Chapter 4: Scientific Communication: Reading, Writing, & Presenting

<table>
<thead>
<tr>
<th>Topics</th>
<th>How to find and read Scientific Literature, Execute scientific writing, and Present your Research</th>
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<td>4. University of Texas Undergraduate Writing Center</td>
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Chapter 4: Scientific Communication: Reading, Writing, & Presenting

Your ability to pen and present your findings is how you address your research colleagues. It quickly becomes one of the most important methods by which you advertise both your accomplishments and your potential to peers, future employers, and the public at large.

If you are a typical university undergraduate student, your previous writing exercises have been focused on fictional creative writing. During this semester, I will focus on developing your scientific writing skills. I hope to do this as painlessly as possible and build your scientific writing skills systematically. I hope throughout the process you can see that good writing is the same in both fiction and non-fiction. Good scientific writing and good creative writing are based on simply: good writing!

Good writing clearly supports a purpose, uses concise words and good grammar, and the information is connected and arranged effectively.

Before you begin writing, you need to do some background research about your topic. In scientific research you may:

1. Do background research to help develop hypothesis, or;
2. You may have a hypothesis in mind and you need to do background research to see what research has been done on your topic.

Scientists perform research on questions that have not yet been previously answered. Typically, scientists only publish novel explanations or solutions to problems.

The first part of this chapter discusses how to read and find scientific literature. The second part of this chapter discusses writing scientific literature. You will find that reading scientific literature is also a very good way to learn how to write your own scientific reports.

Finding and Reading Scientific Literature sources

“Primary literature” refers to scientific articles that report research results and are written by the scientists who conducted the research. Primary literature is always “peer-reviewed”, meaning that other scientists reviewed, edited, and approved of the quality of the article before it was published. These articles are published in scientific journals, rather than in magazines or books. Primary literature keeps researchers up to date in the new developments in their field. Repetitively reading is always necessary because scientific articles are dense with information.

In primary literature, the same general format is used so that readers can quickly get the information they need. The format generally includes the following sections in the following order:

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Introduction</th>
<th>Materials and Methods</th>
<th>Results (with Tables and Figures)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Discussion</td>
</tr>
</tbody>
</table>
Each section always includes the same type of information, but, depending on the journal, the sections might be organized slightly differently.

**Finding scientific literature**

Locating primary, peer-reviewed literature is a critical step in the research process. No problem---right?! But, searching for useful articles can take some practice! Really! Here are several ways you can locate and/or download primary literature:

- University of Texas Library (http://www.lib.utexas.edu/)
- Google Scholar (http://scholar.google.com)
- ChemPort (http://chemport.cas.org/cgi-bin/cps)

**Open Source Journals**

- Open source journals do not charge readers to access its content. You may search, view, print and save articles for no cost or subscription.
- **Beware**, some journals may not be peer-reviewed.
- Websites to Locate Open Source Journals
  - Open J-Gate http://www.openj-gate.com
  - Directory of Open Access Journals http://www.doaj.org
  - BioMed Central http://www.biomedcentral.com
  - Scitopia http://www.scitopia.org/scitopia
  - Scirus http://scirus.com
  - Public Library of Science http://www.plos.org

THINK about your search before you begin. Ask yourself, what do I want to do?

- **Browse?** You may need to browse general search engines, Wikipedia, etc. to become a little more familiar with your topic.
- **Locate a specific information?** You know exactly what you need at this point.
- **Retrieve everything I can on the subject?** You are still fishing a little...

Your answer will determine how you conduct your search and what tools you will use. Now, CREATE your search statement. Following are some tips to help you create your search statement:

- Whenever possible, use nouns and objects as keywords.
- The most important terms should be first in your keyword list.
- Use at least three keywords in your query.
- Combine keywords, whenever possible into phrases.
- Think about words you’d expect to find in the body of the page, and use them as keywords.
- **Apply basic search strategies or Boolean Logic to your search statement**
  - **Boolean logic** takes its name from British mathematician George Boole (1815-1864), who wrote about a system of logic designed to produce more accurate search results through the formation of precise queries. The operators of this logic are: **AND, OR, and NOT**, which are used to link words and phrases for more precise queries.
• **AND** – Narrows your search by retrieving only documents that contain every one of the keywords you enter. Be careful; the more terms you enter, the narrower your search becomes.

• **OR** – expands your search by returning documents in which either or both keywords appear. Since the **OR** operator is usually used for keywords that are similar or synonymous, the more keywords you enter, the more documents you will retrieve.

• **NOT / AND NOT** – limits your search by returning only your first keyword but not the second, even if the first word appears in that document, too. Note that **AND NOT** sometimes can be typed as **ANDNOT** (without space).

• If you can’t find any articles immediately, try different combinations of key words.

My **best advice to you** is to begin with related peer-reviewed review articles to give you a specialized overview of the topic. The most recent and comprehensive review articles also provide a “state of the field” and will reference, discuss, and compare important contributions from the published scientific literature. Go to the works cited page in these reviews to read the primary scientific articles once you determine your focus on a specific topic. Along the way, you may find that you need to read books. Books are comprehensive and typically available in the library versus buying expensive reference books.

**Reading and Comprehension, Note-taking**

If you want to develop something worth saying in your writing, you must interact intellectually with the source material! If you do not fully understand what you are reading you must work through the problem until the problem is resolved. This includes reading this lab manual and your lecture notes and references for full understanding! This also includes going to the work cited in the article and working your way through several articles until something is explained sufficiently for comprehension.

Reading a scientific paper is unlike reading a textbook or work of fiction. A scientific paper is composed of several general sections usually separated as follows: title, abstract, introduction, materials and methods, results, and discussion. First, you have to decide if the paper is relevant and worth reading completely by reading the Abstract and/or introduction. You made read 100 titles or 50 abstracts; yet read only five complete scientific papers (see Table 1).
Table 1: Section (type) in a scientific journal and how many you read on a topic (table is courtesy of Brad Hall, Ph.D.)

<table>
<thead>
<tr>
<th>Type</th>
<th>Read</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>100</td>
</tr>
<tr>
<td>Abstract</td>
<td>50</td>
</tr>
<tr>
<td>Figures</td>
<td>20</td>
</tr>
<tr>
<td>Conclusion</td>
<td>10</td>
</tr>
<tr>
<td>Full Paper</td>
<td>5</td>
</tr>
</tbody>
</table>

Then, scientific literature must be read slowly, thoughtfully, and patiently. You will need to read the paper several times before it can be thoroughly understood. If, after several readings of the paper, and if, after consulting textbooks and other resources, you still do not understand something, ask your instructor for help!

As you read the paper, ask yourself questions to guide you:

1. **Who wrote the article? With which institution(s) are the authors affiliated?** It is important to identify the affiliations of the authors, because their affiliations will give you clues as to the possible perspectives of the authors. For example, researchers at independent universities may have a different perspective than researchers affiliated with government or industry. Look for other papers published by the same authors to provide insight into the background and experience of the authors.

2. **What is the publication date?** In rapidly changing fields of science, it is important to know how this paper fits into the development of ideas over time.

3. **In what scientific journal is the paper published?** Is a peer-reviewed scientific journal, conference proceedings, a government research report? What is the journal’s impact factor (you want to look up what defines the “impact factor“)? Does the journal have a general focus (e.g., *Science*) or a specific focus (e.g., *Journal of Natural Products*)?

4. **What is the goal of the paper?** Scientific papers are written with a variety of goals, most often to report the findings of a particular investigation and therefore advance our knowledge of the natural world. Papers may try to summarize our current knowledge and formulate new generalizations; such papers are termed “review papers.“ A paper may also try to resolve a controversy by proposing a new theory.
5. **What are the specific objectives of the paper?** The research objectives are usually stated in the Introduction, and they may be listed as hypotheses or predictions.

6. **What is the conceptual framework into which this research fits?** The authors should describe the current level of understanding of the research topic and explain how his/her study fits into this topic by reviewing the past works of other scientists and then identifying the need for the current study. You will find this information in the Introduction and Discussion sections.

7. **What methods are used to meet the stated objectives?** A scientific paper must report the methods in sufficient detail to permit replication of the experiments. This level of detail often makes for very difficult reading unless the reader is familiar with the research; however, these details are essential for critical evaluation of the work by other scientists. When you are reading a paper, it is often sufficient to understand the methods in a general way, rather than the procedural details. **What are the controls? Are they sufficient?**

8. **What are the major findings of the investigation?** The results of the study are explicitly stated in the Results section and are usually accompanied by figures and tables. The highlights of each figure and table will also be presented in the narrative portion of the text. Each of the objectives presented in the Introduction should be addressed in the Results section. Are the hypotheses stated in the Introduction supported or disproved?

9. **Are the stated conclusions supported by the data?** Carefully check the results and evaluate for yourself whether the conclusions are justified. Note possible sources of error in the methods, the data analysis, or interpretation.

10. **How do the results relate to the published findings of other authors?** The authors should explain whether their findings agree or disagree with previous research. Does this study resolve a conflict, or create a difference of opinion?

11. **What future research is suggested as a result of this investigation?**

12. **How was the research funded?** The Acknowledgements section will list all sources of funding for the research.

13. **Have the authors drawn upon all the appropriate references?** The Literature Cited section, which concludes the paper, lists the details of the sources which were consulted (and cited) for this investigation.

Source of question list: “Review of a scientific article in the field of plant science.” Robin Kimmerer.

When you read the text, summarize as you go and take notes. This will assist you in avoiding plagiarism. Copying someone’s work or presenting someone else’s idea as your own is considered plagiarism. Plagiarism has serious consequences in scientific literature and academia. Plagiarism is theft. Take notes in your own words! This means you MUST understand what you have read! It is impossible to take notes successfully, if you do not understand the content of the literature source! Also, keep track of your sources as you take notes for including in your reference section later of your own report.
Writing a Scientific Paper

Scientific research articles provide a method for scientists to communicate with other scientists about the results of their research. A standard format is used for these articles, in which the author presents the research in an orderly, logical manner. This doesn’t necessarily reflect the order in which you did or thought about the work. This format is:

| Title | Authors | Introduction | Materials and Methods | Results (with Tables and Figures) | Discussion | Acknowledgments | References |

The sections appear in a journal style paper in the following prescribed order and simply answer the questions in the first column:

<table>
<thead>
<tr>
<th>Experimental process</th>
<th>Section of Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did I do in a nutshell?</td>
<td>Abstract</td>
</tr>
<tr>
<td>What is the problem?</td>
<td>Introduction</td>
</tr>
<tr>
<td>How did I solve the problem?</td>
<td>Materials and Methods</td>
</tr>
<tr>
<td>What did I find out?</td>
<td>Results</td>
</tr>
<tr>
<td>What does it mean?</td>
<td>Discussion</td>
</tr>
<tr>
<td>Who helped me out?</td>
<td>Acknowledgments (optional)</td>
</tr>
<tr>
<td>Whose work did I refer to?</td>
<td>References</td>
</tr>
</tbody>
</table>

WHERE TO START WRITING??? Although the sections of the journal manuscript are published in the order: Title, Abstract, Introduction, Materials and Methods, Results, Discussion, and Conclusion, this is NOT the best order for writing the sections of a manuscript. One strategy is to write your manuscript in the following order:

1. Materials and Methods
2. Results

Materials and Methods and Results can be written first, as you are doing your experiments and collecting the results. After you make some progress then proceed with the following sections. I will assemble my results for a specific paper first when I am performing a lot of experiments simultaneously. I will write my Materials and Methods
sections second, after I know which methods I need to cover based on the results I included.

3. Introduction (Introduction can be written early on to focus your research justification and goal. The introduction is a work in progress until after you gather all your results.)

4. Discussion

5. Conclusion
   Write these sections next, once you have decided on your target journal. Journals are very specific about formatting titles and abstracts.

6. Title

7. Abstract
   Write your Title and Abstract last and based on all the other sections.

**Title**

1. Make your title specific enough to describe the contents of the paper, but not so technical that only specialists will understand. The title should be appropriate for the intended audience.

2. The title usually describes the subject matter of the article.

3. Sometimes a title that summarizes the results is more effective.

*Mediocre (No) and better (Yes) title examples:*

**No:** Plankton sampling in a Small Pond.

**Yes:** Species composition of the spring zooplankton of Small Pond, MA

**No:** Effects of pollutants on sea urchin development.

**Yes:** Influence of Cu\(^{++}\) on fertilization success and gastrulation in the sea urchin *Strongylocentrotus purpuratus*

**Authors**

1. The person who did the work and wrote the paper is generally listed as the first author of a research paper.

2. For published articles, other people who made substantial contributions to the work are also listed as authors. Ask your mentor's permission before including his/her name as co-author.

**Abstract**

1. An abstract, or summary, is published together with a research article, giving the reader a "preview" of what's to come. Such abstracts may also be published separately in bibliographical sources, such as Biological Abstracts. They allow other scientists to quickly scan the large scientific literature, and decide which articles they want to read in depth. The abstract should be a little less technical than the article itself; you don't want to dissuade your potential audience from reading your paper.

2. Your abstract should be one paragraph, of 100-250 words, which summarizes the purpose, methods, results and conclusions of the paper.

3. It is not easy to include all this information in just a few words. Start by writing a summary that includes whatever you think is important, and then gradually prune it
down to size by removing unnecessary words, while still retaining the necessary concepts.

4. Don't use abbreviations or citations in the abstract. It should be able to stand alone without any footnotes. It is also typically written in the passive voice.

**Introduction**

**Introduction**

What question did you ask in your experiment? Why is it interesting? The introduction summarizes the relevant literature so that the reader will understand why you were interested in the question you asked. One to four paragraphs should be enough. The Introduction should provide readers with the background information needed to understand your study, and the reasons why you conducted your experiments.

The Introduction should answer the question:

*What question/problem was studied?*

End the “Introduction” with a sentence explaining the specific question you asked in this experiment.

While writing the background in the introduction, make sure your citations are:

- **Well balanced:** If experiments have found conflicting results on a question, have you cited studies with both kinds of results?
- **Current:** Every field is different, but you should aim to cite references that are not more than 10 years old if possible.
- **Relevant:** This is the most important requirement. The studies you cite should be strongly related to your research question.

*DO NOT* write an extensive literature review in your Introduction, but *DO* cite reviews where readers can find more information if they want it.

Once you have provided background material and stated the problem or question for your study, tell the reader the purpose of your study. Usually the reason is to fill a gap in the knowledge or to answer a previously unanswered question. For example, if a drug is known to work well in one population, but has never been tested in a different population, the purpose of a study could be to test the efficacy and safety of the drug in the second population.

**The final thing to include at the end of your Introduction is a clear and exact statement of your study aims.** The Introduction section should not exceed 1 to 1.5 page lengths.

**Materials and Methods**

This section provides the reader with all the details of how you conducted your study. How did you answer your question?
You should:

- Use subheadings to separate different methods
- If you name a material brand specifically, include the manufacturer name and location in parenthesis after the material brand name.
- Describe what you did in the past tense
- Describe new methods in enough detail that another researcher can reproduce your experiment. Look at scientific journal articles that use the methods you are using to examine their level of detail.
- Describe established methods briefly, and simply cite a reference where readers can find more detail
- State all statistical tests and parameters
- If you had a complicated protocol, it may helpful to include a diagram, table or flowchart to explain the methods you used.
- Do NOT put results into this section!!
- The Materials and Methods section should be brief but informative. A model Materials and Methods Section is illustrated by Pechenik (2004) in her Short Guide to Writing about Biology.

Problem: The Methods section is prone to being wordy or overly detailed.

- Avoid repeatedly using a single sentence to relate a single action; this results in very lengthy, wordy passages. A related sequence of actions can be combined into one sentence to improve clarity and readability:

Problematic Example: This is a very long and wordy description of a common, simple procedure. It is characterized by single actions per sentence and lots of unnecessary details.

"The petri dish was placed on the turntable. The lid was then raised slightly. An inoculating loop was used to transfer culture to the agar surface. The turntable was rotated 90 degrees by hand. The loop was moved lightly back and forth over the agar to spread the culture. The bacteria were then incubated at 37 C for 24 hr."

Improved Example: Same actions, but all the important information is given in a single, concise sentence. Note that superfluous detail and otherwise obvious information has been deleted while important missing information was added.

"Each plate was placed on a turntable and streaked at opposing angles with fresh overnight E. coli culture using an inoculating loop. The bacteria were then incubated at 37 C for 24 hr."

Best: Here the author assumes the reader has basic knowledge of microbiological techniques and has deleted other superfluous information. The two sentences have been combined because they are related actions.

"Each plate was streaked with fresh overnight E. coli culture and incubated at 37 C for 24 hr."
Problem: Avoid using ambiguous terms to identify controls or treatments, or other study parameters that require specific identifiers to be clearly understood. Designators such as Tube 1, Tube 2, or Site 1 and Site 2 are completely meaningless out of context and difficult to follow in context.

Problematic example: In this example the reader will have no clue as to what the various tubes represent without having to constantly refer back to some previous point in the Methods.

"A Spec 20 was used to measure A600 of Tubes 1, 2, and 3 immediately after chloroplasts were added (Time 0) and every 2 min. thereafter until the DCIP was completely reduced. Tube 4's A600 was measured only at Time 0 and at the end of the experiment."

Improved example: Notice how the substitution (in red) of treatment and control identifiers clarifies the passage both in the context of the paper, and if taken out of context.

"A Spec 20 was used to measure A600 of the reaction mixtures exposed to light intensities of 1500, 750, and 350 uE/m2/sec immediately after chloroplasts were added (Time 0) and every 2 min. thereafter until the DCIP was completely reduced. The A600 of the no-light control was measured only at Time 0 and at the end of the experiment."

Results

1. This is the heart of your paper: the most important part of the paper! In this section, you summarize your findings, using tables, graphs, and words. Most of the work in constructing this section of the report involves data presentation. You simply present the results and draw your readers attention to the major observations and key trends in the data.
2. Do NOT discuss the results or speculate as to why something happened; that goes in the Discussion.
3. You don't necessarily have to include all the data you've obtained. This isn't a diary or your lab notebook.
4. Use appropriate methods of showing data. Don't try to manipulate the data to make it look like you did more than you actually did. Be careful about “connecting dots”. Connecting dots is not always the best way to show a relationship and can even be interpreted as falsifying data. Think about what the data means.

The purpose of the Results section is to objectively present your key results, without interpretation, in an orderly and logical sequence using both text and illustrative materials (Tables and Figures). The results section always begins with text, reporting the key results and referring to your figures and tables as you proceed. The Results section should be organized around Tables and/or Figures that should be sequenced to present your key findings in a logical order. Important negative results should be reported, too. Authors usually write the text of the results section based upon the sequence of Tables and Figures.

Write the text of the Results section concisely and objectively. The passive voice will likely dominate here, but use the active voice as much as possible. Use the past tense. Avoid repetitive paragraph structures. Do not interpret the data here. Data interpretation belongs in the Discussion section!
Writing Numbers: Whether to enter numerals or words for a number is often confusing. In different situations, this will vary, but probably a fair generality is that a numeral is shorter than a word, so use a numeral, with the following exceptions:

- **You cannot begin a sentence with a numeral.** The number "1,256,781" must be entered at the beginning of a sentence as "One million, two hundred fifty-six thousand, seven hundred and eighty-one," as ridiculous as it seems. If the number involves a unit of measure, the unit must be likewise spelled out as a word in most cases (pH would be one exception). Work the sentence so you don't have to begin it with the number!
- **When not speaking of data or experimental groupings, use words instead of numerals for small numbers:** "two centuries ago," "For well over fifty years..", "Of the many millions of fish released..
- **Numbers are generally written as numerals when a specific value is named, and always when associated with a unit of measure:** "270 centuries ago," "59 people...", "...47.8 g dry weight...".

Organize the results section based on the sequence of Table and Figures you'll include. Prepare the Tables and Figures as soon as all the data are analyzed and arrange them in the sequence that best presents your findings in a logical way. A good strategy is to note, on a draft of each Table or Figure, the one or two key results you want to address in the text portion of the Results. Simple rules to follow related to Tables and Figures:

- Tables and Figures are assigned numbers separately and in the sequence that you will refer to them from the text.
  - The first Table you refer to is Table 1, the next Table 2 and so forth.
  - Similarly, the first Figure is Figure 1, the next Figure 2, etc.

  Each Table or Figure must include a brief description of the results being presented and other necessary information in a legend.

  - **Table legends go above the Table;** tables are read from top to bottom.
  - **Figure legends go below the figure;** figures are usually viewed from bottom to top.

- When referring to a Figure from the text, "Figure" is abbreviated as Fig., e.g., Fig. 1. Table is never abbreviated, e.g., Table 1.

The body of the Results section is a text-based presentation of the key findings which includes references to each of the Tables and Figures. The text should guide the reader through your results stressing the key results which provide the answers to the question(s) investigated. A major function of the text is to provide clarifying information. You must refer to each Table and/or Figure individually and in sequence, and clearly indicate for the reader the key results that each conveys.
Some problems to avoid:

- **Do not** reiterate each value from a Figure or Table - only the key result or trends that each conveys.
- **Do not** present the same data in both a Table and Figure - this is considered redundant and a waste of space and energy. Decide which format best shows the result and go with it.
- **Do not** report raw data values when they can be summarized as means, percents, etc.
- **Report negative results** - they are important! If you did not get the anticipated results, it may mean your hypothesis was incorrect and needs to be reformulated, or perhaps you have stumbled onto something unexpected that warrants further study. Many important discoveries can be traced to "bad data".

Always enter the appropriate [units](#) when reporting data or summary statistics.

- for an **individual value** you would write, "the mean length was 10 m", or, "the maximum time was 140 min."
- When including a measure of variability, place the unit after the error value, e.g., "...was 10 ± 2.3 m".
- Likewise place the unit after the last in a series of numbers all having the same unit. For example: "lengths of 5, 10, 15, and 20 m", or "no differences were observed after 2, 4, 6, or 8 min. of incubation".

Data summaries may take one of three forms: text, Tables and Figures.

1. **Text**: contrary to what you may have heard, not all analyses or results warrant a Table or Figure. Some simple results are best stated in a single sentence, with data summarized parenthetically.
2. **Tables**: Tables present lists of numbers or text in columns, each column having a title or label. Do not use a table when you wish to show a trend or a pattern of relationship between sets of values - these are better presented in a Figure. For instance, if you needed to present population sizes and sex ratios for your study organism at a series of sites, and you planned to focus on the differences among individual sites according to (say) habitat type, you would use a table. However, if you wanted to show us that sex ratio was related to population size, you would use a Figure.
3. **Figures**: Figures are visual presentations of results, including graphs, diagrams, photos, drawings, schematics, maps, etc. Graphs are the most common type of figure and will be discussed in detail; examples of other types of figures are included at the end of this section. Graphs show trends or patterns of relationship.

**How to refer to Tables and Figures from the text**: Every Figure and Table included in the paper MUST be referred to from the text. Use sentences that draw the reader's attention to the relationship or trend you wish to highlight, referring to the appropriate Figure or Table only parenthetically.
Abbreviation of the word "Figure": When referring to a Figure in the text, the word "Figure" is abbreviated as "Fig.", while "Table" is not abbreviated. Both words are spelled out completely in descriptive legends.

How to number Tables and Figures: Figures and Tables are numbered independently, in the sequence in which you refer to them in the text, starting with Figure 1 and Table 1. If, in revision, you change the presentation sequence of the figures and tables, you must renumber them to reflect the new sequence.

The "Acid Test" for Tables and Figures: Any Table or Figure you present must be sufficiently clear, well-labeled, and described by its legend to be understood by your intended audience without reading the results section, i.e., it must be able to stand alone and be interpretable. Overly complicated Figures or Tables may be difficult to understand in or out of context, so strive for simplicity whenever possible. If you are unsure whether your tables or figures meet these criteria, give them to a fellow biology major (not in your course) and ask them to interpret your results.

Where do you place the legend?

- **Table legends** go above the body of the Table and are left justified; Tables are read from the top down.
- **Figure legends** go below the graph; graphs and other types of Figures are usually read from the bottom up.

The Anatomy of a Table

Table 4 below shows the typical layout of a table in three sections demarcated by lines. Tables are most easily constructed using your word processor's table function or a spread sheet such as Excel. Gridlines or boxes, commonly invoked by word processors, are helpful for setting cell and column alignments, but should be eliminated from the printed version. Tables formatted with cell boundaries showing are unlikely to be permitted in a journal.
Example 1: Courtesy of Shelley Ball.

Table 4. Population variation in hatch success (mean percent) of unfertilized eggs for females from populations sampled in 1997. N = number of females tested.

<table>
<thead>
<tr>
<th>Population</th>
<th>mean (%)</th>
<th>Standard deviation</th>
<th>Range</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaver Creek</td>
<td>7.31</td>
<td>13.95</td>
<td>0-53.16</td>
<td>15</td>
</tr>
<tr>
<td>Honey Creek</td>
<td>4.33</td>
<td>7.83</td>
<td>0-25.47</td>
<td>11</td>
</tr>
<tr>
<td>Rock Bridge Gums Creek</td>
<td>5.66</td>
<td>13.93</td>
<td>0-77.86</td>
<td>38</td>
</tr>
<tr>
<td>Cedar Creek</td>
<td>6.56</td>
<td>9.64</td>
<td>0-46.52</td>
<td>64</td>
</tr>
<tr>
<td>Grindstone Creek</td>
<td>8.56</td>
<td>14.77</td>
<td>0-57.32</td>
<td>19</td>
</tr>
<tr>
<td>Jack's Fork River</td>
<td>5.28</td>
<td>8.28</td>
<td>0-30.96</td>
<td>28</td>
</tr>
<tr>
<td>Meramec River</td>
<td>5.49</td>
<td>10.35</td>
<td>0-45.76</td>
<td>45</td>
</tr>
<tr>
<td>Little Dixie Lake</td>
<td>7.96</td>
<td>14.54</td>
<td>0-67.66</td>
<td>71</td>
</tr>
<tr>
<td>Little Prairie Lake</td>
<td>6.86</td>
<td>7.84</td>
<td>0-32.40</td>
<td>36</td>
</tr>
<tr>
<td>Rocky Forks Lake</td>
<td>3.61</td>
<td>4.12</td>
<td>0-16.14</td>
<td>43</td>
</tr>
<tr>
<td>Winegar Lake</td>
<td>10.73</td>
<td>17.58</td>
<td>0-41.64</td>
<td>5</td>
</tr>
<tr>
<td>Wheatstone Lake</td>
<td>7.36</td>
<td>12.93</td>
<td>0-63.38</td>
<td>37</td>
</tr>
</tbody>
</table>

* = temporary stream, † = permanent streams, ‡ = lakes.

Example 2: Courtesy of Shelley Ball.

Table 2. Log-likelihood tests of deviation from 1:1 sex ratios for nymphs collected from each population in 1997 and 1998. Values are ratios of female:male; sample sizes are in parentheses. Bonferroni corrected probabilities are shown with asterisks.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaver Creek</td>
<td>9.061(20)**</td>
<td>2.671(422)*</td>
</tr>
<tr>
<td>Henry Creek</td>
<td>9.061(26)***</td>
<td>2.671(468)**</td>
</tr>
<tr>
<td>Rock Bridge</td>
<td>3.333(26)***</td>
<td>2.671(468)**</td>
</tr>
<tr>
<td>Cedar Creek</td>
<td>2.053(19)**</td>
<td>2.671(468)**</td>
</tr>
<tr>
<td>Grindstone Creek</td>
<td>1.871(148)***</td>
<td>2.671(468)**</td>
</tr>
<tr>
<td>Jacks Fork River</td>
<td>2.891(135)**</td>
<td>5.371(1477)**</td>
</tr>
<tr>
<td>Meramec River</td>
<td>2.801(138)**</td>
<td>2.411(485)**</td>
</tr>
<tr>
<td>Little Dixie Lake</td>
<td>2.451(494)**</td>
<td>4.611(484)**</td>
</tr>
<tr>
<td>Little Prairie Lake</td>
<td>2.381(71)**</td>
<td>2.081(157)**</td>
</tr>
<tr>
<td>Rocky Forks Lake</td>
<td>2.551(213)**</td>
<td>2.931(298)**</td>
</tr>
<tr>
<td>Winegar Lake</td>
<td>3.411(207)**</td>
<td>7.341(704)**</td>
</tr>
<tr>
<td>Wheatstone Lake</td>
<td>2.691(381)**</td>
<td>2.011(286)**</td>
</tr>
</tbody>
</table>

* = significant at p < 0.05; ** = significant at p < 0.005; *** = significant at p < 0.0001; 
* = temporary stream, † = permanent streams, ‡ = lakes.
Example 3: Courtesy of Greg Anderson

### Table 2.
Planting date, mean planting density, and total number of seed clams planted in plots at Filucy Bay and Wescott Bay in 1979.

<table>
<thead>
<tr>
<th>Location</th>
<th>Plot code</th>
<th>Planting date</th>
<th>Mean planting density in no. clams/m² ± 1 st. dev. (N)</th>
<th>Total no. clams planted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filucy Bay</td>
<td>F10 x 30</td>
<td>5-16-79</td>
<td>994 ± 39(5)</td>
<td>298200</td>
</tr>
<tr>
<td></td>
<td>F3 x 10</td>
<td>5-24-79</td>
<td>994 ± 39(5)</td>
<td>29820</td>
</tr>
<tr>
<td>Wescott Bay</td>
<td>W10 x 25</td>
<td>5-16-79</td>
<td>994 ± 39(5)</td>
<td>248500</td>
</tr>
<tr>
<td></td>
<td>W3 x 10</td>
<td>6-2-79</td>
<td>895 ± 35(5)</td>
<td>26850</td>
</tr>
</tbody>
</table>

*Superscript (a)*: Calculated after clams were planted based on estimated 11% mortality of seed clams between 5-24 and 6-2-79.

---

**In these examples notice several things:**

- the presence of a period after "Table ";
- the legend (sometimes called the *caption*) goes above the Table;
- *units* are specified in column headings wherever appropriate;
- lines of demarcation are used to separate legend, headers, data, and footnotes from one another.
- *footnotes* are used to clarify points in the table, or to convey repetitive information about entries;
- footnotes may also be used to denote statistical differences among groups.

**The Anatomy of a Figure**

The sections below show when and how to use the four most common Figure types (bar graph, frequency histogram, XY scatterplot, XY line graph.) The final section gives examples of other, less common, types of Figures.

**Parts of a Graph:** Below are example figures (typical line and bar graphs) with the various component parts labeled in red. Refer back to these examples if you encounter an unfamiliar term as you read the following sections.
Figure 1. Cumulative germination of Chenopodium seeds after pregermination treatment of 2 day soak in NaCl solutions. 
*n = 1 trial per treatment group (100 seeds/trial.)*

Figure 1. Mean germination (%) (+ SD) of gourd seeds following various pregermination treatments. *N*=10 groups of 100 seeds per treatment and control. Treatments: 12 hour soak in 12 N H₂SO₄, 90 second scarification of seed coat with 80 grit sandpaper, 6 hour soak in 3% H₂O₂.
Some general considerations about Figures:

- **Big or little?** For course-related papers, a good rule of thumb is to size your figures to fill about one-half of a page. Readers should not have to reach for a magnifying glass to make out the details. Compound figures may require a full page.

- **Color or no color?** Use black and white for reports. The rationale is that if you need to photocopy or fax your paper, any information conveyed by colors will be lost to the reader. However, for a poster presentation or a talk with projected images, color can be helpful in distinguishing different data sets. Every aspect of your Figure should convey information; *never use color simply because it is pretty.*

- **Title or no title?** *Never use a title for Figures included in a paper,* the legend conveys all the necessary information and the title just takes up extra space. However, for *posters or projected images,* where people may have a harder time reading the small print of a legend, a larger font title is very helpful.

- **Offset axes or not?** Elect to offset the axes only when data points will be obscured by being printed over the Y axis.

- **Error bars or not?** Always include error bars (SD or SEM) when plotting means. In some courses you may be asked to plot other measures associated with the mean, such as confidence intervals.

- **Tick marks** - Use common sense when deciding on major (numbered) versus minor ticks. Major ticks should be used to reasonably break up the range of values plotted into integer values. Within the major intervals, it is usually necessary to add minor interval ticks that further subdivide the scale into *logical* units (i.e., a interval that is a factor of the major tick interval). For example, when using major tick intervals of 10, minor tick intervals of 1,2, or 5 might be used, but not 4.
Discussion

The function of the Discussion is to interpret your results in light of what was already known about the subject of the investigation, and to explain our new understanding of the problem after taking your results into consideration. The Discussion will always connect to the Introduction by way of the question(s) or hypotheses you posed and the literature you cited, but it does not simply repeat or rearrange the Introduction. Instead, it tells how your study has moved us forward from the place you left us at the end of the Introduction.

Fundamental questions to answer here include:

- Do your results provide answers to your testable hypotheses? If so, how do you interpret your findings?
- Do your findings agree with what others have shown? If not, do they suggest an alternative explanation or perhaps a unforeseen design flaw in your experiment (or theirs?)
- Given your conclusions, what is our new understanding of the problem you investigated and outlined in the Introduction?
- If warranted, what would be the next step in your study, e.g., what experiments would you do next?

Use the **active voice** whenever possible in this section. Watch out for wordy phrases; be **concise and make your points clearly**. Use of the first person is okay, but too much use of the first person may actually distract the reader from the main points.

Organize the Discussion to address each of the experiments or studies for which you presented results; discuss each in the same sequence as presented in the Results, providing your interpretation of what they mean in the larger context of the problem. Do not waste entire sentences restating your results; if you need to remind the reader of the result to be discussed, use "bridge sentences" that relate the result to the interpretation:

"The slow response of the lead-exposed neurons relative to controls suggests that...[interpretation]".

You will necessarily make reference to the findings of others in order to support your interpretations. Use subheadings, if need be, to help organize your presentation. Be wary of mistaking the reiteration of a result for an interpretation, and make sure that no new results are presented here that rightly belong in the results.

**You must relate your work to the findings of other studies - including previous studies you may have done and those of other investigators.** As stated previously, you may find crucial information in someone else's study that helps you interpret your own data, or perhaps you will be able to reinterpret others' findings in light of yours. In either case you should discuss reasons for similarities and differences between yours and others' findings. Consider how the results of other studies may be combined with yours to derive a new or
perhaps better substantiated understanding of the problem. Be sure to state the conclusions that can be drawn from your results in light of these considerations. You may also choose to briefly mention further studies you would do to clarify your working hypotheses. Make sure to reference any outside sources.

**Do not introduce new results in the Discussion.** Although you might occasionally include in this section tables and figures which help explain something you are discussing, they must not contain new data (from your study) that should have been presented earlier. They might be flow diagrams, accumulation of data from the literature, or something that shows how one type of data leads to or correlates with another, etc. For example, if you were studying a membrane-bound transport channel and you discovered a new bit of information about its mechanism, you might present a diagram showing how your findings helps to explain the channel's mechanism. **In general,** no figures and tables are included in the Discussion section.

End with a one-sentence summary of your conclusion, emphasizing why it is relevant and what further studies are warranted.

**Acknowledgements**

This section is optional. You can thank those who either helped with the experiments, or made other important contributions, such as discussing the protocol, commenting on the manuscript, or buying you pizza.

**References (literature cited)**

Before you write, work to understand your resources! Read the section about reading journal articles before you begin to write! There are several possible ways to organize this section. We will follow an ACS format, please follow the instructions below to format your references correctly for this course! I give you two choices for how to cite in text, which will directly impacts how your format your Reference list at the end of your document.

1. In the text, cite the literature in the appropriate places with author and year published or use a number:

Scarlet (1990) thought that the gene was present only in yeast, but it has since been identified in the platypus (Indigo and Mauve, 1994) and wombat (Magenta, et al., 1995).

**OR**

Scarlet (1) thought that the gene was present only in yeast, but it has since been identified in the platypus (2) and wombat (3).

2. In the References section list citations in alphabetical order or by number in the sequence cited. How you make this list depends on the style you chose for the “in text” references.
3. Journal articles are cited as follows for this course if they are available as print, even if you access the article online:
   a. Author's last name comma first initial period space Title of article with no quotations period space abbreviation for journal title italicized (period only if journal title ends with abbreviation) space year bolded comma space volume number italicized comma space pages period.
   b. If there are multiple authors the authors are separated by a semi-colon.
   c. EXAMPLE:
   d. Journal abbreviations can be found in the Chemical Abstracts Service Source Index (CASSI). One word journal names are not abbreviated.

4. ELECTRONIC ONLY journal articles are cited as follows for this course:
   a. Author's last name comma first initial period space Title of article with no quotations period space abbreviation for journal title italicized (period only if journal title ends with abbreviation) space year bolded comma space volume number italicized comma space article number or other description period URL space accessed date in parenthesis period.
   b. EXAMPLE:

5. Books are cited as follows for this course:
   a. Author's last name comma space first initial period space second initial period space Title of Book Italicized and First Letter of Significant Words Capitalized semi-colon space Publisher colon space Place of Publication comma space year semi-colon space p or pp number period.
   b. EXAMPLE:
   c. If citing an authored chapter in an edited book in a specific edition:
      d. EXAMPLE:

6. Websites are cited as follows for this course:
   a. Author (if any) period space Title of Site period space URL space (accessed date) comma space other identifying information, if necessary period.
   b. EXAMPLE:
   c. For a subscription only web site, the URL need not be given.
   d. EXAMPLE:

7. Dissertations and theses are cited as follows for this course:
   a. Author's last name comma space first initial period space second initial period space Title of the thesis or dissertation Italicized and First Letter of Significant Words Capitalized period space indicate M.S. or Ph.D. Thesis or Dissertation
comma space the institution or university name comma space location listed as city comma space state comma space month and year period.

b. EXAMPLE:

A major part of any writing assignment consists of re-writing. Below are tips for revising your paper

1. Make sure every sentence says something!
   - *Salinity is a very important factor in marine environments.* This sentence doesn't tell the reader anything. A better sentence is: *Estuarine fish may be subjected to changes in salinity within a few hours.*

2. Use the word relatively only when making an explicit comparison.
   - *Many of the animals living near deep sea thermal vents are relatively large.* Relative to what? Either delete “relatively” and insert “exceed lengths of 3 meters.” Or insert an explicit comparison: “…relative to their shallow-water counterparts.”

3. NEVER tell a reader that something is interesting!!!
   - *Cell death is particularly interesting phenomenon.* This sentence should never appear in your reports! Instead write: *During the development of all animals, certain cells are genetically programmed for an early death.*

4. Be cautious in drawing conclusions
5. Revise for clarity and remember scientific writing must be accurate. Although writing instructors may tell you not to use the same word twice in a sentence, it's okay for scientific writing, which must be accurate. (A student who tried not to repeat the word "hamster" produced this confusing sentence: "When I put the hamster in a cage with the other animals, the little mammals began to play.")
6. Make sure you say what you mean.
   - *Instead of:* The rats were injected with the drug. (sounds like a syringe was filled with drug and ground-up rats and both were injected together)  *Write:* I injected the drug into the rat.

7. Be careful with commonly confused words:
• Effect and affect. As a noun, effect means a “result” or “outcome”. As a verb, effect means to “bring about”. Affect as a verb means “to influence” or to “produce an effect upon”. Examples using these words properly:
  1. What is the effect of fuel oil on the feeding behavior of sea birds?
  2. What changes in feeding behavior will fuel oil effect in sea birds?
  3. How will the fuel oil affect the feeding behavior of sea birds?

• Varying and various. Varying means “changing over time” or with changing circumstances, while various means “different”.
  1. I used solutions in various concentrations. (This means: The solutions were 5 mg/ml, 10 mg/ml, and 15 mg/ml)
  2. I used solutions in varying concentrations. (This means: The concentrations I used changed; sometimes they were 5 mg/ml, other times they were 15 mg/ml.)

• Use precise quantities versus adjectives when appropriate. It is scientific writing! Show me the numbers!
  1. Less food (ok, can’t count numbers of food)
  2. Fewer animals (can count numbers of animals, use numbers)

• Which and that. Which is commonly preceded by a comma. When deciding to use which and that in your own writing, read your sentence aloud. If the word doesn’t need a pause, or a comma, then the correct word to use is likely that. Misusing these words often leads to ambiguous or false sentences.
  1. The erythrocytes, which are in the blood, contain hemoglobin.
  2. The erythrocytes that are in the blood contain hemoglobin. (Wrong. This sentence implies that there are erythrocytes elsewhere that don’t contain hemoglobin.)

8. Write at a level that's appropriate for your audience.

9. Use the active voice; do not overuse the passive voice. The active voice is more clear and concise than the passive voice (the abstract is the only section that is written in the passive voice).

• Instead of: An increased appetite was manifested by the rats and an increase in body weight was measured.
  Write: The rats ate more and gained weight.

• Instead of: Little is known of the nutritional requirements of these animals.
  Write: We know little about the nutritional requirements of these animals.

10. Use the first person.

• Instead of: It is thought
  Write: I think

• Instead of: The samples were analyzed
  Write: I analyzed the samples
11. Avoid dangling participles and unnecessary prepositions.
   - "After incubating at 30 degrees C, we examined the petri plates." (You must've been pretty warm in there.)

12. Use strong verbs instead of the weak verb "to be"
   - Instead of: The enzyme was found to be the active agent in catalyzing...
     Write: The enzyme catalyzed...

13. Use verbs instead of abstract nouns
   - Instead of: take into consideration
     Write: consider

14. Use short words and make every word count.
    Instead of: Write:
    possess  have
    sufficient  enough
    utilize  use
    demonstrate  show
    assistance  help
    terminate  end

15. Use concise terms.
    Instead of: Write:
    prior to  before
    due to the fact that  because
    in a considerable number of cases  often
    the vast majority of  most
    during the time that  when
in close proximity to near

it has long been known that I'm too lazy to look up the reference

16. Use short sentences. A sentence made of more than 40 words should probably be rewritten as two sentences.

Check your grammar, spelling and punctuation

1. Use a spellchecker, but be aware that they don't catch all mistakes.

   "When we consider the animal as a hole,..." Student's paper

2. Your spellchecker may not recognize scientific terms. For the correct spelling, try Biotech's Life Science Dictionary. Don't, use, unnecessary, commas.

3. Proofread carefully to see if you any words out.

Useful books

Jan A. Pechenik, A Short Guide to Writing About Biology, Boston: Little, Brown, 2004 and 2007 editions are available at the Life Sciences library.


### Summary of Common Scientific Writing Mistakes to Avoid

<table>
<thead>
<tr>
<th>Error</th>
<th>Correct Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>20ºC</td>
<td>There is an oft-forgotten space following the number: 20 ºC</td>
</tr>
<tr>
<td>hydrogens</td>
<td>When writing about atoms, include “atom” after the element name. For example: From the proton NMR, it can be determined that there are three different types of hydrogen atoms in the molecule.</td>
</tr>
<tr>
<td>capitalization</td>
<td>Often, students capitalize chemical names thinking they are similar to proper names. Pay attention to the way the chemical name is written when you look it up. Sometimes there is a capital letter, which is also italicized, indicating a group is present on that atom. Ex: DMF = N,N-dimethylformamide</td>
</tr>
<tr>
<td>at reflux</td>
<td>The correct phrase is “under reflux.”</td>
</tr>
<tr>
<td>expletive</td>
<td>Beginning with “there is” or “there are” is an example of this. This type of sentence construction “robs a sentence of energy before it gets a chance to do its work.”</td>
</tr>
<tr>
<td>construction</td>
<td></td>
</tr>
<tr>
<td>affect and effect</td>
<td>In the type of scientific writing we do, we mostly use effect. For example, “To investigate the effect of the leaving group, different halides were used.” “He added NaH to effect the transformation.” Note the use of affect in the following sentence: “It was clear that base selection affected the outcome of the reaction.”</td>
</tr>
<tr>
<td>Topic</td>
<td>Detail</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Improper reference placement</td>
<td>When using ACS format, references are superscripted and placed <strong>after punctuation</strong>. Although the reference is usually placed at the end of the sentence, it may be put after a colon or comma, if more than one source is referenced in that sentence.</td>
</tr>
<tr>
<td>referencing figures or schemes</td>
<td>Reference the figure or scheme at the end of the end of the <em>first sentence in which you refer to it</em>, even if you don’t mention a structure by number.</td>
</tr>
<tr>
<td>use of abbreviations without definition</td>
<td>The first time you discuss a reagent, write out the full name. You may indicate the abbreviation you will use in parenthesis immediately following the name. Try to stick to conventional abbreviations, and use caution making up your own. There are already so many; you don’t want to confuse your reader.</td>
</tr>
<tr>
<td>numbering of structures, figures, schemes, tables</td>
<td>Please review the writing lesson on scheme numbering for a discussion of how to appropriately number images or tables in a scientific document.</td>
</tr>
<tr>
<td>use of the word “data”</td>
<td>Data is the plural of datum. When referring to data, it is appropriate to say “these data” or “data are.”</td>
</tr>
<tr>
<td>use of “prove”</td>
<td>Prove is a strong word in science. You should use phrases like “support” “provides evidence for.” You don’t prove a hypothesis; you gain support for it through your results.</td>
</tr>
<tr>
<td>tense</td>
<td>In general, we use past tense, as we are describing research that had been done or that we have done.</td>
</tr>
<tr>
<td>use of “however”</td>
<td>Unless “however” is used at the beginning of a sentence, a <strong>semicolon</strong> should appear before and a <strong>comma</strong> after: “All attempts to improve the reaction did not meet with success; however, these investigations were needed to determine if it was a matter of reaction conditions or substrate specificity that was affecting the reaction outcome.”</td>
</tr>
<tr>
<td>weak pronoun reference</td>
<td>“Use of <strong>it</strong>, <strong>this</strong>, <strong>that</strong>, <strong>these</strong>, <strong>those</strong>, <strong>they</strong>, and <strong>which</strong> without clear reference to a noun.”</td>
</tr>
<tr>
<td>anthropomorphism</td>
<td>This mistake is very common. Basically, anthropomorphism means that human qualities are given to an inanimate object.</td>
</tr>
</tbody>
</table>

**Presenting your Research**

You will have the opportunity to present your research if you stay with the FRI program more than one semester. Opportunity?!?! Yes!!!! By the time you are ready to present your research, you have successfully executed your research (not a trivial challenge) and you have successfully communicated your results in the written format (also, not trivial!)! Now, it is time for you to present your work to a larger audience and communicate your results through an oral presentation. Sound intimidating?

Trust me; the only way to improve your presentation skills is to: PRACTICE! Practice, practice and more practice with a lot of preparation thrown in. Know your material and your experiments inside and out. That shouldn’t be hard since you executed the research and have already written about it. Then, know your audience. The audience is important as it will determine what terms require further explanation or even what terms you will use when describing your research.

Finally, and this may be the most difficult part, is how to format your visual aids to communicate your results effectively and enhance your presentation but do not overshadow or compete with your words. If you are using a Powerpoint format, it is imperative that the slides are not too busy. Also, since it is a scientific presentation, embellishments should be minimized to eliminate any distractions from the data. The first reference I listed in this lab manual chapter is an excellent resource: *Dazzle'em with style: the art of oral scientific presentation by Robert Anholt*. The reference is available online from the UT library website. Please read it!