**How to Write a Scientific Research Paper**

Updated 2019

Prefacing Notes:

* These are the guidelines we will use for this class. They will differ in some ways from the writing guidelines you have been given in other science classes, but will follow what is generally done in the biological sciences. These guidelines are generic for Dr. Duncan’s upper-level courses. Refer to expectations given for your specific class for particular requirements, such as word length, due dates, etc.
* The best way to learn technical writing is by reading lots of technical papers and getting a “feel” for how technical writing sounds and studying how they are constructed. These papers are based on the rules detailed below.
* Each scientific journal has its own set of guidelines. I require that you use those adopted by the Ecological Society of America’s publications. These instructions can be used in place of the instructions below, or in conjunction with them. This URL takes you to those instructions: <https://esajournals.onlinelibrary.wiley.com/>
* A major proportion of the grade on your paper is based on whether you follow these guidelines. Read these guidelines right now, when you begin writing, at various times while you are writing, and when you think you are done writing your paper.

These guidelines are designed to help you write scientific research papers for all of your biology courses. They are only guidelines and may be superseded by specific instructions from the instructor for a specific course. They will also be helpful for any objective scientific writing that you must do, but they are geared for the specific format found in biological journals. There are slight differences in the details between different biological journals and there may be slight differences between your instructors' expectations, but these guidelines focus on the commonalties. Your instructor should provide an example format from an appropriate journal. If you have any doubt about specific details, ask your instructor.

**Budget your time**: Writing a good scientific research papers is not difficult but it is time-consuming. It is almost impossible to "pull an all-nighter" and get a good grade on a scientific research papers. It will be very obvious if you have spent little time on it and your grade will suffer. You also will not learn very much by rushing through it. Start early! Plan ahead and start on your paper early. You can start on your Introduction and Materials and Methods before your experiment is completed.

**Maximize your grade**: Most errors on scientific research papers are because students failed to follow directions. This document is a very extensive explanation of how to design and write your scientific research paper. We have spent a lot of time preparing these guidelines so please use them! There is no reason why you shouldn’t earn an A on your paper if you follow these guidelines. Also, use the resources of the Writing Center (Humanities Center 102) at any stage of the writing process. They can help you outline your organization, write your ideas clearly and edit your text. Bring this guide with you when you go to see them. They may not be able to understand the concepts, but should be able to help you write clearly, efficiently, and correctly. Arrange an appointment with the Writing Center early, as they get busy at the end of the semester.

**Writing style and paper format**: Scientific research papers should be written at a reading comprehension and knowledge level of an undergraduate biology student such as yourself or your classmates. Do not try to sound elaborate and pompous as many people misperceive scientific writing to be (e.g., by using big words). Strive for clarity and efficiently. Avoid ambiguity. Use as few words as possible and do not use words that you do not understand.

For those of you planning careers in the sciences, you will be called upon frequently to communicate your findings with your peers. It is essential that you effectively articulate your ideas, and that you follow directions for formatting. Even if you will not be writing many papers in your professional career you will almost definitely be reading and interpreting them. If you become a practicing MD, as do many of our students, you will need to continually review the medical research literature. You need to understand the format to understand the research papers therein. Therefore, your papers will be graded for content, formatting, grammar, and spelling. If you have questions about grammar, style and punctuation you may consult W. Strunk and E. B. White's book, The Elements of Style, published by Macmillan or Writing Papers in the Biological Sciences by Victoria McMillan, published by Bedford Books. You may also use the Writing Center as a resource for questions on grammar, punctuation and style.

The overall format of the research paper is based on the one used in scientific papers published in peer-reviewed research journals (aka the primary literature). Think about your work as a research paper not a lab report. Avoid terms such as, "lab instructions," "lab instructor" etc. If you are not familiar with this format it would behoove you to go to the library and read a few scientific journal articles (but do not emulate Science or Nature as these journals do not follow mainstream formatting rules).

One thing to keep in mind about scientific writing is that not every reader reads the entire article. Many read only part based upon their needs and how well the first part was written. Each section of a scientific paper has a different purpose, as explained below. It is very important that each section of the paper have the appropriate information and only the appropriate information. Each paper should contain the following sections:

**1. Title Page**: On your title page, include a descriptive title, your name, the name of your partners (if any) and the date (see example at the end of this section). Do not treat the title as a throwaway, it is very important. The title should be extremely specific, giving your key finding if possible, in order to communicate what you did in your study without giving the impression that it covered a broader topic than it did. Very general titles are too vague to be helpful. The first author listed is the one who did most of the writing; otherwise, use alphabetical order according to last name.

**2. Abstract**: This is an extremely concise summary of the entire paper. One point of an abstract is to give the reader the chance to figure out whether they want to read the whole paper. With the volume of scientific information that is being published today, reading an abstract is a quick way for a scientist to evaluate if the subject matter in the paper is sufficiently close to her/his interests to warrant further reading.

Aim for 250 words or less for your paper. Leave out details that are not needed for understanding the very basics of your study. Start by providing a brief overview of the background information that is the context for your study. Then briefly describe your purpose and experimental hypothesis. Give a short summary of your basic methodology, followed by a summary of your main results. Provide a short discussion of the results and a brief conclusion. All in all, be very brief, but don’t sacrifice clarity. The abstract should not be written until the rest of the paper is completed (only then will it be clear to you what to include). Here are several other rules to follow with abstracts:

* Summarize comparative statistics without providing the mathematical details (e.g., don’t provide P-values).
* Descriptive statistics are appropriate. If a mean is given it should be accompanied by the SD or SE.
* Abstracts do not include citations.
* Be sure to describe your study species with scientific name
* Double-space the abstract

**3. Introduction**: Essentially, this section provides 1) background information, 2) the purpose for your experiment, 3) and a statement of your experimental hypothesis, and 4) a very brief non-detailed summary of the methods, Background: Give the reader the historical and conceptual background to the study. Concepts should be directly relevant to the study. Avoid writing style like you find in a textbook or magazine article. It is a good idea to model your structure after published scientific articles of good quality. Start by reviewing the literature you have gathered on the subject. Then, design an outline of the *relevant* concepts you have learned. This outline should be designed to ‘motivate’ the hypothesis that will be presented at the end of the introduction. As Dr. Duncan likes to put it, the introduction should be written such that you are “holding the hand of the reader as you walk them down a path that leads them to your purpose.” This means that you should start with broad information, explaining the relevant basics of your study system, then get increasingly specific about the particular question you address. The ideas presented should logically flow from one to the next. Don’t leap from one topic to another. Avoid mentioning a bunch of information gleaned from the literature, hoping that it is enough background “filler”. As part of the introduction you should introduce your study entity (e.g, the species, ecosystem, gene, protein). For species, you must present the scientific name (genus and species) formatted correctly (italics or underlined; lowercase for species name; e.g., *Lemna minor*). The final stage of the background material should lead to the presentation of your purpose and hypothesis. By the time the reader gets there, it should be very clear why you chose to ask the question you asked, and why you predict the results that you predicted in your hypothesis. Purpose: It is very important that you explicitly state the purpose of the experiment. This is usually done in the last paragraph of the introduction after the background information has been reviewed. Hypothesis: You need to state your *investigative hypothesis*. Do not describe your null and alternative hypotheses – these are specific methodological steps used in experimentation, especially when conducting a statistical test. Your experimental hypothesis is a statement of what results you expect to find from your experiment. Be as specific as possible. Don’t say “We hypothesized that nutrient X would affect the growth rate of *Lemna minor* populations.” Instead say “We hypothesized that addition of nutrient X would cause more rapid growth of the experimental *Lemna* populations than the control populations.” Be sure that your hypothesis is justified based on the background information and ideas you have presented. Summary of the Methods: After you state your purpose, you should very briefly summarize your methodology. This should be done in 1-2 sentences simply to give the reader a ‘heads up’ on how your experiment was designed (e.g., we sampled fish from lakes with high and low pollution levels).

Additional points:

* Go back to your text when done. Look at every major concept or hypothesis that you discuss. Check if the rationale for it is explained in the background material. Ask: will reader understand why I am going to test this hypothesis?
* Because the introduction is a description of research completed before your experiment it should never contain any of your results.
* The introduction and discussion should mirror one another. When you write your discussion, you should return to the themes presented in the introduction.
* Do not attempt an exhaustive broad review of the literature generally related to your project. Do, however, spend time describing and citing the key studies that have been done on questions very similar to yours.
* Explain concepts likely to be unfamiliar to a scientifically-literate reader when they are first mentioned (e.g., define what a thallus is the first time you mention it).

**D. Materials and Methods**.

* Scope: The Materials and Methods (M and M) section should report how, when, where, and what you did. It should describe the study site and procedures. It is critical that the M and M section provide detailed descriptions of what was done. The goal is that after reading this section, the reader should be able to repeat your experiments. Provide the reader with details of experimental design, including control and experimental treatments, sample sizes of each and the reasons why these sample sizes chosen, and descriptions of unusual apparatus and techniques used. The M and M must be written in past tense. Different fields of biology have their own idiosyncrasies, so check with your instructors on what specifics are expected of your paper.
* For ecological studies, the M&M often starts with a description of the study site. This is analogous to describing the stage upon which the actors will perform. Describe the geographic location (from lat and long; state, county and nearest city; ownership of the study area; and size of the study area) and important ecological and landscape features. Also include the timing of the study. Sometimes it is relevant to list the climate and weather conditions (do you know the difference?) of when the study was conducted, but only if it is relevant to the hypotheses being tested/phenomena you studied.
* Do not provide a list of materials. The M & M is written using complete sentences.
* For protocols that come from previously published sources (e.g., your lab handout), you should cite that source (cite your lab handout like any other publication) and still give *in your own words* full details of the procedure with emphasis on any changes made. Note any changes in procedures from your handout.
* Omit minutiae that are obvious or self-evident (e.g., how/that you labeled your containers or measured volumes of liquid). Do include those methods that would not be intuitive for reader (e.g., how you determined whether the plant was alive or dead, or, the magnification power of a microscope used).
* You may use subheadings and divide this section if appropriate, but this is only really needed for very long papers.
* If you are using a statistical procedure, you should describe which statistical test was used, and in some cases it will be appropriate to describe why that test was appropriate. For example, you might state "To compare the two populations, a Mann-Whitney U test was used, since the data from the populations were not normally distributed." State explicitly what your alpha level was (level of significance) which will usually be alpha = 0.05. Cite the computer program or textbook used to conduct that analysis and include this source in your Literature Cited.
* Never present results in the methods section.

**E. Results**: The results section of your paper objectively describes your findings without any interpretation. The results are purely the data you find as a result of your work.

When writing the Results, you need to decide on the best way to present the summary of your data. Some results will need to be presented or described in the text, while other results are presented in tables or figures. In ecological studies, the actual data are only rarely presented because they are so extensive. Instead, the data are summarized using descriptive statistics that are presented in either the text, or a graph or table. Descriptive statistics include the mean, median, or mode; standard deviation (SD) or standard error (SE); range of values; and sample size (N) if it is not given in the methods section. Comparative statistics are the results you get from completing statistical tests (e.g., t-test, correlation) that analyze sets of data.

**Text**: The texts of most Results sections need to include two major items: a description of the trends or patterns in the data, and a description of the results from statistical tests or analyses. For any particular set of results, start with a description of the trend, then provide the results of any statistical test. Trends in the data can be summarized with the descriptive statistics described above. The actual numerical variables (e.g., the means) of descriptive statistics are given in the text when there are few treatments or variables to describe. However, if there are many treatments or variables to provide descriptive statistics for, a figure or table may be more appropriate way to display these numbers. When descriptive statistics are presented in the text, their presentation needs to follow a particular set of guidelines for efficiency and clarity. For example:

"The mean number of thalli at day 21 in the control treatment (mean = 15.3 thalli, S.D. = 2.4, range 12 - 17 thalli, n=6 cups) was greater than that in the experimental treatment (mean = 12 thalli, S.D. = 2.1, range 8 - 14 thalli, n=6 cups).”

In the previous sentence, note that the sentence provided a ‘picture’ of what the data looked like. Providing this description of the data is a critical first step in the Results section. Note also the punctuation used to separate groups of variables that belong together.

If, however, the descriptive statistics are presented in a table or figure, then you will need to provide a written summary of the trend/pattern of the data in the text. For example, if the descriptive statistics in the above example were provided in a figure, then you might describe the trend this way:

“Average thalli number at day 21 was greater in the control than experimental treatment (Figure 1).”

In this case, your summaries of the results should describe the patterns and trends that you think are important for the reader to notice when viewing the table or figure. Don’t focus on the trends or details you think are unimportant for understanding your results.

A common strategy used in many research papers is to present in the text a non-numerical description of the patterns in the data, followed by a summary of the statistical tests, including the numerical results. A figure would then illustrate the details of the pattern graphically. Learning how to best design a results section for any experiment can be difficult, so consult your TA or instructor for advice. The following sections describe what you need to do to construct tables and figures for most scientific research papers.

When writing the text, do not structure your writing around references to the figures and tables. For example, don’t say “Figure 1 shows the means from the control and experimental treatments at day 21.”. Instead, in this case you would describe the trend and refer to figure parenthetically. For example, “Average consumption by day 21 in the control group exceeded that in the experimental group (Figure 1).”

***Describing comparative statistics in the text***: Results from statistical tests are often provided in the text. These usually follow the presentation of the descriptive statistics, and are often in the same sentence. When presenting comparative statistics in the text, it is important to provide the information following a particular set of guidelines for efficiency and clarity. When presenting results of statistical tests, you need to include the name of the statistical test, the important test statistic(s), the P value, and the degrees of freedom. Do not provide the critical value from a statistical test, for the reader can figure that out based on your alpha level and your reported degrees of freedom. Do not provide alpha (it should be reported in the Methods). Returning to our example, here are several ways the comparative statistics in the text might read:

If the descriptive statistics are in a figure (Figure 1):

“While the feeding rates of group 1 were higher than group two (Figure 1), these differences were not significant (t-test, t = 2.33, P = 0.125, d.f. = 9).”

If the descriptive statistics are in the text:

"While the feeding rates of group 1 (mean = 15 items/minute, S.D. = 2.4, range 12 - 17 items/minute, n=10 animals) were faster than those of group 2 (mean = 12 items/minute, S.D. = 2.1, range 8 - 14 items/minute, n=10 animals), these differences were not significant (t-test, t = 2.33, P = 0.125, d.f. = 9).”

***Use the terms significant or non significant***: Use the word “significant(ly)” to indicate differences that were statistically different (usually P < 0.05). Any two sets of data are different, by definition. You only have justification for claiming there is an important difference between two sets of data (or an important relationship if you are doing correlations or regressions) if there is a statistically significant difference. Results not statistically significant can be described as “nonsignificant” or “not significant” (don’t use the term “insignificant” instead, that would imply something different). Using the language of ‘significant/nonsignificant’ alerts the reader to the outcome of your statistical tests. Thus, to avoid confusion, don’t use these terms in the text when you mean to say‘important’, ‘major’, or ‘meaningful’. This applies to all sections of your paper, not just Results.

***Other rules about the Results text:***

* Do not discuss the Null hypothesis and alternative hypothesis. These hypotheses are steps in a statistical test or scientific method, but shouldn’t be mentioned in a technical paper for publication. Instead, discuss your investigative hypothesis, the hypothesis that frames the question you are asking.
* Do not give equations for statistical tests unless you have created your own.
* Do not attempt to interpret or discuss your data in this Results.
* Do not present methods or experimental design in this section.
* When making statements about data that are presented in tables or figures refer to the appropriate numbered table or figure that contains the data.
* In this section and elsewhere, NEVER refer to the “instructor” or “professor” (e.g., “duckweed was supplied by my professor”). Instead, write the paper as if you are a research scientist working on your own research.

**Figures and Tables:**

***General***: Tables are used to present results (descriptive or statistical) when it is more efficient or helpful than presenting those results in the text. Data can also be summarized in figures for efficiency, or to present illustrations of data trends that would be difficult to describe in the text (e.g., correlations, regressions, change in population size). Most researchers find it easier to view data in figures than in tables.

Never provide tables or figures that are not referred to in the text. If you present data in a figure or table, in the text you *must* summarize the trend illustrated by the figure or table. For example, “By day 14, the mean number of thalli in the control treatment exceeded the mean number of thalli in the experimental treatment (Figure 1).”

Never refer to tables or figures directly. For example, don’t say “In table 1 the means for the control and experimental treatments are presented”. Instead, refer to the table parenthetically, and describe the data directly. For example, “The means for control populations were consistently higher than those of the experimental treatments (Table 1)”.

Note the way the figure is referred to at the end of the sentence, thus directing the reader to see the figure where this trend is provided in detail. The same type of notation is used for referring to tables in the text.

It is important that you do not provide the same information more than once in the Results section. This wastes precious space (and the reader’s time), and creates more work for you. Thus, if you present a mean and SD in a figure, it should *not* also be presented in the text or a table.

Figures and tables should be constructed such that they can stand-alone. That is, all the information required to understand a figure or table must be included in it.

Each Table and Figure should be on its own page at the end of the scientific research papers.

***Figures***: Figures are any graphs or illustrations included in a research paper (e.g., bar graph, map, picture). Graphs are displays of data, while illustrations are drawings, diagrams, or pictures. Data or descriptive statistics should usually be presented in graphs as it is easier to see trends in the data. Graphs are often the clearest and easiest way to depict all of your data, they give the reader a "feel" for all the points (e.g., scatter plots, bar graphs). There are many rules to follow when constructing your figure. The following are rules important for formatting graphs, specifically:

* A figure is composed of two elements: the figure and the figure legend.
* The legend of a figure describes the components and contents of a figure in words. The legend includes any detail that is necessary to interpret the figure. Legends always go below the figure.
* In graphs, each axis is labeled, and the units of measurement are specified. When you present a figure in a lab write-up, the variables, the scale, and the range of measurements should be clear. Use a font of 12 pt. or larger for axis labels and numbers.
* A key must be provided that explains the patterns used to portray the data. The key should be placed within the confines of the graph without overlapping any of the data displayed.
* Do not include a border around the entire figure. Nor should you include a border around the area in the graph that contains the illustrated data. Only the axis should be included.
* Do not include horizontal or vertical grid lines across the graph.
* With rare exception, do not include a graph title.
* Only use black, white, or gray in your figure. Most publications will not publish color unless you pay extra.
* When presenting means, you need to supply the SE or SD with each mean. Do not just ‘check the box’ in MS Excel that asks you if you want to display ‘error bars’. The automatic error bars provided are completely meaningless. For details on how to provide SD or SE in your graph, see the help function in Excel, or ask your instructor for guidance.
* Number each figure consecutively according to the order they are referred to in your text using Arabic numerals (e.g., Figure 1 should be the first figure referred to in the text.)
* If the figure is how you are presenting your descriptive statistics, then include all the important descriptive variables relevant to your results (e.g., mean, SE, range, N). Some of these can be described in the legend. SE or SD for each mean should be plotted as error bars on the graph. The legend should explain what the error bars are (e.g., "Values shown are means of 10 samples +/- 1 standard deviation."

Example Figure and its legend:



Figure 1. The mean number of thalli per cup during the course of the experiment (n = 8 cups per treatment). Error bars represent +1 standard error.

***Tables***: The rules of constructing tables are similar to those of figures (so refer to the above). The important point is that the data are presented clearly and logically. The decision to present data in a table rather than a figure is often arbitrary, however, a table may be more appropriate than a figure when the data set is too small to warrant a figure, or the data set is large and complex and is not easily illustrated. Here are some rules to follow when constructing tables:

* Generally, only use tables if you can't put the data in a figure.
* Tables need to have a minimum of three horizontal lines. One horizontal line is the top border, a second is the bottom border, and a third separates the column headings from the data. Lines are never used to separate rows of data, though, in long tables, groups of data are sometimes separated by horizontal lines.
* Never include vertical lines in your table.
* The descriptions of each table are called table ‘headers’ or ‘titles’. Like figure legends, they must be thorough. Unlike figure legends, table headers should be placed above the table.
* Number each table consecutively according to the order they are referred to in your text using Arabic numerals.
* Columns and rows of numerical data in your tables must be labeled, including the units of the data (e.g., pmol glucose/mg/h).
* Do not label every number in a row unless it is unique.
* Round to the same significant figure for all numbers in a column.

Example Table**:**

Table 3. Means and standard deviations (in parentheses) of variables describing the forest in survey plots in the ridge and valley (n = 7 and 8 plots, respectively) sections of Oak Mountain State Park, Alabama. P values represent results of Mann-Whitney U tests comparing the two communities.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Ridge | Valley | P value |
| Mean # trees | 13.2 (2.3) | 14.6 (4.5) | 0.370 |
| Mean tree height (m) | 15.2 (4.5) | 30.5 (7.2) | 0.042 |
| Mean # of species | 4.3 (2.2) | 8.3 (2.7) | 0.033 |
| Mean litter depth (cm) | 5.2 (2.3) | 12.4 (6.2) | 0.011 |

**F. Discussion**. In the discussion you will lead the reader through a logical critique of your findings and towards your major conclusions. There are four major steps that need addressing to achieve this: 1) interpretation of your results and formation of new hypotheses (if needed); 2) critique of your methodology (if needed), 3) relation of your results to those of other studies, and 4) offering of conclusions. You will need to present a thorough interpretation and presentation of these issues in a logical order that flows nicely. It is in the discussion where we instructors are looking for you to employ higher-brain function (i.e., critical thinking!). Any automaton can format a paper correctly - you, on the other hand, need to think carefully and demonstrate that you have an in-depth understanding of the concepts and the relevance of your own research. Here are some pointers on writing an effective discussion section:

* Generally, a discussion is the mirror image of the introduction. While the introduction starts broad (overview of your study system) and finishes narrow (your hypothesis), the opposite is true for the discussion. Start the discussion with a summary of your findings and how they relate to your experimental hypothesis (not null or alternative hypothesis). The overall shape of the paper is an hourglass (broad – narrow – then broad again).
* Interpret the results that were obtained, being careful to state any assumptions that you are making in arriving at a particular conclusions. Did you find support for your hypothesis? Why? Why not? Or why is it not clear? Provide more than a “yes, the results supported my hypothesis” or “no, the results did not support my hypothesis”. Provide in-depth analysis based on the comparative statistics (e.g., the strength of the p-values) and patterns/trends in the data. Even if your results are as expected you should mention and discuss any reasonable alternative explanations for them. As an example, "Our results are consistent with the hypothesis that crawfish in freshwater would have a higher metabolic rate due to the cost of osmoregulation, however the stress of being handled may have increased their metabolic rate as well."
* Carefully explain what biological factors led to your results in your opinion. If, for example, you are conducting an experiment studying how plants respond to nutrients, then explain why you think your experimental and control treatments respond the way they did.
* A major component of the discussion will be relating your findings and conclusions to those of others that have studied your system, or similar systems. Refer to scientific books or papers in peer-reviewed journals. This is part of your interpretation of your results. Do your findings support or conflict with those of others working in the same research area? Are your findings of importance to long-standing questions in the field? If your results completely go against all the trends found in the literature for your question/study system, do you still have confidence in your findings? After discussing your findings and those of others, explain whether you still think your findings/hypotheses are accurate. Alternative hypotheses and explanations for your data should be given here if your results are unexpected. Or, do you think you should revise your hypothesis, or construct a different one? If so, what is the new hypothesis? Or do you wish to defend your hypothesis even if your results didn’t support it? Explain why. Bottom-line: you need to employ some critical thinking in the interpretation of your results and how they relate to other studies.
* Critiquing your methodology. Different professors want different things here. I expect you to provide what you would need to put in a real research paper. Sources of error should not be a laundry list of all possible problems. Rather, discuss factors that you truly think influenced the outcome. If you don’t think a potential source of error likely happened, then don’t mention it. Do not talk about or use the catch-all phrase “human error” unless you have reason to suspect that someone truly made a specific error. If you think there were mistakes, then be very specific about how your actions, decisions, experimental design, etc., may have affected the results.
* Discuss how you would improve your study, and/or, what the next step of research would be if you were to continue working on your study system.
* Your discussion should end with a few conclusion statements that provide the reader with the “take home message” or “bottom line”.

Important points about Discussions:

* Do not report the figures from comparative statistics (e.g., P-values). Such information should only be in the methods. Summarize in words, not values, the main findings from the comparative statistics.

**G. Acknowledgments**. In this section, you should thank the individuals and organizations that helped you with your paper. For example, they may have helped take your data, assisted you with statistics, read your paper and offered comments, or provided supplies for the project. Also thank institutions that allowed you access to their land (e.g., parks or preserves), provided data, or provided infrastructure (e.g., lab space, computers etc.).

**H. Literature Cited (and In-text Citations):**.

**In-text Citations**: Throughout you paper you should provide reference (citations) to any of the sources of information that you have summarized in the text. Any information that is not derived from your personal experience needs to be cited in the text. Most of this information will be in the Introduction and Discussion, but there will usually be some sources cited in the Materials and Methods. Unlike papers written for many of your non-science courses, you are to never quote your sources of information in a scientific paper. Instead, present the information in your own words. Also, do not use footnotes, give authors last names and year of publication, as follows.

Gannon and Wheatly (1994) reported that crawfish that moved from freshwater to saltwater had lower metabolic rates.

or

Crawfish moved from freshwater to saltwater had lower metabolic rates (Gannon and Wheatly, 1994).

If the source that you are citing has more than two authors, then it is cited in the text as follows (et al. means “and others” in latin):

Gibbons et al. (2002) showed that salamanders that are found in ponds with fish predators show reduced levels of activity.

or

Salamanders collected from ponds with predators showed less activity than those collected from temporary ponds (Gibbons et al., 2002).”

Any source cited in the text of the paper must be included in the Literature Cited section, and vice versa.

**Literature Cited or Bibliography**

The literature cited section at the end of your paper should contain the full bibliographic citation for each source cited in the text of the paper. Sources must be listed alphabetically by author's last name (surname). You should include all of the information necessary for someone else to find your source. Do not include any sources that are not cited in the text. Sources in the Lit Cited but not cited in the text cannot count towards any minimum required number of references for the assignment.

These are example bibliographic formats in the style used by the journal Ecology. Use these formats for your research paper, but other science courses may require a different style. Below are examples for books, book chapters, journal articles, and websites. If you have a source to cite that is not covered by one of these information sources, or the examples given, consult your teaching assistant or instructor. Pay attention to the minor details here.

Book

*General Format:*

Author(s). Year. Title, Edition\*. Publisher, City.(\*edition given only if > 2nd edition.)

*Example:*

Alberts, B., A. Johnson, J. Lewis, M. Raff, K. Roberts, and P. Walter. 2002. Molecular

Biology of the Cell. Garland Science, New York.

Book chapter

*General format:*

Author. Year. Chapter Title. ‘Pages’ in editor(s). Book Title. Publisher, City.

*Example with one author:*

Patzner, R. A. 1998. Gonads and reproduction in hagfishes. Pages 379-395 in J. M.

Jorgensen, J. P. Lomholt, R. E. Weber, and H. Malte, editors. The Biology of Hagfishes. Chapman and Hall, London.

*Example with two authors*

Dodd, J. M., and M. H. I. Dodd. 1985. Evolutionary aspects of reproduction in cyclostomes

and cartilaginous fishes. Pages 295-319 in R. E. Formen, A. Gorbman, J. M. Dodd, and R. Olsson, editors. Evolutionary Biology of Primitive Fishes. Plenum Press, New York.

Journal article:

*General Format:*

Author. Year. Paper Title. Journal **volume**:pages.

*Example with one author*

Sower, S. A. 1998. Brain and pituitary hormones of lampreys, recent findings and their

evolutionary significance. American Zoologist **38**:15-38.

*Example with more than one author*

Bird, D. J., I. C. Potter, S. A. Sower, and B. I. Baker. 2001. The distribution of melanin-

concentrating hormone in the lamprey brain. General and Comparative Endocrinology **121**:232-241.

Information from Website:

*General Format for Internet Sources:*

Author(s). Year. Title of Document or Webpage. Sponsoring

Organization, Organization’s Location. Retrieved Month day, year from the World Wide Web: URL.

*Example:*

Duncan, R.S. 2003. Identification of tree species on the Birmingham-Southern

College campus. Birmingham-Southern College, Birmingham, AL. Retrieved December 19, 2010 from the World Wide Web: <http://www.bsc.edu/FILES/Classes/Duncan/trees.html>

*Notes and Explanations:*

*Year refers to when the document was written, posted, or most recently updated. If the year is not provided, this is one sign that it may not be a source that is reliable. If it is from a reliable source and doesn’t include a publication or posting date, then give the year that you read the information on the website.*

*Sponsoring organization is the entity that is posting the information. If this information is not provided, then the information is probably not from a source that can be considered reliable.*

*Author: For websites where the author is not given, treat the agency, institution, or organization as the author (e.g., the EPA).*

*Organization’s Location. If the organization has an office, headquarters, or any physical location*

**Peer-reviewed Sources**:

Most of the scientific research papers you will write in biology classes require that you obtain a minimum number of peer-reviewed sources of information (‘primary literature’) from the range of published materials available. Peer-reviewed literature should have been discussed during your first biology courses. In brief, the process of peer-review is where scientists critique drafts of scientific papers before they are published. This helps ensure that published information is accurate and well-presented. The BSC library provides a handout on how to determine if information is peer-reviewed, and where to find such sources (typically journal articles or book chapters).

Non-peer-reviewed literature (also know as ‘secondary literature’) is information that has not undergone peer-review. Below is a list of journal that are NOT peer-reviewed, but are often assumed to be peer-reviewed by students who are not careful:

National Geographic

Discover

National Wildlife

Economist

Natural History

Scientific American

The New York Times

World Watch

Note that the secondary literature is a great source of information for learning about your subject, especially since it is usually written in a non-technical format for non-scientists to read. They are very appropriate to cite in a typical scientific research paper, but will not count towards the minimum number of peer-reviewed sources required.

Note that many journals that publish peer-reviewed scientific articles also publish non-peer-reviewed reviews of important scientific events. Thus, just because an article is from the journal Science, does not mean it is appropriate to cite as one of the peer-reviewed literature sources you need to have for your research paper. Refer to the information on the library handout you received during the first lab to help you determine whether an article is from the primary or secondary literature.

**Final Tips on How to Write a Successful Research Paper:**

1. Follow Directions: Read and re-read the instructions and guidelines provided. Use the example grading rubrics provided to see whether you have missed any important points.
2. Work from an outline. Outline each section so that you know exactly what you need to say before you begin writing. Otherwise, you will find that during the course of writing, you wind up deleting sections of text (and losing hours of work) once a pattern of organization becomes apparent to you.
3. Communicate clearly: Learning to write effectively is one of the (if not *THE*) most important skill you can develop in college. If you can learn to communicate well in technical writing, then you will be a more effective writer in other disciplines and contexts. Check grammar; try using MS Word’s grammar check. Have you shifted between past and present tense within the paper? Have you used complete sentences? Do you switch between first- and third-person? Are there run-on sentences? Are any of your sentences possibly interpreted in different ways (i.e., they are ambiguous)? Your papers will be graded for content, grammar, spelling, and formatting. In short, each paper should be technically polished so that we will be able to understand your ideas.
4. Proofread your papers. There is no excuse for failing to proofread a paper with your name on the title page. An occasional glitch such as a typo is understandable. However you will lose credit for a paper that is riddled with typographical errors, missing lines and misspelled words. If you know that you are not a good speller, consult a dictionary to check the spelling of difficult words, or use a spelling checker on a word processor before you hand in a paper.
5. Get Help: Have someone else read your paper to help proofread. It can be exceedingly helpful to get comments from another reader. Ask your TA or instructor to review a polished draft of the paper. Make sure the person you choose is a good writer, or the advice you will get will not necessarily be useful. The folks at the Writing Center can be very useful.

**Grammar Tips from the Grammar Grouch:** While it is not my job to reform your grammar skills, below are a few problems that come up frequently

* Avoid slang and words with vague meanings (e.g., say ‘dilemma’ instead of ‘catch-22’). Avoid phrases like “dealt with” or
* Never quote anything in a scientific research paper. Summarize information in your own words.
* Whether you use first or third person (you can use either), be consistent in your choice.
* Scientific names need to be underlined or italicized, not both, and not bolded. The genus name is capitalized, the species name is not. No special formatting is used for higher taxonomic levels.
* If you talk about a correlation, or some other relationship, specific the directionality (e.g. “positive correlation”)
* Never say “prove” or “disproved”. We never prove anything using the scientific method. Instead, say something like: “Our data strongly suggest that …”
* The word “data” is plural. Datum is singular.
* A “hypothesis” is different from a “theory”. Make the distinction in your writing. Theories are phenomenological principles supported by many different studies and lines of evidence (e.g., the theory of evolution). Hypotheses are the specific expectations that you have about your study. Note that non-scientists often (and unfortunately) use the word ‘theory’ to mean ‘hypothesis’.
* Double quotations marks (“ ”)should only be used when actually quoting someone (which you shouldn’t be doing in scientific research papers). If you need to off-set a word, use single quotation marks (‘ ’).
* Use paragraphs to break up your text into sections unified under a common theme or topic.
* For numbers of one through ten, spell out the words. Use figures for numbers >11. However, always use figures if they have a unit associated with them (e.g., 2 cm). Numbers at the beginning of a sentence should be spelled-out, however, you can usually rewrite the sentence to avoid this.
* Be as efficient (space-saving) as possible without sacrificing clarity. For example, don’t write “…Tuesday April 23, 2004 through Monday April 29, 2004.”, instead, write “…April 23-29, 2004.” Note that a curious reader can always look to a calendar to determine the day of the week an event occurred.

*Sample title page:*

**EVERYTHING YOU WANTED TO KNOW ABOUT WRITING A SCIENTIFIC RESEARCH PAPER BUT WERE TOO AFRAID TO ASK**

**R. Scot Duncan**

**Biology Department**

**Birmingham-Southern College**

**BI XXX, Tuesday PM Lab**

**Spring 2019**