HOW TO WRITE A RESEARCH PAPER

Writing your final paper for BIOL 198, 298 or Neuro 298

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Note: The final paper will be graded by your research mentor, and thus they are empowered to change any of these directions as they choose.
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GETTING STARTED
TELL A STORY WITH FIGURES & TABLES

You want your research to tell a story. You want your research to be interesting and effective in communicating your take home message or why you did something, how you did it, what you found, and its importance. Start by summarizing the story or your take home message(s) in 1-2 sentences and keep this at the top of your document.

As you go through this guide, keep your story in mind. However, writing your research paper will not happen in chronological order of the sections outlined in this document. In scientific writing, you probably want to start by writing your Figures and Tables first, followed by the methods. Then go on to write up the results, and the discussion. Once you know how the story ends, write the introduction and then finally, write the abstract.

For inspiration look at this three-page guide “Ten Simple Rules for Writing Research Papers” https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1003453

It takes a lot of time to write a paper. During the first month of your research, start your draft using this document as a template or electronic notebook. If you have a proposal, you can copy and paste sections into the introduction, methods, results, discussion and literature cited. You will likely edit these as you write your paper, but it is a great place to start.

Enjoy your writing and use it to show the exciting and important parts of your research!
MANUSCRIPT ORGANIZATION

- Use this document as a guide for writing your paper.
- If you need more information about a particular point, follow the guidelines for PLoS Biology, Submission Guidelines, Manuscript Organization: [https://journals.plos.org/plosbiology/s/submission-guidelines](https://journals.plos.org/plosbiology/s/submission-guidelines).
- Note the journal webpage organization includes the Materials and Methods after the Discussion section. You are welcome to put the Materials and methods after the Introduction or after the Discussion section.
HOW TO WRITE AN ABSTRACT

If you have written the Figures & Tables, Introduction, Methods, Results and Discussion, you are ready to start writing the abstract. If not ..... Stop!

In scientific writing, you probably want to develop your Figures & Tables first and the abstract last. So go back, read the “Getting Started” section and then proceed.

PURPOSE OF AN ABSTRACT

• Present a condensed **summary** of the **entire** manuscript – highlighting the most important aspects and take-home messages from the presented study

GENERAL RULES

• **For this assignment, your abstract should have 4 sections: Background, Hypotheses/Predictions, Methodology/Principal findings and Conclusions/Significance**

  Here is a link to this type of abstract from the open access journal PLoS Neglected Tropical Diseases, except the linked article does not include the Hypotheses/Predictions
  **https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0010633**

• **Keep it short (~250 words)**

• **The abstract should be concise, easy to read, and follow the order of the manuscript**
• It should only include information needed for the reader to understand the study
• It should exclude references to figures and exclude previous research. No citations.
• Recommendation – read the abstracts of your references and use them to help guide you!

RECOMMENDATIONS

• Organize into 1-2 sentences per section (as outlined below)

GUIDELINES FOR YOUR ABSTRACT SECTIONS

• Use broad **background** statement(s) of essential information to understand and introduce the study.
• **Hypotheses and predictions** include the purpose of the study, what are you testing and what is predicted.
• **Methodology/Principal findings** The methods tell what you measured and how. The results show and explain clear patterns and trends.
• **Conclusions/Significance** Explain how the data do or do not support your hypotheses, why this study is important, and how it adds to the greater scientific field.
A good story starts out general

“It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of light, it was the season of darkness, it was the spring of hope, it was the winter of despair.”

— Charles Dickens, A Tale of Two Cities

PURPOSE OF THE INTRODUCTION

- **Provide relevant background information on the subject matter**
- **Define key terms, concepts & abbreviations**
- **Discuss previous findings on the subject AND describe the gap in knowledge this research fills**
- **Present a measurable argument (question + hypothesis/prediction)**
- **(Briefly) explain what you did, how you did it, and why you did it**
- **Give major conclusion of the research**
- **Describe the significance of your work**
- **Describe any areas that remain unanswered**
GENERAL RULES

- Be concise. A good introduction should be 500 to 1000 words.
- Follow a logical structure. Start broad and work toward the specific, like an inverted pyramid.
- Consider your audience (a scientist who is likely somewhat familiar with the subject matter).
- Write the introduction in the present tense up until you describe your specific experiment in the final paragraph, at which point you should switch to past tense.

RECOMMENDATIONS FOR YOUR INTRODUCTION

- 5 paragraphs (~500-1000 words)
- Minimum of 5 citations. These need to be peer-edited scientific journal articles. For health-related articles, utilize PubMed.
- Use the PLoS Biology, https://journals.plos.org/plosbiology/s/submission-guidelines citation format

GUIDELINES FOR INTRODUCTION PARAGRAPHS AND DIVISION OF INFORMATION

Paragraph #1 – The overarching problem that you are addressing.
Paragraph #2 – The broad biological context.
Paragraph #3 – A description of the specific dataset you are analyzing.
Paragraph #4 – What is the gap in knowledge?
Paragraph #5 – What did you do? – question/hypothesis, a brief summary of methods, a brief synopsis of the main results & overarching conclusions.
HOW TO WRITE A
METHODS SECTION

PURPOSE OF THE METHODS SECTION

• Explain your procedure with enough detail for someone to understand what you did, and then, be able to replicate it
• In short, explain what you did, how you did it, and why you did it!

GENERAL RULES

• If it seems appropriate present your procedure in chronological order, if not organize it to be clear and set up the story line of the results.
• Write in complete sentences. No bullet points.
• Be sure to include any approvals you received, for example working with vertebrates or humans. Here is a link to appropriate guidelines https://journals.plos.org/plosone/s/animal-research

RECOMMENDATIONS

• Write the methods in past tense and use active voice
  o Incorrect: “Data were analyzed using an ANOVA.”
  o Correct: “I conducted an ANOVA to assess the effect of nucleotide class on GC content.”
• Include key details and steps necessary to replicate the analysis
• Exclude routine details (e.g., that you typed your paper in Microsoft Word or that you used a Macbook to run your stats software).

• Provide rationale for novel steps and all statistical analyses

SUBSECTIONS WITH REQUIRED INFORMATION:

• Subsection #1 – Where the data came from and what they represent.

• Subsection #2 – Animal, human or other research details and permissions
  o Details of the animals you used
  o Details of approvals (e.g., IACUC)

• Subsection #3 – Statistical analyses
  o The statistical analysis software that you used.
  o The details of the specific statistical procedures that you chose to employ and WHY

The number of subsections will likely differ between research papers. Some may require more subsections to provide enough details on the methodology and experimentation.
HOW TO WRITE A RESULTS SECTION

PURPOSE OF THE RESULTS SECTION

• To present graphical, statistical, and written results for your key findings.
• Do not provide interpretation or reasoning as to why your results occurred, this is what you do in the Discussion. The reason for this is that you want the reader to be able to read your results clearly without you clouding the presentation of your results with your own interpretation, opinion, or bias. There is nothing more annoying than reading a results section in which the authors have provided their own interpretation, especially when the reader may disagree with that interpretation.

GENERAL RULES

• Present results in a logical order. Consider the types of data being presented and how you would like this section to flow. You can use your subsections outlined in the Methods section to help with this order.
• Write exclusively in the past tense.
• Write clearly and succinctly.
• The written results section, which consists of approximately 1 paragraph per figure/table, should describe the patterns in the graphs with more detail. Topic sentences for each paragraph should describe the main
results. Again, there should be no interpretation of the results in the Results section.

- All figures and tables must be described in the results section. Look at your references for examples of how to do this. You must reference figures and tables in each sentence that describes a pattern seen in that figure or table. You must reference any statistical tests and values of the test statistics and relevant p-values if a sentence describes them.

RECOMMENDATIONS

- When writing the written results section, focus on the patterns and trends observed and use the statistics to support the pattern.

- Write IN ENGLISH. No seriously, write in a language that emphasizes the biological pattern and do not use “statistics-speak”.
  - For example, do NOT write
    “The ANOVA showed that there was a statistically significant difference.”
  - Instead, use the opportunity to highlight your message
    “Flies that developed from egg to adult at the higher temperature (25°C) had significantly higher heat tolerance than flies that developed at 18°C (Figure 1; ANOVA, p < 0.005).”
HOW TO WRITE YOUR FIGURES AND TABLES

PURPOSE OF THE FIGURES AND TABLES

• The recommended way to start writing your paper or telling your story is with the Figures and Tables. The figures and tables should form a series telling the story of the paper.

• Drawing and diagrams; micrographs and gel photos; and graphs such as line graphs, histograms, and bar graphs along with tables can help visualize your results or clarify your methods.

GENERAL RULES

• Each figure and table should be clearly designed and the legends for figures and the titles and footnotes for tables brief and clearly written.

• Tables can present individual information such as for all specimens or summarize information to reinforce a point.

• Methods figures and tables present background information and should state the topic and the material described. For example, the table below sets out the number and percentage of houses surveyed in the study. . .

<table>
<thead>
<tr>
<th>Village</th>
<th>Surveyed n (%)</th>
<th>Uninhabited n (%)</th>
<th>Households not participating n (%)</th>
<th>Total houses n</th>
<th>Months surveyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anenito</td>
<td>181 (86.6)</td>
<td>23 (11.0)</td>
<td>5 (2.4)</td>
<td>209</td>
<td>June</td>
</tr>
<tr>
<td>Ixcanal II</td>
<td>140 (91.5)</td>
<td>5 (3.3)</td>
<td>8 (5.2)</td>
<td>153</td>
<td>August</td>
</tr>
<tr>
<td>El Naranjo</td>
<td>52 (83.9)</td>
<td>5 (8.1)</td>
<td>5 (8.1)</td>
<td>62</td>
<td>September</td>
</tr>
<tr>
<td>San Ramon</td>
<td>104 (95.4)</td>
<td>2 (1.8)</td>
<td>3 (2.8)</td>
<td>109</td>
<td>September</td>
</tr>
</tbody>
</table>
• Results figures and tables show data that support results. Tables presenting individual data can be in supplemental information.
• Subheadings can divide headings into more categories, for example there could be a heading of houses with subheading surveyed and uninhabited in the figure above.
• Columns on the left list entries that you have data for, the related data are in columns on the right.
• If the sample sizes (n) differ among rows include them in a column.
• Include units in parentheses in the column heading or axes labels.
• Use symbols to indicate statistically significant differences and define them in a footnote (e.g., * P < 0.05, ** P < 0.01).

RECOMMENDATIONS

• Read these 10 simple rules for better figures. https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1003833
• The figures and tables together should form a clear sequence that tells the story of the paper. To create a clear sequence, design them to be sequential, each figure and table preparse the reader for the next.
• Use the fewest figures and tables needed to tell the story. Following 5-6 is easier than 15-16.
• Graphs should be uncluttered, put information in the figure legend if necessary for clarity.
• For tables, keep headings short by using short terms or abbreviations and explain the abbreviations in footnotes if necessary.

GUIDELINES

• Create at least 4 separate figures and tables with properly labelled titles, captions, heading and axes.
• Do not present the same data in both a figure and a table.
• The figures and tables tell your story as well as show what the text states. Although it seems repetitive, state the point of each table and figure in the text, referencing the table or figure number in the sentence.
• Use the same terms throughout the table titles, column and sub column headings, figure headings, axes, labels, and text.

• Figure captions go below and contain important information about the parameters of the graph. Start with the most important information, that is the pattern/trend observed in the figure. Also include the type of data presented, the type of statistical test and the statistical results.

• Table captions go above the table and provide a short explanation of the information included.

• Make your graphs look good! Use at least 12 point font and shape sizes to make things easy to read and see, and/or add colors and patterns when appropriate. Keep colors and patterns consistent among figures! If you used blue for the “cold treatment”, make sure blue is the cold treatment in all figures.

• The graph below has an inset plot of log-transformed values. To create a graph with an inset like the one shown below, use the Layouts functionality in Graphpad Prism to combine multiple plots onto a single layout and resize them accordingly.

**Figure 1. G6PD from tropical *D. melanogaster* is thermally stable.** Plotted is the residual glucose-6-phosphate dehydrogenase (G6PD) activity (%) for *D. melanogaster* enzyme preparations that were subjected to 40°C for 0, 5, 10, 20, 45, or 60 min (n = 22-24 per region and timepoint). There was a significant negative effect of heat treatment on residual enzyme activity, regardless of region of origin (Least-squares linear regression, tropical: y = -0.017x + 1.92, $R^2 = 0.40$, $P<0.0001$, temperate: y = -0.029x + 1.86, $R^2 = 0.39$, $P<0.0001$). However, tropical enzymes were significantly more thermally stable than temperate enzymes (ANCOVA, $F(1,214) = 8.497$, $P=0.004$).
HOW TO WRITE A DISCUSSION SECTION

PURPOSE OF THE DISCUSSION SECTION

- Interpret the findings from your results section with thoughtful and clear explanations that align with existing knowledge and previous research
- The main goal is to answer the questions you posed in the introduction, and explain how the results fit the hypothesis and predictions
- Discuss the implications of your research, how it adds to our greater scientific understanding, and possible future research directions

GENERAL RULES

- The organization of the discussion is key – think of a pyramid. Start with the specifics of your research and then branch out to discuss findings from the broader, previously published literature.
- Begin by summarizing the data and restating your question or hypothesis.
- Do your actual results support the initial hypotheses or do you fail to reject null hypotheses?
- Explain the rationale behind your observed results (i.e. how are they consistent with what has been seen in previously published articles?)
- Discuss and interpret all of your results, even those that are not statistically significant. Highlight whether any of your results were surprising or conflict with your predictions.
RECOMMENDATIONS

- Describe the pattern from each major finding that you presented in your results section in the following manner:
  - Does the observation fit the hypothesis/answer the question?
  - What was the observed pattern for this specific result?
  - How does this fit with the literature? (Cite published articles)
- If your results conflict with previously published data, explain why your data could make sense regardless of what has been previously shown.
- Identify limitations and weaknesses of your experiments or how they are different from previous work – never is an experiment perfect, and it is important to identify potential areas for improvement or areas where the experiment may have been limited or different.
- Provide recommendations for future directions of the research – think critically about expanding on the research topic, and don’t just fall on “We could redo the experiment with a larger sample size...” What questions would you address if you worked in this area longer?
- Describe the implications and scientific importance of this study (i.e., what gaps does this research fill in the field?).
- Overall, there is a lot to talk about, but be concise, clear, and direct.

GUIDELILNES

- Organize the discussion should into 4 to 7 paragraphs (~1000 words):
  - Summary paragraph – state how your results supported your hypotheses and predictions
  - Two to five paragraphs of how major findings align with previous research
  - A potential limitations of the study paragraph
  - An implications of the study and future directions paragraph
  - Include at least 10 previously published articles in your discussion, properly formatted in the text and in a literature cited section.
For citations in the text, do not plop all of the citations at the end of a sentence, it is more helpful to have them throughout the sentence for specificity. For example:

“Despite the potential for thermal adaptation across the broad range of thermal habitats represented in this study, our data corroborate recent studies (Porcelli et al., 2017) and suggest that natural selection on thermal tolerance does not act equally across life stages in Drosophila spp.”
All in-text citations and the literature cited should be formatted following the guidelines of PLoS Biology, https://journals.plos.org/plosbiology/s/submission-guidelines.


