**RUBRIC FOR WRITING LAB MANUSCRIPTS**

This document gives guidelines on writing lab manuscripts as well as grading rubrics for the three different roles: First Author, Computer, and Reviewer.

FIRST, a Sample Manuscript is available on Canvas. This is an actual professional manuscript that has been highlighted to illustrate the key points below, as well as examples of what the Computer and the Reviewer are expected to provide.

1. All lab papers will be written in the style of professional scientific papers. Distinct sections must be included: abstract, introduction, methods, results, and discussion. See below for guidelines for each section.
2. Don't write the paper like you are reporting an exercise done for class. Each experiment you will write about has at least one distinct hypothesis, and the paper should be crafted to present that hypothesis, the methods used to test it, and evidence for or against the hypothesis.
3. Each manuscript should include figures as necessary to represent the relevant data and analyses. Figures can be made in Microsoft Excel or any other software package, or even drawn by hand on graph paper. See below for figure guidelines. The lab manual gives a rough description of the figures and tables that should be used for each manuscript.
4. References should be used as appropriate.
5. The paper should be written in the past tense, and in the third person plural (e.g. "We did such and such", "Our results suggest that….", etc.)

**TITLE**

 Your paper needs a title. "Environmental Tolerance lab report" is awful. Give it a name that reflects your findings. For instance, "Bacteria from a single soil sample show divergent environmental preferences".

**ABSTRACT**

 The abstract should give a brief synopsis of the report. Use no more than 200 words to briefly restate the hypothesis being tested and/or the point of the experiment, the major results, and the conclusions.

**INTRODUCTION**

 The introduction gives some background on the experiment. Why is it being conducted? What is the hypothesis? What historical problems or questions are under consideration? For instance, the first lab report on growth curves tests the hypothesis that the environmental preferences of a bacterium will reflect the environment were it is found. Your introduction should talk about both of these topics -- what is known about bacterial responses to temperature, pH, etc? What are the theoretical supports for the hypotheses? Etc. The introduction should cite at least two outside references, not counting the lab material and the textbook. Online resources are fine. Wikipedia is a fine place to start, but shouldn't be your sole reference -- remember that every article on Wikipedia cites references that you can usually find somewhere on the Internet.

**METHODS**

 The methods section needs to give enough detail that your work could be replicated. It must be written in narrative style, not as a step-by-step protocol. Excessive detail should be avoided in favor of clear mechanistic descriptions. For instance: "10-fold dilutions of cultures from 10-1 to 10-5 were plated on nutrient agar" is way better than "100 μL of an overnight culture was diluted into 9.9 mL of sterile saline, then 100 μL of that tube was placed into another tube of sterile saline, and then 100 μL of that was placed on a nutrient agar plate".

 It is a good idea to separate the methods section into individual procedures. For instance, you might have one section for how cultures were grown, another for how optical density and viable counts were performed, and a third for how the data were analyzed (e.g. statistics). Importantly, there should be NO data in the methods section! All of that goes in the results.

**RESULTS**

 Here you will present your data. Make sure to include all the relevant data you collected, including each piece of information mentioned in the "For Your Report" section of the lab handout. The section should be written in narrative style, explaining the data without drawing conclusions about whether or not they support your hypotheses. All values should include measures of variation if they exist, and any statistical findings should be presented here as well, explicitly stating what test was used, how many replicates were performed, and what the p-value was. For instance, don't say "Our organism's exponential growth rate at 37C was 0.37 per hour, which was greater than its growth rate of 0.29 per hour at 30C." Instead, say something like "The mean exponential growth rate of 4 replicate cultures at 37C was 0.37 +/- 0.04 per hour (95% confidence interval), and at 30C was 0.29 +/- 0.08 per hour. The two measurements were significantly different (t-test, p = 0.015)."

 This section should include several graphical representations of data as well. Broadly, there are three types of graphics you can use:

1. TABLES are good for presenting numerical data when you have a number of different things measured for several different cultures. Tables are often better than graphs for complicated data. DON'T represent the same data in both table and graph format, however! All tables should have a title which includes a number and a brief description. For instance:

Table 1. Growth rates (per hour, +/- 95% confidence interval) of unknown isolates at different temperatures.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 15 C | 25 C | 37 C | 55 C |
| Isolate 1 | 0.29 +/- 0.08 | 0.32 +/- 0.06 | 0.37 +/- 0.04 | 0 +/- 0.00 |
| Isolate 2 | 0.36 +/- 0.11 | 0.25 +/- 0.08 | 0.12 +/- 0.06 | 0 +/- 0.00 |

1. GRAPHS are usually the best choice for presenting your main data. The two types you're most likely to use are bar graphs and scatter plots. Make sure your graphs give a fair representation of the variation in your dataset, either by including "error bars" or by plotting all the replicate measurements instead of just the average value. Make sure both axes on your graph are labeled, and make sure to include units as appropriate. All graph figures should have a figure legend including a number, a title, and a brief description of what the symbols, lines, etc mean. Example (note that 2 replicates are plotted separately):

Figure 1. Growth of Unknown 1 at 37C (black circles) or 30C (white triangles).

1. PHOTOS are the best way to show qualitative visual data. For instance, if you want to say "Our colonies were red at 30C but white at 37C" you'll want to have a photo to prove this. Like graphs, photos will have a figure number and a legend explaining them.

Figure 2. Exponential growth rates of two isolates at different temperatures. Error bars indicate the 95% confidence interval of 4 replicate measurements.

 Importantly, you can't claim any results or conclusions without presenting data in this section! Every conclusion MUST be supported by data or evidence shown in the results section.

 Also important: the results section MUST NOT contain any conclusions about the data beyond the results of statistical tests, and explanation should be kept to a minimum. For instance, it's okay to say "Isolate 1 grew significantly faster than Isolate 2 at 37 C (Fig. 2, t-test, p = 0.01)" but it's not okay to then say "The optimum growth temperature of Isolate 1 was higher than Isolate 2". This section is purely objective; your conclusions will be in the discussion section.

**DISCUSSION**

 In this section you will draw conclusions based on the data you presented in the results. Here, you should explicitly state whether the hypotheses you presented in the introduction were supported or not, and what the evidence for or against was. Keep it minimal, but make sure to address anything you thought was important enough to bring up in the introduction. It's okay to speculate (within reason) here; you can say what you THINK is going on, as long as you justify your statements with facts from the results section (or from outside research).

**REFERENCES**

 Last, you'll include a list of any references you cited.

**HOW TO BE A COMPUTER**

In the not-so-distant past, all scientific computing was done by human beings. You may have seen the award-winning movie "Hidden Figures", about the experiences of human computer Katherine Johnson during the early days of the US space program. Since you have access to a digital computer, you don't need to be a brilliant mathematician like Ms. Johnson -- you just have to know how to type in some Excel code and interpret the answers it gives you. Each paper required for this course has a list of calculations and statistics that need to be performed, as well as figures and/or tables that need to be made. As computer, your job is to do all of these calculations and deliver the results to the first author.

You will do all of these calculations in Excel, and submit your finished spreadsheet for your grade. Make sure to include enough notes, column headings, and so forth in the spreadsheet that the first author and I can tell what you've done. It's a good idea to write out your interpretation of the results of the statistical tests, like you would expect to see them mentioned in the paper. For instance, if you did a t-test comparing sets of growth rates and found that they were significantly different with a p-value of 0.02, you might write in the spreadsheet:

"The growth rate of isolate Mello Yello at 30C was significantly higher than at 37C (t-test, p = 0.02), but both were significantly higher than the growth rate at room temperature (t-tests, p < 0.05 for both comparisons)."

The first author can then just copy your sentence into the main paper and edit it as needed to make it fit.

**HOW TO REVIEW A PAPER**

Reviewing is NOT the same as proofreading (although you should do that too). If you are the reviewer, your job is to read the manuscript as a skeptic, looking for flaws in the arguments or methods, and suggesting ways that the first author can improve the paper. You can either use the Review tools in Word to insert comments and suggestions, or you can write them out in a separate document. If you do the latter, make sure to indicate where in the paper your comment belongs. For instance:

"In the second paragraph on page 3, the author says that the growth rates of the two isolates at 37C were significantly different, but I don't see what statistical test was used, and there are no error bars in Figure 2 either."

As the reviewer, your grade doesn't come from the quality of the finished paper -- only how well you spot the flaws in the first draft. If there are deficiencies in the finished paper and you didn't catch them, both you and the first author will take a hit for that. You're also responsible for looking over the work that the Computer has done. You don't need to re-do the calculations or look for arithmetic errors or that sort of thing -- you mainly need to ensure that the types of calculations that were done are appropriate and that the figures are useful, understandable, and complete.

Many students are very hesitant to write a critical review of their classmates, and that's understandable. In the "real science" world, peer review is almost always anonymous to make it easier to say what needs to be said about a not-so-great paper. However, it's important that you not "pull punches" in these reviews. Every paper can be improved, and your review is the best advice that your teammate will get before submitting their paper for a grade. Remember -- it's possible to be critical without being nasty. It's very likely that your teammate will appreciate your criticism, because it means that they will get a better grade after addressing each point.

**MANUSCRIPT SCORE SHEET -- FIRST AUTHOR**

**Student: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. **Abstract (5)**
	1. **Informative Title \_\_\_\_\_\_**
	2. **200 words or less \_\_\_\_\_\_**
	3. **Contains hypotheses \_\_\_\_\_\_**
	4. **Contains results \_\_\_\_\_\_**
	5. **Contains conclusions \_\_\_\_\_\_**
2. **Introduction (15)**
	1. **States hypotheses \_\_\_\_\_\_**
	2. **Not in "lab report" style \_\_\_\_\_\_**
	3. **At least 2 references \_\_\_\_\_\_**
	4. **Gives background on experiments \_\_\_\_\_\_**
	5. **Writing \_\_\_\_\_\_**
3. **Methods (15)**
	1. **Complete \_\_\_\_\_\_**
	2. **Narrative, not protocol style \_\_\_\_\_\_**
	3. **No excessive detail \_\_\_\_\_\_**
	4. **No results/discussion \_\_\_\_\_\_**
4. **Results (20)**
	1. **No discussion/conclusions \_\_\_\_\_\_**
	2. **Clear \_\_\_\_\_\_**
	3. **Complete \_\_\_\_\_\_**
	4. **Statistics appropriate \_\_\_\_\_\_**
	5. **No unsupported statements \_\_\_\_\_\_**
5. **Figures (15)**
	1. **Appropriate/not redundant \_\_\_\_\_\_**
	2. **All required figures/tables included \_\_\_\_\_\_**
	3. **Cited appropriately in text \_\_\_\_\_\_**
	4. **Informative legends \_\_\_\_\_\_**
6. **Discussion (20)**
	1. **No results \_\_\_\_\_\_**
	2. **All hypotheses dealt with \_\_\_\_\_\_**
	3. **Conclusions appropriate \_\_\_\_\_\_**
	4. **All statements supported by evidence \_\_\_\_\_\_**
	5. **Writing \_\_\_\_\_\_**
7. **References (5)**
	1. **At least 2 in addition to textbook/lab handouts \_\_\_\_\_\_**
	2. **Professional format \_\_\_\_\_\_**

**MANUSCRIPT SCORE SHEET -- COMPUTER**

**Student: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. **Calculations (50)**
	1. **All required calculations performed \_\_\_\_\_\_**
	2. **Appropriate statistics \_\_\_\_\_\_**
	3. **Spreadsheet well-organized \_\_\_\_\_\_**
2. **Figures/Tables (50)**
	1. **Clarity \_\_\_\_\_\_**
	2. **All required figures/tables included \_\_\_\_\_\_**
	3. **Appropriate/not redundant \_\_\_\_\_\_**
	4. **Variation represented \_\_\_\_\_\_**
	5. **Axes labeled \_\_\_\_\_\_**
	6. **Informative legends \_\_\_\_\_\_**

**MANUSCRIPT SCORE SHEET -- REVIEWER**

**Student: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. **Content (75)**
	1. **Significance \_\_\_\_\_\_**
	2. **Proposes improvements \_\_\_\_\_\_**
	3. **Entire paper examined \_\_\_\_\_\_**
2. **Attitude (25)**
	1. **Professional/courteous \_\_\_\_\_\_**
	2. **Appropriately critical \_\_\_\_\_\_**
3. **Missed Problems (up to -20)**

**Team: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**FINAL PROJECT SCORE SHEET**

1. **Significance of the hypothesis (3)**
	1. **Relevant to the literature**
	2. **Non-trivial**
	3. **Potentially interesting to outside researchers**
2. **Thoroughness of the experimental work (4)**
	1. **Lab time used effectively**
	2. **Controls relevant and complete**
	3. **Sufficient replication**
	4. **Honest statistics**
	5. **Troubleshooting and iteration**
3. **Creativity of the project (3)**