitalized properly | | | 18-19 |
| Common names capitalized correctly | | | 18-19 |
| Numbers and units formatted properly | | | 19 |
| Direct quotes only used when essential | | | 19 |
| **Introduction** | | | 5-6 |
| Broad context provided | | | |
| Study system described | | | |
| Hypotheses/predictions stated | | | |
| Methodological approach briefly summarized | | | |
| **Methods** | | | 7-8 |
| Written in past tense | | | |
| 3rd person generally used | | | |
| Methods thoroughly described (refer to list in text) | | | |

| Section | Yes? | No? | Refer to page(s): |
|---|---|---|---|
| **Results** | | | 8-9 |
| Written in past tense | | | |
| Statistics reported correctly | | | |
| All figures/tables referenced | | | |
| Statistics/results reported in text not redundant with figures/tables | | | |
| Bulleted list (pg. 7) followed | | | |
| **Discussion** | | | 9-10 |
| Results interpreted in light of original hypotheses | | | |
| Remaining/new questions discussed | | | |
| Findings summarized, broader implications discussed | | | |
| **Literature Cited** | | | 10-12 |
| All citations in text included in Literature Cited | | | |
| All citations in Literature Cited are cited in the text at least once | | | |
| All citations formatted properly | | | |
| **Tables/Figures** | | | 13-17 |
| Tables/figures numbered according to the order they are referenced in the text | | | |
| All tables have headings | | | |
| All figures have legends | | | |
| All figure axes are clearly labeled, with units | | | |
| Figures do not contain un-informative stylistic embellishments | | | |