# Lab Report Format

*Some portions modified from NCSU’s LabWrite  program:*[*http://labwrite.ncsu.edu*](http://labwrite.ncsu.edu)

So you have conducted an experiment, have buckets of data, and have given things some thought. It is now time to communicate the results of your experiment. Formal lab reports are important (labs count for as much in your course average as exams do), and there are certain expectations that you should follow when you write one for AP Biology.

In AP Biology, we will use the IMRaD format when writing lab reports. IMRaD (Introduction, Methods, Results, and Discussion), is a standard format for reporting the results of experiments in the scientific community. This document explains the specific details of our IMRaD lab reports. It is important that you read this document fully, and ask any questions that you have prior to submitting your first AP Biology Lab Report.

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# General Guidelines:

Generally, you will be given several weeks to work on a formal lab report at the conclusion of a lab experience. This is both because I am a gracious soul, and because I fully expect that the document that you will submit will be evidence of your **best possible effort**. To that end, there are a few, basic things that you should make sure you have done prior to submitting the lab:

* You should address all points of each section as delineated below.
* You should proofread your lab for spelling and grammatical concerns.
* You should adhere to all appropriate scientific conventions. Organisms are referred to by their proper, scientific, names (*Genus species*), concentrations are listed for all reagents, and all the rest of them.
* You should go through your lab and make sure that all sections are properly and consistently formatted. You shouldn’t have changes in font type (use a legible, non-decorative, font) or font size (12 point is expected), except where you have deliberately chosen to do so (e.g. headings, titles), etc. Line spacing is consistent (I prefer 1.5 spacing for these reports). Margins are responsible (I think 1 inch margins are the bee’s knees). Pages are numbered.

# Submission Guidelines:

All labs in this course are to be submitted to me via google docs. **You must create them in Google Docs on the Deer Park Google Apps Portal**. This process must be specifically adhered to. There are several things that you must make sure you do when submitting your lab:

* Make sure the filename of the lab (top left corner of the document) is formatted as follows: <LASTNAME><TOPIC>Lab Report (note: angled brackets and all caps are not necessary).
* I must have **editor access** to the document at my work email address (knuffke.d@deerparkschools.org). This is accomplished by putting your lab in your dropbox folder for this course in google docs. You can also manage sharing more directly via the big blue Share button on the top right of the Google Doc composition window.
* The lab must be either publicly viewable (managed via the big blue “Share” button) or published to the web (managed via the file menu in the composition window), and the link to the document must be published on the course blog in a post that includes both the link, an explanatory sentence or two, and an image of your choosing related to the lab.
* A template document is provided for your use [at this link](https://docs.google.com/document/d/1WwDosDfIc7JekYHvwAZYLh3izWY_svlumdamDknBPCo/edit).
* In many cases, I will send you a template via doc deployment to either the class view folder, or your share folder. Do yourself a favor, and use either that document, or something that looks a lot like it. If the template is in the view folder, use the “Make a copy…” option in the file menu to make a copy for your own usage.

**ANY LAB THAT DOES NOT FOLLOW THESE GUIDELINES WILL NOT BE COUNTED AS SUBMITTED, AND MAY BE PENALIZED FOR LATENESS (10 POINTS/DAY) ACCORDINGLY.**

# Sections:

### **Title: What is the name of your experiment?**

Not a section, per se, but it should be mentioned. At the top of your page, you should give your report an appropriate title . “Appropriate” means that it is related to the investigation that you conducted, and the variable that you manipulated. So a title like “Brine Shrimp” is not acceptable. A title like “The Effect of Salinity on Brine Shrimp Hatching Rate” is just about perfect. As always, I love a bit of humor, so if you want to go with something like “The Law of The Briny Deep: Brine Shrimp Hatch Rate as a Function of Salinity”, it’s totally fine. But the bottom line is that we put this:

**The Effect of INDEPENDENT VARIABLE on DEPENDENT VARIABLE.**

Or a variation therein somewhere in the title.

## Introduction: Establishing a context for the lab

The introduction section for your report should include the following sub-sections. These can be individually delineated, or cohesively integrated, as per your preference:

A. Background

In this section of the lab report, you will provide the reader with background information that will use to help them understand the experiment you have done. The introduction should also inform the reader about the underlying biological concept of the lab. This section should include any unfamiliar terms that might be used to clarify ideas for the reader, particularly ones that you are going to use later on in your report. You are going to want to **cite information from somewhere** other than your own brain, and as such, you should include the sources you have cited here in your reference section at the end of the lab. Do not forget to include in-text citations in this section, where appropriate.

### B. Objectives:  Establishing the lab’s purpose

You will always need to list what the objectives of the lab experiment are. Why did you do this lab? What was the point. I’ll give you something that should clue you in, in the material that I provide you with for each lab (which can be cited as per the previous section), but the demonstration of independent thinking is always appreciated. Bullet points are fine to use here if it helps you frame your thinking.

### C. Research Question and Hypothesis: Establishing a question and a prediction

In this section, you will formulate a testable question that addresses a problem. This problem can either be one your teacher assigns, or one you devise on your own. You will also establish what you think will happen during the lab. Your hypothesis should be testable.  You should identify your dependent and independent variables. While I won’t take points off if you have to use the “if, then” format, I won’t be super psyched about it, either. After stating your hypothesis, you should include a few sentences explaining why you think your hypothesis is what it is. In other words, don’t just state your hypothesis and move on, put some thought in to a justification of why your hypothesis is a reasonable one.

## Methods: What equipment, organisms, or reagents did you use?

The Methods section for your report should include the following sub-sections. These can be individually delineated, or cohesively integrated, as per your preference:

### A. Materials

A complete list of the supplies used during the experiment should be given. Be as specific as possible. Include the volumes of tubes and cylinders. If organisms are used, scientific names (*Genus species*) must be provided. If chemical reagents are used, concentrations of these reagents must be given, if known. Include the model and manufacturer of any complex apparatus.

### B. Procedure: How was the experiment conducted?

This section should outline exactly what steps were taken to conduct the experiment and should be written in in third person past tense.  Do not use “I.” This section should be concise and describe exactly what was done during the experiment. In this section, you should also clearly identify your independent and dependent variables, as well as your control treatment (if there is one) and your constants. Generally speaking:

* You want to have at least **5 degrees of variance** in your independent variable (though there will be exceptions to this).
* You want to hold every variable that isn’t your independent variable constant across all trials.
* You need to have at least **1 control treatment** for your experiment. The control is the experimental treatment that is used for a comparative purpose across all other experimental trials. Make sure you explain how you are going to measure changes in your dependent variable.

This section should be written in sequential order (numbered steps are fine). If you did not design the procedure yourself, you do not write up this section of the lab, you can simply reference the document that you took your procedure from (citations strike again). Similarly, if you adapted your procedure from another protocol, you can say as much and then delineate how you have adapted the procedure for your purposes:

* You must provide a reference to any borrowed or adapted protocol in your reference section, along with an in-text citation in this section.
* Include a diagram or photograph of how you set up the experiment. Be sure your diagram includes a title and any necessary labels. It is recommended that this diagram be annotated to illustrate how the variables were involved.
* If you have to decide how much of a substance or a solution to use, state your reasoning or show the calculations.

Make sure that your procedure is detailed enough so that another person could repeat your work by reading your report. Your procedure should speak to validity measures. Validity measures are things kept constant to make sure experimental measurements are valid and consistent (ex. cleaning test tubes prior to use, cleaning the microscope lenses, using the same ruler…). Your procedure must clearly state how you collected data:

* What measuring device did you use, what data did you record, when did you collect data?
* What qualitative observations did you look for? Explain how you set up the investigation so you had multiple trials of data collection.
* The procedure must allow collection of “sufficient relevant data”. The definition of “sufficient relevant data” depends on the context. The planned investigation should anticipate the collection of enough data so that the problem question can be suitably addressed and an evaluation of the reliability of the data can be made. As a rule, the lower limit is a sample size of five. Very small samples run from 5 to 20, small samples run from 20 to 30, and big samples run from 30 upwards. Obviously, this will vary within the limits of the time available for an investigation.

If you will be combining data with data collected by other students in the class, you should indicate that explicitly in your procedure and explain why this pooling of data was done. If you are sampling only a portion of a population, you must explain how and why you ensured that the sample was randomly selected.

Your procedure must be safe and ethical. Organisms, including humans, can not be subject to harm in your investigation. List any safety precautions that were taken during the lab.

## Results: What data do you have?

The results section is evaluated according to two separate criteria.

### A. Data Collection: What information have you gathered?

Your data section will include your raw data gathered during the lab. This should include both qualitative and quantitative data (both need to be present):

* Qualitative data can include descriptions and photographs or sketches, which must be in color since we are often working with living materials. Sketches must accurately represent what is being depicted so that the reader does not have a question about what the sketch is supposed to represent.
* Quantitative Data Calculations should be shown (my advice would be to use the equation editor for nice looking calculations. Statistical analysis (mean, standard deviation, standard error, chi-square analysis, t-testing, etc. as necessary) should similarly be demonstrated.

**Degrees of precision:**

It is important to be aware of the precision of the measuring instruments that we use. Generally the accepted rule is that the degree of precision is ± the smallest division on the instrument. Let’s look at an example using a ruler, graduated in millimetres, to measure the length of a leaf. You will probably find the edges of the leaf lie close to a millimetre division but probably not right on it. Recording the leaf is "4.5cm-and-a-bit" long is not very useful. So the length of the leaf in this example is recorded as 4.5cm ± 0.1cm. The degree of precision will influence the instrument that you choose to make a measurement. For example if you used the same ruler to measure an object 0.5cm long the degree of precision (± 0.1cm) is 20% of the measurement, this is very large error margin and, so, it is not very precise. Therefore, we must choose an appropriate instrument for measuring. Use this understanding when conducting and recording measurements in lab.

### B. Data Presentation: How will you represent the data you collected?

All lab reports must include at least one graphical representation of your data and two data tables (processed data should always go here. A raw data table should be included here or provided in an appendix for the lab depending on how extensive it is). Additionally, all calculations need to be shown in this data section. All items in this section should have a one-sentence explanation of what is being shown. Label all graphs, drawings, and images as figures in numerical order (ex: figure 1, figure 2, etc.). Do the same for tables, though number them separately from figures (ex: table 1, table 2, etc.). For each graph or table you construct, provide a brief description of the data trend the graph or table shows. For example, if a graph clearly shows a negative correlation between two variables, give a brief statement about the trend underneath that graph. If drawings/photographs are included, they should be clearly labeled and accurately representative of what you are depicting. **Clarity is important!**

#### Data tables:

Tables should be organized, and informative. Units should be used wherever possible. Here are some items to keep in mind when constructing data tables:

* The table is easy to understand
* The table has a specific title
* The table has column headings
* The table includes the unit of measurement (always in metric units)
* The table includes the measurement uncertainty of the measurement tools used (or, if the data was a count, indicates that “counts have no measurable uncertainty”).
* Uncertainly is usually stated in a column heading or as a footnote at the bottom of the table.
* The table has a consistent and correct number of digits for each measurement
* The table has decimal points aligning down a column (if applicable) and numbers centered in the column
* The table indicates which data was collected by which student IF the data was collected and pooled across multiple students.

#### Graphs:

Graphs should be generated on a computer program/website of your choosing, and adhere to all proper graphing techniques.The trend being shown in your graph should be clear and not obscured by poor design choices. Here are some items to keep in mind when deciding how to represent graphs:

* Use the correct type of graph for the type of data you are presenting.
* Graphs need to have appropriate scales, labeled axes with units, and accurately plotted data points.
* If necessary, add smooth lines or curves to show the overall trend of the data.
* If a mean is calculated, only graph the mean, not all data points. When a mean is graphed, its associated standard deviation error bar must also be included (and labeled as such).
* Legends (keys) are not always necessary, but should be used whenever more than one trend line is graphed on a common set of axes.

#### Drawings/Images:

Drawings and images are considered to be lab data. Unlike tables and graphical representations, not all labs require drawings/images (though they are acceptable in all lab reports). Here are some items to keep in mind when deciding how to represent drawings and images:

* Include labels written off straight, horizontal lines to the right of the side of the drawing. The labels should form a vertical list.
* Be accurate. Draw what you see; as you see it, not what you imagine should be there.
* Include a title that states what is being shown and what lens power (if any) it was drawn under. The title must be informative, centered, and larger than other text.
* Include a scale that indicates how many times larger the drawing is compared to life size and a scale line that indicates relative size.

#### Statistics:

Statistics are useful mathematical tools which are used to analyze data. Common statistics used in biology are:

* Mean
* Range
* Median
* Percent change
* Standard deviation (to determine amount of variation around a mean)
* Standard error (to determine the amount of variation in the magnitude of error)
* T-test (to compare two means to determine if they are statistically different from each other). When a t-test is calculated, you must indicate the significance level at which your critical T value is determined (we typically use the 95% confidence interval, 0.05).
* Chi-square (to determine if “observed” results are significantly different from “expected” results).
* Monte-Carlo simulation techniques. If possible, include a link to the spreadsheet or other simulation you used in your Monte-Carlo technique.

For each statistic you calculate, you must explain why you elected to do that calculation. What does the calculation tell you about the data?

#### Calculations and Data Processing:

Show an example calcualtion for each statistic you calculate. **Given the nature of electronic word processing programs, it is strongly recommended that you use an equation editor to render equations and calculations (links to several equation editors are provided in the references for this document).** Show the units of measurements in all calculations. Pay attention to the number of digits! Don’t lose accuracy by carelessly rounding off. Round only at the end of a calculation. Do not truncate. Present your data processing results in a table. The initial raw data and the processed (calculated) data may be shown in one table provided they are clearly distinguishable. Be sure your processed data table adheres to all table guidelines mentioned above.

## Discussion: What does your data mean?

The methods section for your report should include the following sub-sections. These can be individually delineated, or cohesively integrated, as per your preference:

### A. Conclusions: What does this all mean?

The conclusion section of the lab is where you explain and analyze your results, relate the experiment to course concepts, discuss potential limitations to the activity you did, note any errors made, and provide suggestions for improvement or future study. The following questions will help guide you in writing the conclusion section for any of our lab activities. Do not address these questions individually (or even in total), but use them to construct your narrative:

* How has your understanding of the concept improved or otherwise changed from doing the lab?
* If you used a T-test/chi-square test, be sure your conclusion is congruent with the results of that test.
* Did your data support your hypothesis or was it refuted? If not, why do you think your data did not support your hypothesis? Explain how you came to this conclusion.
* How might what you have learned in the lab be applicable in the future?
* How might what you have learned in the lab be connected to the larger understandings of the course?
* Did the lab work the way that you thought it did, or were there any unexpected results? If so, why do you think this is? If not, why do you think it didn’t?
* What are some of the limitations of your experiment? How could these limitations be addressed?
* What are some of the limitations of your conclusion? Can the results be generalized to other situations/conditions? How might your results explain a process in the “real world”

Additionally, you may find useful items for discussion in the materials that you are provided with when conducting a particular lab. If possible, cite literature related to your conclusion. Does you result coincide with published results? Does it refute published results?

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### B. Experimental Evaluation:

For every lab, you will need to evaluate your procedure, how you thought it would work compared to how it actually worked, how you could improve/refine the procedure and generally what you could do in the future to have a better lab experience. This section should also include a discussion of sources of error in your lab. The following questions will help guide you in writing the experimental evaluation for any of our lab activities. Do not address these questions individually (or even in total), but use them to construct your narrative:

* In general, how much confidence do you have in your results. If you did a hypothesis test, make sure to state your answer in terms of the percentage that the hypothesis test determined.
* Why do you feel confident (or not confident) in your results?
* What did you do to ensure validity?
* Looking back on the lab, is there anything that you, your group, or the class could have done differently? Be detailed in your recommendations.
* Discuss the sources of error in the lab, why/how they contributed to errors, and what could be done (if anything) to address those sources of error. Here are some of the more common sources of error seen in labs:
	+ Human error: Human error can occur when tools or instruments are used or read incorrectly. Human errors can be systematic because the experimenter does not know how to use the apparatus properly or they can be random because the power of concentration of the experimenter is fading. Automated measuring using a data- logger system can help reduce the likelihood of this error; alternatively you can take a break from measuring from time to time.
	+ Calibration error: Some instruments need calibrating before you use them. If this is done incorrectly it can increase the risk of systematic error.
	+ Random errors: In biological investigations, the changes in the material used or the conditions in which they are carried out can cause a lot of errors. Biological material is notably variable.
	+ The act of measuring: Could the measurement uncertainty have affected the results? Why or why not?
	+ Uncontrolled variables: What variables were not controlled? What effect might each of these uncontrolled variables have had on your data? On the conclusion?
* How could the lab be changed or modified to provide more accurate data or to measure other aspects than what was measured? What improvements could be made? How could the weaknesses identified be improved?
* What are some of the areas of future or expanded investigation that might be worth looking at?

Additionally, you may find useful items for discussion in the materials that you are provided with when conducting a particular lab. Do not be incomplete in your response in this section. Do not use vague or nonspecific language. Be precise and complete!

## References:

All lab reports should adhere to stylistic conventions of either the APA or IEEE (preferred) editorial style. If you are unclear about how these stylistic conventions apply (both in terms of a reference list, AND in-text citations), I encourage you to consult the references provided below. Wikipedia should never be used as the sole source for any aspect of a lab report.

## Appendices:

If you choose to include appendices (for raw data, perhaps), they should come after the reference section and be presented in lettered order (ex: Appendix A, Appendix B, etc).

# Length Considerations:

Obviously, there is no such thing as “correct length” for a lab report. At the same time, it might be suggested that since these documents are the result of weeks of effort, and given what is required in them, there are certain benchmarks that should sound an alarm if they are not close to being met for particular sections. To that end, I would expect that the Introduction would be at least a page, and that the Discussion sections would be at least two pages (they could easily be much longer). Materials and Results will vary in length considerably from lab to lab, and as per the decisions made by the author(s). Again, I wish to stress that these are guidelines and not hard rules.

# Collaboration Considerations:

**The following specifically applies to independently written lab reports.**  To be clear: the following aspects of a lab report are allowed to be similar/identical among members of the same group:

* Raw data (values/photos/etc.)
* Tables, Graphs & Diagrams
* Calculations
* Sources used.

All other work must be independently generated. While groups are encouraged to work together, the work that is submitted must be original enough to not be demonstrated to be identical when subjected to computational similarity analysis (ex. via turnitin.com). Plagiarism considerations are likewise noted (all non-original work and words must be cited).

# Lab Data Check:

As part of your grade, your lab notebook will be checked to verify the accuracy and quality of the data that you are taking during laboratory activities. The caliber of this data is accounted for in scoring the lab, typically as a grade multiplier outside of the main categories.

# Exceptions/Alterations

This document is intended as a guide, not as a “no exceptions” use case. The particular details of any one lab report may change from what is described above, in some cases significantly so. In all instances, the specific details and requirements for any lab report will be discussed with the class, and a forum posting for the lab will be available to track any changes to the report that will be produced/provide help with writing the report. Any details/alterations to a specific lab report take precedence over the guidelines explained above.

# References:

The following references may be helpful for particular aspects of your lab report writing:

## Process

LabWrite Lab Report Help:

* <http://labwrite.ncsu.edu>

Wikipedia IMRAD format Page:

* <http://en.wikipedia.org/wiki/IMRAD>

## Technical Help

### Google Docs Help Pages:

* <http://support.google.com/docs/>

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### Graphing-

General Graphing Primer (also contains a lot of other information about the lab report process):

* <http://goo.gl/Evuw5>

Making Graphs (aka “Charts”) in Google Docs Spreadsheets:

* <http://goo.gl/T4wJ4>

Plot.ly: Robust Online Graphing Tool (my preferred online graphing tool):

* <https://plot.ly/>

Using the Google Chart API directly (no spreadsheet required- 2 different sites):

* <http://acme.com/chartmaker/>
* <http://almaer.com/chartmaker/>

Create-A-Graph Graph Construction Website:

* <http://nces.ed.gov/nceskids/createagraph/>

### Equations-

Editing equations on a computer can be a bit tricky to learn. As you probably know, trying to format an equation in a document is almost impossible (at least if you want it to look good). On computers, all equations are basically handled by a markup language called LaTeX, which is really powerful, but also a bit tricky to learn. Fortunately, there are a variety of visual editors that you can use to help you make your equations, but you are going to make a few mistakes before you “get” the logic that works under these systems. Google Docs has an in-program editor (available in the view menu) which is based on LaTeX, but is a bit simplified.

Using the Google Docs Equation Editor:

* <http://goo.gl/aukUz>

There are some nice visual equation editors that use full LaTeX scripting (you would export these equations as .png files and then import them into your lab report). Here are two that are pretty easy to use:

* <http://www.codecogs.com/latex/eqneditor.php>
* <http://www.sciweavers.org/free-online-latex-equation-editor>

## Citations

### APA Style Guide:

* <http://www.apastyle.org/learn/tutorials/basics-tutorial.aspx>

### IEEE Style Guide:

* <http://libguides.murdoch.edu.au/IEEE>

### Citation Machine Reference Formatter

(does not do IEEE style citations):

* [http://www.citationmachine.net](http://www.citationmachine.net/)

# Grading Criteria:

Provided below are the criteria that are considered when grading a lab report. Not all criteria are given equal consideration when scoring a lab.

|  |  |
| --- | --- |
| ***Category:*** | ***Criteria*** |
| ***Introduction:*** *Background and Objectives* | •Introduction is thorough, connecting the material of the course to the activity of the lab. •The introduction provides the reader with key terms.•Appropriate, properly formatted citations are provided.•The underlying biological concept of the lab mentioned and is clearly explained. |
| ***Introduction:****Research Question/ Hypothesis* | • Research Question is stated• Rationale is provided for question.• Testable Hypothesis is stated and is justified.• Independent and dependent variables are explicitly identified. |
| ***Methods:****Materials* | • Materials list is complete (according to lab report guidelines).• Concentration of chemical reagents used (when known), scientific names of organisms are named, volumes of apparatus, etc. are provided. |
| ***Methods:****Procedure* | • Procedure is concisely written using third person past tense.• There is an acceptable range of variance in the independent variable.• Constants are clearly identified.• Control group is identified.• Labeled Diagram or photo is provided.• Validity measures are addressed.• The procedure allows for the collection of “sufficient relevant data”• The protocol states that data will be combined (if necessary).• Procedure is safe and ethical.• At least one, properly formatted citation is provided. |
| ***Results:****Data Collection* | • Raw data is recorded.• Processed data is recorded.• Both quantitative data and qualitative data are recorded.• Data adheres to precision guidelines.• Units are present on quantitative data. |
| ***Results:****Data Presentation* | • Report includes at least one graph and two data tables (raw data and processed data)• All tables, graphs, drawings, and calculations adhere to lab report guidelines• Relevant statistical analysis of data is demonstrated.• Calculations are clearly demonstrated.• All elements in the data section are explained with at least one descriptive sentence. |
| ***Discussion:******Conclusions*** | • Conclusion is based on reasonable interpretation of data.• Clear connection is made between hypothesis and data collected.• Clear connection is made between the lab activity and the understandings of the course.• Discussion of limitations of the experiment is provided.• Discussion of unexpected results is provided (when applicable).• Applicability of the conclusions of this experiment to other situations is provided. |
| ***Discussion:****Experimental Evaluation* | • Statement of confidence in the experiment is provided and justified.• Measures to ensure validity are discussed.• Recommendations for refining the experiment are provided.• Identification and discussion of sources of error is provided.• Specific recommendations to address identified weaknesses are provided. • Suggestions for future avenues of research are provided. |
| ***Overall:****Aesthetics* | • Report demonstrates proper spelling, grammar, and consistent design considerations (formatting, spacing, etc.)• Report adheres to APA or IEE citation conventions in-text and in the reference section.• Report is shared correctly, posted publicly on course blog correctly, and posted in a timely fashion. |

**Lab Notebook Data Verification:** The quality and accuracy of your lab data serves as a score multiplier for your overall grade, ranging from .9 at the low end, to 1.1 at the high end. In other words, if you keep poor records, it can cost you up to 10% of your total grade earned. Likewise, keeping exemplary records in your lab notebook can earn you an additional 10% on your score.