

## Process of Science Companion Vol. 1

# Process of Science Companion Vol. 1

*Scientific Writing Manual*

*UW-MADISON BIOCORE PROGRAM*

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# WRITING MANUAL

## About This Manual

The purpose of this manual is to introduce you to scientific writing, specify our expectations for writing in Biocore labs, and provide other information developed over the years in response to problems Biocore students have experienced with writing. In addition, we include a primer for oral presentations and development of scientific posters. Although these other resources are included, the manual's main focus is on writing laboratory reports using the format most commonly used for scientific journal articles. Many of the guidelines are also valid for other forms of writing.

**Editors' note:** We are eager for your comments and suggestions. Please tell us your ideas for improving future editions. We welcome verbal, written, or email ([jcbatzli@wisc.edu](mailto:jcbatzli@wisc.edu)) comments given to us directly or through your TA. Please be as specific as possible.

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# Introduction: Why Write?

The Biology Core Curriculum (Biocore) is a four-semester, laboratory-intensive, writing-intensive intercollege honors program. Each fall, approximately 120 students enter the sequence through Biocore 381/382. The combinations of Biocore 381/382 and Biocore 384 each fulfill the University's Communication B requirement. In these courses, we provide opportunities for students to become actively involved in the process of science and 'do biology'.



Writer (CC0)

**Writing is a key component in our courses** because writing is an integral part of 'doing biology' which involves asking questions, proposing experiments, communicating results to other scientists, and exposing one's ideas to discussion and review by peers. We feel that this process is essential in your training as a scientist to get familiar with and gain confidence in the conventions of the discipline. In addition, we feel strongly that writing helps students think about their science, organize their thoughts, and grapple with new ideas. Learning how to write well is empowering and will help you in any profession you choose.

## WRITING IS AN INTEGRAL PART OF THE PROCESS OF SCIENCE AND HOW WE KNOW WHAT WE KNOW.

The process usually begins when someone gets curious about a topic, asks questions, and forms an idea for an experiment. If the experiment is carried out and yields reproducible results and new knowledge, a scientist writes a paper and/or does an oral presentation to communicate those results.

Through this type of communication, the scientist explains the background and biological rationale for the experiment, presents the data, and generates conclusions using data from the experiment as evidence. The scientist submits the paper to a scientific journal, and the editor sends it to a small group of peer reviewers, 2 or 3 scientists doing research in the same field. The reviewers evaluate the experiment and the conclusions with such questions as:

- Has the author clearly stated the question being investigated and have they posed a testable hypothesis?
- Was the experiment logically designed and does the experiment really test what the author claims it tests?
- Were experimental techniques appropriate and properly performed?
- Do the data show what the author claims they show; did they include appropriate controls that rule out alternative explanations for the data?
- Are the conclusions logical based on the evidence presented?

The answers to these questions determine whether the peer reviewers recommend to accept or to reject the paper for publication. They may recommend acceptance after the author has made suggested revisions. If published, peers in the larger scientific community evaluate the merit of the experiment. The experimental

results may spark new questions, reveal conflicting evidence, or insights among members of the community and point to new directions of study, and the process continues. That is how knowledge is generated and accepted in science.

Through writing about your science, you will learn new concepts, you will develop a whole new vocabulary and language. You will practice the language of biology through your writing, gaining greater precision and accuracy, and understanding as you write. In addition, the process of writing will help you clarify thoughts and identify aspects that you have yet to understand.

## **SCIENTISTS SPEND A TREMENDOUS AMOUNT OF TIME WRITING.**

In addition to journal articles, they write grant proposals, progress reports, review articles, technical reports, lectures, textbooks, memoranda, evaluations, letters of recommendation, product descriptions, press releases, and news articles.

We provide many opportunities for you to write and receive feedback in Biocore, not only because writing will be important in your future career, but also because writing is one of the best ways to learn. In *Writing to Learn* (1988), William Zinsser notes, “writing is how we think our way into a discipline, organize our thoughts about it, and generate new ideas.” Writing sharpens your thinking and reasoning skills. To write clearly you must think clearly. To think clearly you must understand the topic you are trying to write about. As you try to reason your way through a paper you find out what you know – and what you don’t know – about whatever you’re trying to learn, and you begin to make it your own (Zinsser, 1988). If you need any further motivation, note that graduate and medical school admissions tests now include a section for assessing your writing ability.

## **LEARNING TO WRITE EFFECTIVELY IS A PROCESS.**

Even experienced writers struggle to be clear and seldom achieve it on the first try. It takes practice and feedback and more practice. You will have many opportunities to have your writing reviewed by TAs and peers in all of your Biocore labs. Initially, the review process may be painful. Try not to be discouraged. It is the writing that is evaluated, not the writer. Use these evaluations as opportunities to help you improve your writing.

# Avoiding Plagiarism



Image by Lsanabria  
licensed under CC BY-SA  
4.0.

## PLAGIARISM IS BAD—DON'T DO IT.

Often, when we identify instances of plagiarism, the plagiarist claims ignorance, saying that they did not know they were plagiarizing. Therefore, we want to take a moment to explain.

**Please read carefully! Educate yourself. Do not put yourself and the Biocore staff in the unpleasant situation of having to deal with academic misconduct!**

**Plagiarism is presenting someone else's words, ideas, or even graphical designs as your own.**

## THE FOLLOWING ARE DIFFERENT EXAMPLES OF PLAGIARISM:

- Copying word for word from a published source or another student's work without quotation marks and a citation is plagiarism. If you use someone else's exact words, you must put them in quotation marks and cite the source.
- Knitting together sentence fragments or paragraphs from various sources (sometimes called "Google-stitching") is plagiarism. If you use someone else's ideas, even if you paraphrase them, you must **cite the source(s)**. This includes your classmates' work as well as lab manuals and published sources.
- Paraphrasing another student's lab report is plagiarism. We want you to work together, and discuss projects and the ideas that you have about them with your classmates. However, written papers, posters, oral presentations and supporting slides must be your own individual work unless we specifically ask for a group report. In the case of group reports, you must identify your collaborators, just as all scientists do. Not doing will erode trust and the community.
- Using another student's graphical design or poster layout is plagiarism. You may draw inspiration from another students' design, but be sure to make it your own.
- Using someone else's photograph or other image without credit is plagiarism. Some images are freely available for use without credit such as clip-art (like the 'thumb-down' image above), and images available from federal government agencies such as the USDA or NASA. Otherwise, images require a credit line referring to the artist, photographer, program/institute affiliation, and URL (web address) located either in the figure legend or directly below the image itself. You do not need to include the source of images in your Literature Cited section.

**Here are two excellent campus resources explaining how you can avoid plagiarism by quoting and paraphrasing appropriately:**

- The Writing Center [http://www.wisc.edu/writing/Handbook/QPA\\_plagiarism.html](http://www.wisc.edu/writing/Handbook/QPA_plagiarism.html)
- UW Libraries Plagiarism Video Tutorial (3 min) <https://lo.library.wisc.edu/plagiarism/>

## Sample Paraphrases: Unsuccessful and Successful

Paraphrasing is often defined as putting a passage from an author into “your own words.” But what are your own words? How different must your paraphrase be from the original? Based on the source paragraph below, consider two improper ways of handling source material: (A) word-for-word plagiarism and (B) “The Patchwork.” At the bottom of the table is a model example of a legitimate paraphrase. **You must understand how to differentiate proper from improper paraphrasing. You are responsible for your work as well as the consequences for plagiarism.**

### SOURCE PARAGRAPH

“Huntington’s disease is a progressive brain disorder that causes uncontrolled movements, emotional problems, and loss of thinking ability (cognition). Adult-onset Huntington disease, the most common form of this disorder, usually appears in a person’s thirties or forties. Early signs and symptoms can include irritability, depression, small involuntary movements, poor coordination, and trouble learning new information or making decisions. Many people with Huntington disease develop involuntary jerking or twitching movements known as chorea. As the disease progresses, these movements become more pronounced. Affected individuals may have trouble walking, speaking, and swallowing. People with this disorder also experience changes in personality and a decline in thinking and reasoning abilities. Individuals with the adult-onset form of Huntington disease usually live about 15 to 20 years after signs and symptoms begin. (From Genomic Home Reference 2014 <https://ghr.nlm.nih.gov/condition/huntington-disease>)

### DIFFERENT FORMS OF PARAPHRASE PLAGIARISM:

#### A. Word-for-word plagiarism from source

Huntington’s disease is a fairly common genetic disorder that occurs in 3 to 7 in 100,000 people of European ancestry (no citation). The disease is due to a mutation in the gene that codes for the protein huntingtin (no citation).

Huntington’s disease is a progressive brain disorder that causes uncontrolled movements, emotional problems, and loss of thinking ability (Genomic Home Reference 2014). Adult-onset Huntington’s disease usually appears in a person’s thirties or forties, and symptoms include irritability, depression, small involuntary movements, poor coordination, and trouble learning new information or making decisions (Genomic Home Reference 2014). Affected individuals develop involuntary jerking or twitching movements known as chorea, may have trouble walking, speaking, and swallowing, and can experience changes in personality and a decline in thinking and reasoning abilities (Genomic Home Reference 2014). Adults with Huntington’s can live about 15 to 20 years after signs and symptoms begin (Genomic Home Reference 2014).

*Notice that the writer has not only “borrowed” source material with no acknowledgment, but has also largely maintained the author’s method of expression and sentence structure. The underlined phrases are directly copied from the source. Even though the author acknowledged Genomic Home Reference as the source of the content, the language of the passage would be considered plagiarized because no quotation marks indicate the phrases that come directly from the source.*

## **B. The Patchwork Paraphrase**

Huntington’s disease is a disease of the brain that causes uncontrolled movements, emotional problems, and loss of thinking ability (Genomic Home Reference 2014). The disease typically appears in adults ages 30-40 with symptoms including irritability, depression, small involuntary movements, poor coordination, and trouble learning new information or making decisions. In addition, individuals may present twitching or jerking behavior called chorea, or develop difficulty walking, speaking, swallowing and can experience changes in personality. Although the symptoms are severe, many suffering Huntington’s disease can live up to 15-20 years beyond diagnosis (no citation).

*This paraphrase is a patchwork composed of pieces in the original author’s language (underlined) and pieces in the student-writer’s words, all rearranged into a new pattern, but with none of the borrowed pieces in quotation marks. Thus, even though the writer acknowledges the source of the material, the underlined phrases are falsely presented as the student’s own.*

## **LEGITIMATE PARAPHRASE**

Huntington’s disease is a disease of the brain that causes involuntary and unrestrained movement, loss of memory and capacity to reason, and changes in emotion (Genomic Home Reference 2014). The disease typically appears in adults ages 30-40. According to Genomic Home Reference (2014) symptoms can include “irritability, depression, small involuntary movements, poor coordination, and trouble learning new information or making decisions” together with changes to personality. In addition, individuals may present symptoms of twitching or jerking behavior called chorea, or have difficulty moving, speaking, and swallowing. Although the symptoms are severe, many suffering Huntington’s disease can live up to 15-20 years beyond diagnosis.

*The writer has documented the source material and specific language (by direct reference to the author and by quotation marks around language taken directly from the source). Notice too that the writer has modified the source language and structure and has added material to fit the new context and purpose — to present the distinctive functions of experts and nonexperts in several professions.*

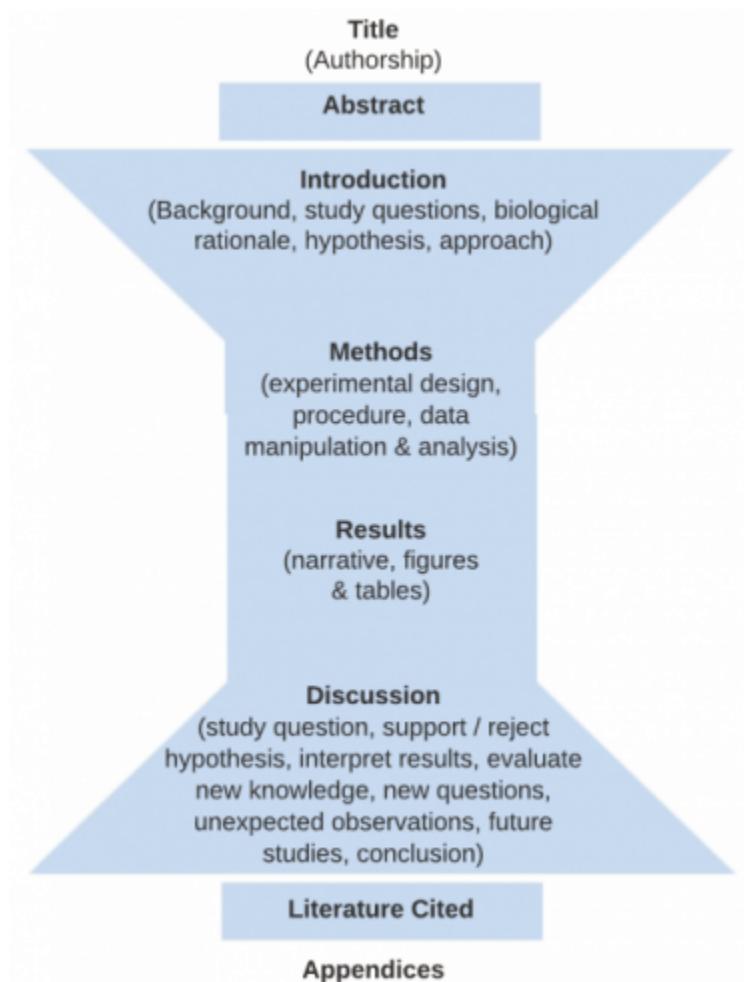
# Structure of a Biocore Lab Report

A primary way that scientists communicate with one another is through scientific papers. We will model our Biocore lab reports on the format most commonly used by scientific journals. **Your lab reports should follow the guidelines described below unless the lab manual or your TA specifically tells you otherwise.** Some lab reports have a modified format or require only a subset of the standard sections listed below.

The figure below indicates the four main sections (Intro, Methods, Results and Discussion) that form the body of a scientific paper. Each section of the paper (except for “Title”) should begin with one of these terms as a heading. These main sections are bookended on the front end with a Title and Abstract summarizing the whole document and on the back end by a Literature Cited and Appendices (optional) in support of the document.

*Other classes and some scientific journals deviate from this format, and you should always consult the guidelines specified before preparing a paper for another class (or submitting a manuscript for publication).*

- **Title**
- **Authorship**
- **Abstract**
- **Introduction**
- **Methods and Materials**
- **Results (including figures and tables)**
- **Discussion**
- **Literature Cited**



[View lab report structure diagram as a pdf](#)

Consider the structure of the paper as having an “hourglass” shape—with the **Introduction** moving from general question and background information to more specific biological rationale, and even more specific hypothesis and approach to your experiment.

The **Methods** and **Results** are specific to your hypothesis and the experiment you performed.

Then the **Discussion** starts more narrowly focused on whether you support or reject your hypothesis, but then broadens to integrate your findings into the existing literature, and finishes with a conclusion that is based on the experimental evidence you present.

## Title

The title is a **clear, specific statement of the subject** of your report. Think of the words in your title as key search terms. It introduces the reader to your paper and lets them know what to expect.

**Titles should:**

- Be concise and informative and need not be complete sentences.
- Avoid filler words like “Studies on” or “Investigations of” and opening words like A, An, or The.
- Be as specific as possible.
- Avoid abbreviations and jargon.
- state the results.

VAGUE TITLES	Specific Predictive Titles (Good for Research Proposals)	Particularly Effective Titles
A Study of Aquatic Plants in a Pickle Jar	<i>Elodea Canadensis</i> proposed to have greater [DIRECTION] abundance [DEPENDENT VAR] when in competition for space [INDEPENDENT VAR] with <i>Ceratophyllum demersum</i> in a Model Aquatic Ecosystem [SYSTEM]	Addition of caffeine ( <b>INDEPENDENT VARIABLE</b> ) to aquatic culture in concentrations of 0.1 to 0.5M decreases ( <b>DIRECTION</b> ) the stem length ( <b>DEPENDENT VARIABLE</b> ) of <i>Phalaris arundinacea</i> , reed canary grass ( <b>STUDY ORGANISM</b> )
The Effect of Salt on Aquatic Waterflea, <i>Daphnia magna</i>	Red light expected to increase biomass and average hypocotyl length in <i>Brassica rapa</i> compared to far-red light	*Brine shrimp ( <i>Artemia franciscana</i> ) grown in acidic water (pH of 3-5) have faster heart rates than brine shrimp grown in water with pH of 7-9

\*If your report constitutes the results of an experiment where you manipulated variables and analyzed the result, include the independent and dependent variables, the direction of your results, as well as the study organism/ subject in your title.

**How will titles be evaluated?** To see our expectations for your Title, see the Biocore Research Paper Rubric in this Writing Manual.

## Authorship

In scientific journal articles, the first author listed is the primary author, and subsequent authors are listed according to the magnitude of their contribution to the study. Research mentors such as principal investigators (PI's) of labs, are typically listed last. If all authors have made equivalent contributions to the article, then the paper will state that authors' names are listed in alphabetical order.

In Biocore you will work within teams to do independent research projects, but we usually ask for individual lab reports because we want to give you many opportunities to work on your writing and thinking skills. At other times we will ask you to submit group posters and PowerPoint presentations. Here is how you should list teammates for various Biocore assignments:

- Individual papers or mini-posters: List yourself first as the primary author under your title, then list teammates as contributors at the top of the page in alphabetical order. Also list your lab section and TA.
- Group posters or PowerPoint presentations: We assume that all of you have made equivalent contributions to these collaborative group assignments, so include all researchers' names as authors in alphabetical order.



# Abstract

**\*Not all Biocore lab reports require abstracts!** Research proposals generally do not require abstracts, but check assignment description for details.

The abstract forces the author to distill the essence of the paper to a **very brief summary (100-200 words)**. Think of the abstract as the two-minute version of your entire experiment. Many readers use the abstract to decide whether they want to find and read the entire paper.

You must be concise. One way to do this is to summarize, in **one or two sentences each**:

1. the rationale behind the experiment (goal of your experiment, model system, most important background information)
2. your hypothesis
3. the approach you took (how and what you actually tested)
4. results or expected results
5. conclusions/implications

## Other tips:

- Always write the abstract last, after you thoroughly understand the experiment and its meaning.
- Abstracts should be understandable without referring to the rest of the paper.
- You do not cite references in an abstract. General and/or specifically applicable knowledge is assumed or is cited elsewhere in your paper.

## EXAMPLE ABSTRACT FROM SYSTEMATIC OBSERVATION STUDY

### Adapted from paper by Kristin Magliocco (Fall 2009)

Phosphorus in the runoff to urban streams such as Willow Creek can lead to phosphorus build up and ultimately eutrophication of larger bodies of water. Rain gardens have been constructed on the UW Madison campus adjacent to Willow Creek to prevent accumulation of phosphorus in the creek itself. [Background] By slowing and delaying runoff from reaching the creek, the rain gardens are intended to retain phosphorus and, therefore decrease the amount of phosphorus that reaches the creek. [BR] To test the efficacy of the rain gardens, we hypothesized that there would be no significant difference in the phosphorus concentrations of the water in Willow Creek upstream and downstream of the boundaries of the northeast rain garden. [Hypothesis] We selected four replicate locations in the rain garden itself and in Willow Creek, both upstream and downstream of the rain garden, where we used a Hach phosphorus colorimeter to measure phosphorus concentration. [Approach] Our data supported our hypothesis, with the upstream mean concentration of  $0.07335 \pm 0.00471$  mg/L and the downstream mean concentration of  $0.08213 \pm 0.0139$  mg/L showing no statistically significant difference. [Results] We cautiously concluded that the rain gardens near

Willow Creek do prevent further phosphorus accumulation in the stream, but pointed toward future studies focusing on amount of rainfall as an important factor in rain garden efficiency. [Conclusion]

**How will abstracts be evaluated?** To see our expectations for your Abstract, see the Biocore the Biocore Research Paper Rubric in this Writing Manual.

## Introduction

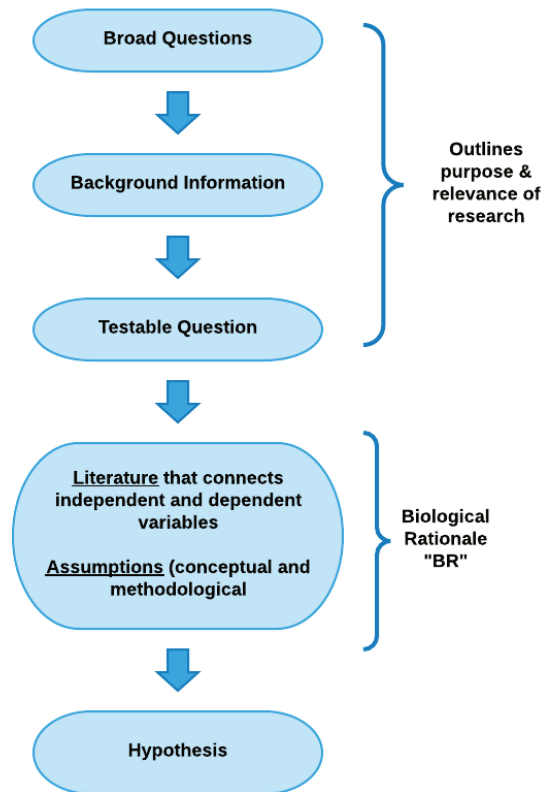
This section provides guidelines on how to construct a solid introduction to a scientific paper including **background** information, **study question**, **biological rationale**, **hypothesis**, and general **approach**. If the Introduction is done well, there should be no question in the reader's mind why and on what basis you have posed a specific hypothesis.

**Broad Question:** based on an **initial observation** (e.g., "I see a lot of guppies close to the shore. Do guppies like living in shallow water?"). This observation of the natural world may inspire you to investigate background literature on previous research by others or gather some initial data/ observations as a pilot study. Broad questions are not always included in your written text, but are essential for establishing the direction of your research.

**Background information: key issues, concepts, terminology, and definitions** are needed to understand the biological rationale for the experiment. The background often includes a summary of findings from previous, relevant studies that introduce the study system, the independent and dependent variable. Remember to cite references, be concise, and only include relevant information given your audience and your experimental design. Your concise summary of background information should lead to specific scientific knowledge gaps that still exist. (e.g., "No studies on lake guppy distribution to date have examined whether guppies do indeed spend more time in shallow water.")

**Testable Question:** these questions are much more focused than the initial broad question, are specific to the knowledge gap identified, and can be addressed with data. (e.g., "Do guppies spend different amounts of time in water less than 1 meter deep as compared to their time in water that is greater than 1 meter deep?")

## Biocore - Testable Question



*[View testable question diagram as pdf](#)*

**Biological Rationale (BR):** The BR explains why you expect your independent variable(s) to affect your dependent variable(s) in the way your hypothesis indicates. After you have summarized the background information relevant to the study, the “BR” provides the logic and reasoning for your hypothesis and experimental approach, describing the biological mechanism that connects your independent and dependent variables and the assumptions that **provides evidence for why your hypothesis should be supported**. The biological rationale is based on your interpretation of the scientific literature, your personal observations, and the underlying assumptions you are making about how you think the system works. If you have written your biological rationale logically and clearly, your reader should see your hypothesis in your introduction section and say to themselves— “Of course this hypothesis is supportable. It seems very logical based on the rationale presented.”

### Steps for Developing a BR—Based on your background information:

1. **Dependent Variable(s)**- List key aspects of the dependent variable (DV) that are known (based on the scientific literature) and those that are unknown that you may need to assume or may be associated with a knowledge gap.
2. **Independent Variable(s)**- List key aspects of the independent variable (IV) that are known (based on the scientific literature) and those that are unknown that you may need to assume or may be associated with

a knowledge gap.

3. Connection between DV and IV- List **what is known and what you are assuming about the ways (mechanisms or relationships) in which the IV influences the DV**, either directly or indirectly, either in the system you are studying, in a similar system, or a more distant dissimilar system. If possible, note literature that support any assumptions. The biological link between your IV and DV(s) is central piece of your BR.
4. Based on #3, articulate the specific **knowledge gap** you hope to fill in this study.
5. Generate a draft hypothesis based on steps 1-4.

Once you have done steps 1-5, start to sketch out your reasoning using a conceptual or graphic model

In Biocore, we will ask you to construct two different types of models as you are learning to develop your BR:

1. **Conceptual Model**– a logical flow of ideas utilizing boxes and arrows to indicate how variables are connected and support your hypothesis. Conceptual models are helpful for developing logical thought progression but are generally not included in a paper or final presentation.
2. **Graphic or Visual Model**– A cartoon or graphic depiction for how variables interact to result in your predicted outcome. Graphic models are often included in scientific posters and Powerpoint presentations, and sometimes in scientific papers.

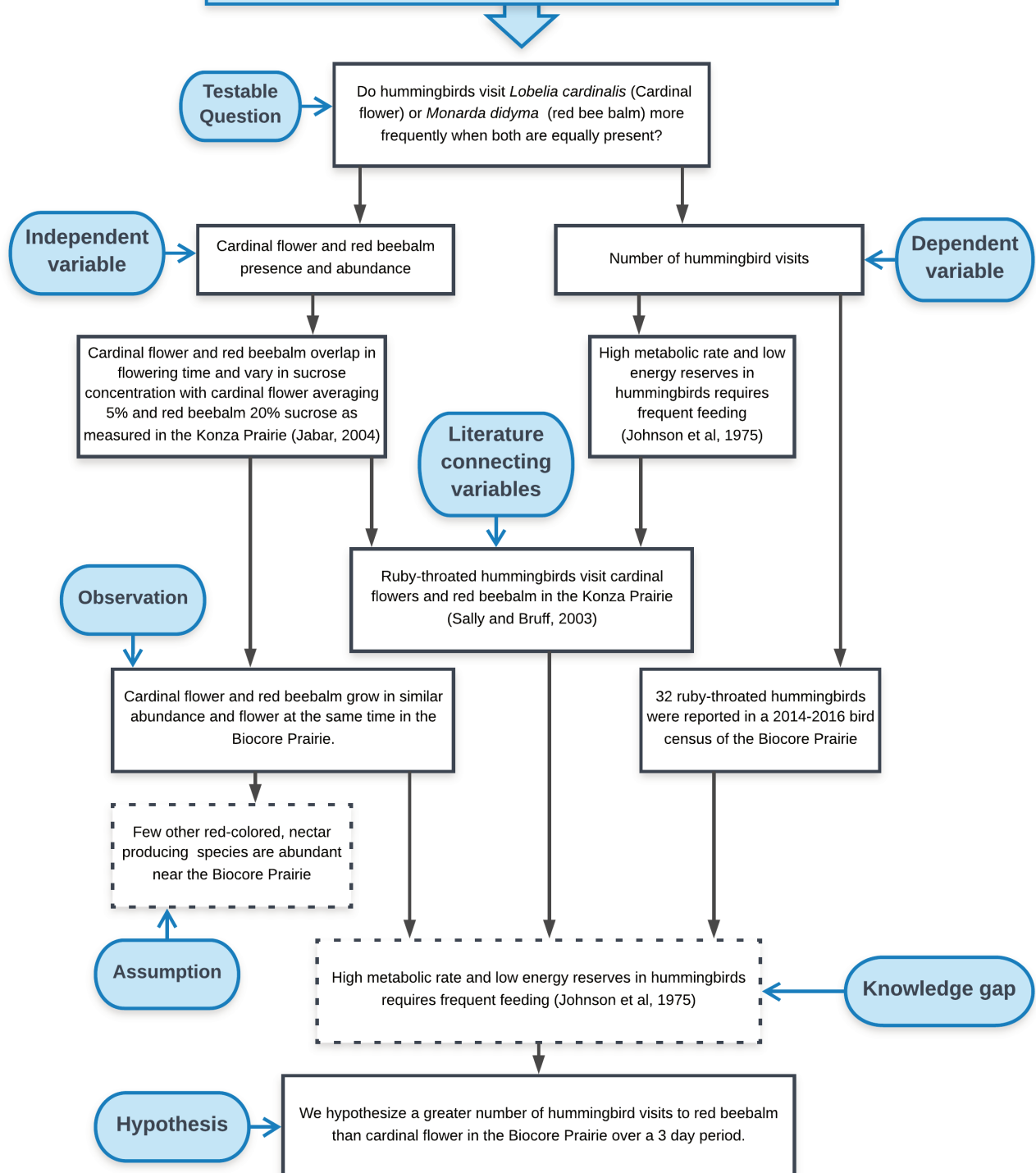
**See following sections for examples of Biological Rationale in the form of Conceptual and Graphic Models**

## Conceptual Model

In the **Conceptual Model** example below, the biological rationale is depicted as a logical flow of statements beginning with a testable question and ending with a hypothesis.



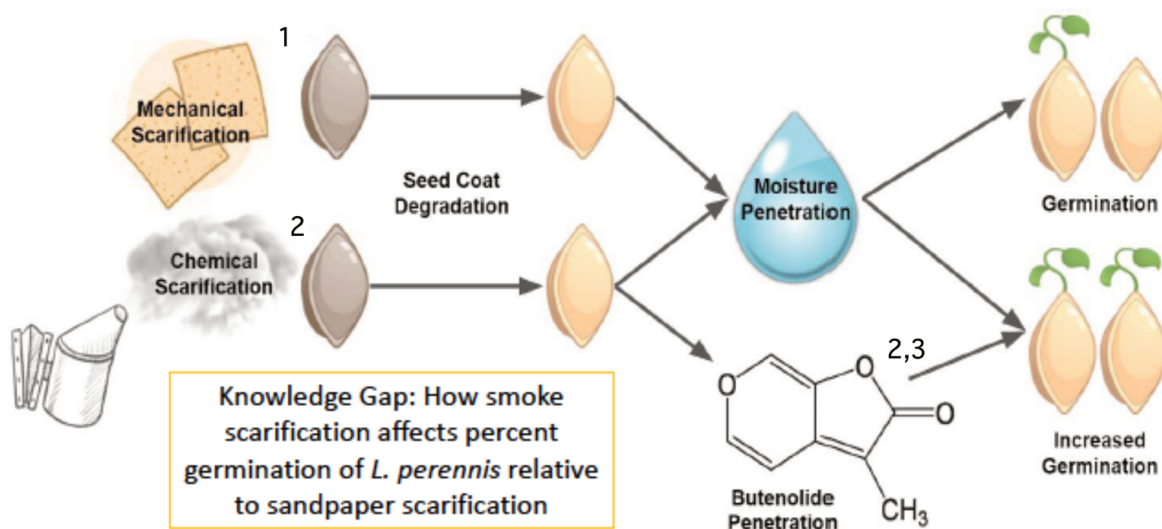
Before generating your BR, gather background information on hummingbirds (their movements, feeding patterns, and ecology) and how hummingbirds relate to flowers more generally



## Graphic or Visual Model

**Graphic or Visual Model** uses cartoon diagrams and symbols to communicate the predicted interaction among variables and the mechanism by which they interact. Visual models use shorthand literature citations (superscript numbers) to indicate literature references that are further discussed in an oral presentation (poster or PowerPoint) or written narrative (paper).

**Example Graphic Model of Biological Rationale** appropriate for diagram in a paper, poster, or presentation. Adapted from poster by McKenna DeFoer, Sadie Gugel, Evan Polce, Kyrie Sellnow in Biocore 486, Organismal Biology lab.



**Narrative:** Scarification using sandpaper abates the seed coat of *L. perennis*. This process allows moisture to permeate the seed coat during stratification and initiates the biochemical pathway for germination (1. Diboll 2008). Similarly, exposing seeds to cellulose-derived smoke causes chemical scarification (2. Egerton-Warburton 1997). This type of smoke contains butenolide, a compound synthesized during the combustion of plant material that has been found to further stimulate germination (3. Keeley and Fotheringham 1997).

More on Biological Rationale:

- A thorough rationale defines your **knowledge gap** about the system that has not been revealed in scientific literature or from previous observation. The **knowledge gap is the knowledge we are attempting to create**. The interpretation of your experimental data and the integration of literature will fill

or partially fill the knowledge gap. In order to fill the knowledge gap, you may need to make **assumptions** about how your system operates. Assumptions are aspects of the system that you are not testing directly, but you think are particularly important since they *drive the direction* of your specific hypothesis or general predictions. Sometimes students confuse the knowledge gap and assumptions. Data gathered during the experiment can address the knowledge gap but generally do not provide direct evidence to support or refute assumptions.

- **Defining the BR** is probably the most critical task for a writer, as it tells your reader why your research is biologically meaningful. It may help to think about the *rationale* as a link between your independent and dependent variables, because the rationale answers these questions—*how is this investigation related to what we know, what assumptions am I making about what we don't yet know, AND how will this experiment add to our knowledge?*
- Expect to spend time and mental effort on your BR. You may have to do considerable digging into the scientific literature to define how your experiment fits into what is already known and why it is relevant to pursue.
- Be open to the possibility that as you work with and think about your data, you may develop a deeper, more accurate understanding of the experimental system. You may find the original rationale needs to be revised to reflect your new, more sophisticated understanding.
- As you progress through Biocore and upper level biology courses, **your rationale should become more focused and matched with the level of study** i.e., cellular, biochemical, or physiological mechanisms that underlie the rationale. Achieving this type of understanding takes effort, but it will lead to better communication of your science.

**Hypothesis / Predictions:** specific prediction(s) that you will test during your experiment. **For manipulative experiments, the hypothesis** should include the **independent variable** (what you manipulate), the **dependent variable(s)** (what you measure), the **organism or system**, the **direction** of your results, and **comparison** to be made. See the following examples.

Hypothesis that Needs Work (manipulative experiment)	Better Hypothesis (manipulative experiment)
<p>We hypothesized that <i>Daphnia magna</i> reared in warm water will have a greater sexual mating response.</p> <p>[The dependent variable “sexual response” has not been defined enough to be able to make this hypothesis testable or falsifiable. In addition, no comparison has been specified—greater sexual mating response as compared to what?]</p>	<p>We hypothesized that <i>Daphnia magna</i> (<b>STUDY ORGANISM</b>) reared in warm water temperatures ranging from 25-28 °C (<b>IND. VAR.</b>) would produce greater (<b>direction</b>) numbers of male offspring and females carrying haploid egg sacs (<b>DEPEND. VAR.</b>) than <i>D. magna</i> reared in cooler water temperatures of 18-22°C.</p>

If you are doing a **systematic observation**, your hypothesis presents a **variable** or set of variables that you predict are important for helping you characterize the system as a whole, or predict differences between components/areas of the system that help you explain how the system functions or changes over time.

### Hypothesis that Needs Work (systematic observation)

We hypothesize that the frequency and extent of algal blooms in Lake Mendota over the last 10 years causes fish kills and imposes a human health risk.

[The variables “frequency and extent of algal blooms”, “fish kills” and “human health risk” have not been defined enough to be able to make this hypothesis testable or falsifiable. How do you measure algal blooms? Although implied, hypothesis should express predicted direction of expected results (e.g. higher frequency associated with greater kills). Note that cause and effect cannot be implied without a controlled, manipulative experiment.]

### Better Hypothesis (systematic observation)

We hypothesize that increasing (**DIRECTION**) cell densities of algae (**VAR.**) in Lake Mendota over the last 10 years is correlated with 1. increased numbers of dead fish (**VAR.**) washed up on Madison beaches and 2. increased numbers of reported hospital/clinical visits (**VAR.**) following full-body exposure to lake water.

Note that hypotheses/ predictions you develop in Biocore lab are much more specific than the general hypotheses that guide the research questions you encounter in scientific literature or in faculty research labs. That is because the research projects you do in Biocore are short-term, small(er) in scale or context specific, and therefore require greater specification to be testable within our class context.

**Experimental Approach:** *Briefly* gives the reader a general sense of the experiment, the type of data it will yield, and the kind of conclusions you expect to obtain from the data. Do not confuse the **experimental approach** with the **experimental protocol**. The experimental protocol consists of the detailed step-by-step procedures and techniques used during the experiment that are to be reported in the Methods and Materials section.

## \*\*\*SOME FINAL TIPS ON WRITING AN INTRODUCTION\*\*\*

- **As you progress through the Biocore sequence** for instance, from organismal level of Biocore 381/382 to the cellular level in Biocore 383/384, we expect the contents of your “Introduction” paragraphs to reflect the level of your coursework and previous writing experience. For example, in Biocore 384 (Cell Biology Lab) biological rationale should draw upon assumptions we are making about cellular and biochemical processes.
- **Be Concise yet Specific:** Remember to be concise and only include relevant information given your audience and your experimental design. As you write, keep asking, “Is this necessary information or is this irrelevant detail?” For example, if you are writing a paper claiming that a certain compound is a competitive inhibitor to the enzyme alkaline phosphatase and acts by binding to the active site, you need to explain (briefly) Michaelis-Menton kinetics and the meaning and significance of  $K_m$  and  $V_{max}$ . This explanation is not necessary if you are reporting the dependence of enzyme activity on pH because you do not need to measure  $K_m$  and  $V_{max}$  to get an estimate of enzyme activity.
- **Another example:** if you are writing a paper reporting an increase in *water flea* heart rate upon exposure to caffeine you need not describe the reproductive cycle of water fleas unless it is germane to your results and discussion. Be specific and concrete, especially when making introductory or summary statements.

### Where do you discuss Pilot Studies?

Many times it is important to do pilot studies to help you get familiar with your experimental system or to improve your experimental design. **If your pilot study influences your biological rationale or hypothesis, you need to describe it in your Introduction.** If your pilot study simply informs the logistics or techniques, but does not influence your rationale, then the description of your pilot study belongs in the Materials and Methods section.



**How will introductions be evaluated?** To see our expectations for your Introduction, see the Biocore Research Paper Rubric in this Writing Manual.

## EXAMPLE INTRODUCTIONS

### EXAMPLE INTRODUCTION FROM SYSTEMATIC OBSERVATION STUDY

Adapted from a paper by Will Klein 2009

Throughout history, humans have discovered and used chemicals derived from plant extracts as antimicrobial compounds for medicinal purposes. Although useful to humans, why would a plant create an antimicrobial defense that affects the growth of bacteria? **[broad study question]** As non-mobile organisms, plants have evolved mutually beneficial associations with beneficial microbes (Brooker et al. 2011) and a full arsenal of adaptations for defense against pathogenic microorganisms (bacteria, viruses, fungi). Borchardt et al. (2008) did an antimicrobial screening of 339 plant species growing in Minnesota and Wisconsin, many of which are prairie plant species. The researchers tested aerial plant parts (leaves, stems, flowers) for growth inhibition of one, two or three common mammalian pathogens (*Escherichia coli*, *Staphylococcus aureus*, *Candida albicans*) and found 109 species inhibited growth of at least one microorganism. Leaf extracts of *Silphium* sp., a species found in the Biocore Prairie, contains antimicrobial compounds that inhibit the growth of many types of Gram-negative and Gram-positive bacteria (Kowalski and Kedzia, 2007; Kowalski, 2008). **[background information]**

Plants may produce chemical defense in the form of antimicrobial compounds contained in stems, roots, leaves, bark, flowers or fruits. **[BR: assumption]** By investing energy to generate these antimicrobial compounds, the plant maximizes its likelihood to succeed in its particular ecological niche (i.e. the Biocore Prairie) and improves its biological fitness. **[BR: assumption]** No studies however have directly examined the effect of native Biocore prairie plant extracts on indigenous soil bacteria growth. **[testable question]**

Through preliminary investigations in the Biocore Prairie during summer 2010, we sought to find prairie plant species and extracts from different plant parts (roots, leaves or stems) that would inhibit soil bacteria-bacteria cultured from soil that the prairie plants are growing in. Although most soil bacteria are beneficial or do nothing to affect prairie plants, we reasoned that plant species coexisting in the same environment with particular soil microbes may have efficient defense mechanisms towards pathogenic "prairie soil" bacteria. **[BR: assumption]** *Huechera richardsonii*, *Monarda fistulosa*, and *Euphorbia corollata* are three species common to the Biocore Prairie. Although leaf tissue of these three species have all been shown to contain antimicrobial properties against *S. aureus* (Borchardt et al. 2008), how extracts from these species influence growth of bacteria indigenous to the Biocore Prairie is not known. **[knowledge gap]** We believe these plant

species will contain antimicrobial properties in leaves to protect the tissue from microbial leaf pathogens that also occur in the soil. **[BR: assumption]**

We hypothesized that leaf extracts of *Huechera richardsonii*, *Monarda fistulosa*, and *Euphorbia corollata* would exhibit antimicrobial properties on the bacteria found in their native environment.

**[hypothesis]** Our approach was to grow soil bacteria collected from the Biocore Prairie on agar plates, and then expose bacteria to leaf extracts absorbed on filter paper discs and measure the extent to which the extracts inhibited bacterial growth. **[approach]**

**\*Note: If you are a Biocore 382 student—do not worry if you don’t understand the scientific content in these two examples. We will get there! These examples are provided to refer to as you progress through the curriculum**

## EXAMPLE 4: GOOD INTRODUCTION FROM MANIPULATIVE EXPERIMENT IN CELL BIOLOGY LAB

(adapted from a poster by Kari Esselman, John Kinzfogel, Amber Kugel, & Katie Luetttgen, Spring 2003)

In the yeast (*Saccharomyces cerevisiae*) mating signal transduction pathway, interaction of the complete  $\alpha$ -mating factor with

the G-protein-coupled receptor on a MAT- $\alpha$  cell induces cell cycle arrest in the G1 phase, morphological changes or “shmooing,” and activation of genes involved in the mating process (Hoopes et al., 1998). In *Saccharomyces cerevisiae*, the amino acids Trp1, Lys7 and Gln 10, the central  $\beta$ -turn conformation, and the amino acids near the C-terminus are directly involved in the binding of the  $\alpha$ -mating factor to the receptor (Saskiawan et al., 2002). Altering the structure of the  $\alpha$ -factor produces a conformational change in the receptor that is distinct from the conformational change of the normal  $\alpha$ -factor, consequently altering or even inhibiting the mating cascade of events (Bukusoglu and Kemmess. 1996). Elimination of Lys7 and Gln10 from the  $\alpha$ -mating factor results in greater than a 100 fold decrease in mating signal transduction (Xue et al., 1996). **[all background info]**

It is unclear whether elimination of amino acid residues other than Lys7 and Gln10 in the  $\alpha$ -mating factor also decrease the yeast mating response. **[broad question]** When introduced to MAT- $\alpha$  *Saccharomyces cerevisiae* cells, this sort of a  $\alpha$ -factor fragment could: 1. bind to the receptor site and induce the same change that the complete  $\alpha$ -mating factor would; 2. bind to the receptor site but not induce the same changes as the complete  $\alpha$ -factor, or 3. not bind to the receptor site at all. **[BR: assumed biological mechanism]** If the mating response to this fragment is different than normal **(BR: assumption)**, this would indicate which amino acid side groups are important in binding the

receptor. An examination of *Saccharomyces cerevisiae* response to an a –mating factor fragment missing amino acids other than Lys7 and Gln10 would thus increase our understanding of the specificity of the a –factor receptor for its ligand. **[BR: study goal/broader implication]**

We hypothesized that the introduction of an a –mating factor fragment missing amino acids 7 through 13 to MAT-a *Saccharomyces cerevisiae* cells would cause more budding and less mating gene transcription and shmooing, as compared to the response to the complete a –factor.

**[hypothesis]** We tested this hypothesis by adding this a –factor fragment to yeast cells transformed with a plasmid containing the FUS1 promoter attached to the lacZ reporter gene and recording the resulting morphological changes (budding and shmooing) and  $\beta$ -galactosidase ( $\beta$  -gal) activity.

**[approach]**

## EXAMPLE 5: GOOD INTRODUCTION FROM MANIPULATIVE EXPERIMENT IN ORGANISMAL BIOLOGY LAB

(adapted from a paper by Matt Young, Fall 2003)

The diving response is a set of characteristic reactions following the immersion of certain body parts in water. It is observed primarily in diving mammals and ducks, but humans have also elicited the response, perhaps as a trait that was not selected against during their evolution (McCulloch et. al. 1995; Hlastala and Berger 2001). Gooden (1993) clearly demonstrated that the diving reflex prepares the animal's body for the effects of long periods of apnea (breathing cessation) associated with being underwater. It does this by decreasing oxygen consumption and redirecting blood flow out of the peripheral structures and towards the central organs such as the heart and brain.

McCulloch et. al. (1995) showed that the diving response is initiated by the stimulation of the trigeminal (Vth cranial) nerve, a primary sensory supply from the face, including the nose and forehead areas. Stimulation of this nerve results in a complex series of sympathetic and parasympathetic nerve activations (Gooden 1994). Increased parasympathetic activity triggers the vagus nerve to inhibit the cardiac pacemaker, resulting in reduced heart rate (Andersson et. al. 2000). Limb vasoconstriction occurs in response to increased sympathetic nerve activity, which results in increased mean arterial blood pressure (MABP) (Andersson et. al. 2000; Gooden 1994). **[all background info in previous paragraphs]**

Along with submersion in water, apnea is believed to be a major component in eliciting a proper diving response. It is still not clear, however, how necessary apnea is for the induction of the diving response or the mechanism for this induction (Gooden 1994). **[broad question]** Campbell et. al. (1969) argued that apnea, whether voluntary or involuntary, is essential for a diving response to occur, while Andersson et. al. (2000) found that facial immersion with eupnea resulted in reduced, but noticeable, diving responses. **[background info]**

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diving response. It is still not clear, however, how necessary apnea is for the induction of the diving response or the mechanism for this induction (Gooden 1994). **[broad question]** Campbell et. al. (1969) argued that apnea, whether voluntary or involuntary, is essential for a diving response to occur, while Andersson et. al. (2000) found that facial immersion with eupnea resulted in reduced, but noticeable, diving responses. **[background info]**

It is believed that apnea stimulates chemoreceptors and thoracic stretch receptors in order to exert its effects. The thoracic stretch receptors are sensitive to movements in the airways, while chemoreceptors are sensitive to the oxygen lack associated with breath-holding. Increased firing of these two receptors due to their respective stimuli is believed to be the method by which apnea influences the diving response, but the exact pathway this firing takes to exert such effects remains unclear. It may either directly affect the cardiovascular centers, or indirectly affect the cardiovascular system via the medulla (Gooden 1994). **[background info which identifies knowledge gap]**

Does apnea significantly increase the human diving response during facial submersion? **[testable question]** It seems plausible that simultaneous activation of the trigeminal nerve, thoracic stretch receptors, and arterial chemoreceptors would produce a more pronounced cardiovascular diving response. **(BR: biological assumption)** The goal of this experiment is to examine whether the diving response in eupneic (normal breathing) situations is significantly different than that observed during apneic situations. **[BR: study goal]** We will focus on heart rate and blood pressure changes, two of the many responses associated with the diving response. If heart rate and blood pressure changes during apneic submersion are significantly greater than those observed during eupneic submersions, this would indicate that simultaneous stimulation of the trigeminal nerve, thoracic stretch receptors, and chemoreceptors produces a greater cardiovascular response than stimulation of the trigeminal nerve alone. **[BR: assumed mechanism]**

We hypothesized that diving responses in human participants would be more pronounced in those experiencing apnea during immersion compared to those experiencing eupnea. More specifically, we expected non-breathing participants' heart rates to decrease and blood pressures to increase significantly more than breathing participants in response to facial immersion in cold water.

#### **[hypothesis]**

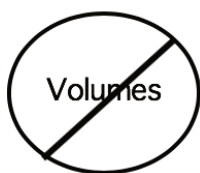
We tested this hypothesis by having 12 human subjects immerse their foreheads, noses, and cheekbones in cold water. We used a paired analysis to determine whether the change in heart rate and blood pressure from just prior to immersion to the end of immersion was different during apneic as compared to eupneic submersions. **[approach]**

## Methods and Materials

This section is often the easiest to write since it is simply **a clear explanation of the specific procedures, techniques, and materials you used**. In some cases (e.g., the projects carried out in the Biocore Prairie), it is necessary to include procedures carried out by previous classes as well. Provide enough details that a knowledgeable reader (e.g., a Biocore peer who is not enrolled in lab) could replicate the experiment. This will also allow him/her to evaluate whether to trust your findings. In the case of field investigations, include a description of the type of community and the location of the site studied.

**Mathematical manipulations or statistical analyses applied** to the data should be explained under a subheading, but keep these brief. Although calculations are not normally included in a scientific paper, we sometimes ask you to include examples to check whether you are doing them correctly. If this is the case, put them in an appendix at the end of the paper.

**Focus on essentials that affect the results.** For example, in a genetics experiment with flies, it is important to state whether the females used for the crosses were virgins; it is not necessary to list the type of food or anesthetic used. However, these details would be important if your experiment was testing how different diets affected fruit fly activity level or some other physiological parameter. In cases where detailed protocols are given in the lab manual, merely cite the appropriate chapter of the lab manual, note any details relevant to the experiment but not specified in the protocol (e.g., identify the particular strain of organism you and your teammates used when several were available), and describe any manipulations you made that are not outlined in the manual. **Include only what is vital for the reader's understanding** of how the results were obtained. (E.g., Drawing white poker chips out of a 1 quart Babcock Vanilla flavored ice cream container to get two numbers to pace out and place quadrats is not as important as the fact that quadrat placement was random.) If you are having trouble deciding what to put in and what to leave out, consult with your TA, peers, or other instructional staff for guidance before handing in your final paper.



Organize the procedures in the Methods & Materials section **logically**:

- Use subheadings, including one called “data analysis”
- Describe your schedule of procedures in chronological order (if it makes sense to do so)
- When writing a final paper, use the past tense for this section (because you refer to procedures that you carried out in the past). When writing a proposal, use future tense.
- Report final concentrations (in molar, millimolar, micromolar etc). rather than final volumes (see table below). Readers can replicate concentrations, but often find it difficult to discern concentrations when only volumes are reported.

#### Not helpful to other researchers

Reporting final volumes. E.g., ‘We added 5 ml of NaCl solution to the reaction mixture.’

#### Very helpful

Reporting final concentrations. E.g., ‘The final reaction mixture contained 2 mM of NaCl.’

## EXAMPLE OF GOOD METHODS TEXT

(Excerpt adapted from a paper by Beth Theusch, Biocore 384, Spring 2003: Inorganic phosphate competitively inhibits alkaline phosphatase-catalyzed hydrolysis of p-nitrophenylphosphate)

*Pilot Study\**

A pilot study using various Pi concentrations but a constant substrate concentration close to the  $K_m$  value was conducted in order to determine a  $\text{Na}_2\text{HPO}_4$  concentration that has a moderate effect on initial reaction velocity to use in the inhibitor kinetics study. We tested a range of concentrations between 2.5  $\mu\text{M}$  and 200  $\mu\text{M}$   $\text{Na}_2\text{HPO}_4$  in tubes containing 0.05 M Tris-HCl, pH 8.6, 0.05 mM pNPP (the approximate  $K_m$  value), and 4  $\mu\text{g}/\text{ml}$  bovine intestinal alkaline phosphatase in a total volume of 5 ml. There was a control with no  $\text{Na}_2\text{HPO}_4$  added and a blank with no enzyme added.

#### *Experimental Protocol*

The inhibitor kinetics study involved two sets of replicated reactions over a 0-0.5 mM range of pNPP substrate concentrations. One set of reactions was conducted in the absence of inhibitor and used as a control. The other set of reactions had a uniform concentration of Pi inhibitor, which was determined to be 0.05 mM from the pilot study, added to each tube. All tubes had 0.05 M Tris pH 8.6, 4  $\mu\text{g}/\text{ml}$  alkaline phosphatase, and the appropriate amount of distilled water to bring the total volume of each tube to 5 ml. In each case, there was a control with no substrate added and a blank with no enzyme added. The pH of the  $\text{Na}_2\text{HPO}_4$  salt solution was checked to ensure that the pH was approximately the same in the uninhibited and the inhibited reactions. Four replicates were performed for both the inhibited reaction and non-inhibited reaction.

For a complete protocol of the non-inhibited experiment, refer to “Enzyme Catalysis” in the Biocore Cellular Biology Lab Manual (Becker, Metzenberg, Dehring, 2003). For the inhibitor kinetics study, the product concentrations were used to calculate the initial reaction velocities at each substrate concentration in the presence and absence of inhibitor. Michaelis-Menten curves and Lineweaver-Burk plots were then generated to compare the values of  $K_m$  and  $V_{\text{max}}$  for the inhibited and uninhibited reactions.  $K_i$  was determined using the relationship that the inhibited  $K_m = (1 + [\text{inhibitor}] / K_i)$  times the uninhibited  $K_m$ .

#### *Statistical Analysis*

We performed an independent sample T-test to determine whether the differences between the average  $K_m$  and  $V_{\text{max}}$  values between the inhibited and uninhibited reactions were statistically significant.

**\*Note:** Not all papers require the inclusion of pilot studies in the Methods section. Discuss this with your instructors.

**How will methods/materials be evaluated?** To see our expectations for your Methods & Materials, see the Biocore Research Paper Rubric in this Writing Manual.

## Results

The Results section is a **logically organized presentation of your observational and numeric data**. This is an opportunity to emphasize points or trends that you will be focusing on in your discussion. In many cases the organization and subheadings of this section should be consistent with those of the Methods and Materials section.

Before you start writing, make sure you have discussed the data and have shared your plan for analysis with

your group members. Your group should **share a common data set** and, therefore, should be working with the same mean, standard deviation, and other descriptive statistics. As long as all group members have the same raw data set, you may choose to display the data differently.

**There are usually two parts to this section:**

- text
- tables and figures

**Text:** The key purpose of the text in the results section is to point out and emphasize patterns in your data. You may choose to illustrate some of these patterns, especially those that pertain to your hypothesis, in figures or tables. However, each figure and table needs accompanying text to point out the obvious—or sometimes the not so obvious.

- Briefly describe, but **do NOT make conclusions about (i.e., interpret) your data here—save that for the Discussion section.**
- Point out any trends. (Trends are relationships between one variable and another. e.g., as variable one changes, variable 2 tends to change in a consistent way.)
- Note differences or similarities between treatment groups.
- If you perform statistical analyses, report any significant *biological differences* you found, followed by pertinent statistical summary information (test score such as a “t” or “F” value, degrees of freedom, one or two-tailed p-value; see Biocore Statistics Primer for more info).

Not helpful to other researchers	Very helpful
We found statistical significance.	The average reaction velocity (54 nmol/min, SE $\pm 0.084$ ) in the inhibited reactions was lower than the average uninhibited reaction velocity (25 nmol/min, SE $\pm 0.12$ ). This difference was statistically significant ( $t(12)=135.4$ , $p<0.001$ , two tailed).

Refer your reader to “Table 1” or “Figure 1” as you explicitly identify relationships, patterns, or general trends that you see in the data. Remember that relationships that are obvious to you may not be obvious to someone who has not carried out the experiment.

- Never write a sentence that just tells the reader where the data are. Point out to your reader the general trends in the data, then refer to the figure or table parenthetically.
- When using the term **“significant”** in your results section recognize that it has a specific connotation in science that reads “statistically significant.” Therefore, use the term “significant” when explaining differences you observe only if you found statistically significant differences.

The Results section should not be controversial since you are merely reporting findings, not saying what you think they mean. Avoid judging your data as “good” or “bad.” Data are facts and facts simply are what they are.

**Remember: you are not graded on whether your experiment “worked” or on your results; you are graded on how you handle them.** Always report what you saw, not what you think you should have seen.

See the following excerpt from a good Results section describing data from a systematic study.

## Example of a Good Results Section from a Systematic Observation Study

(excerpted from a Biocore 382 paper by Kim Trembl, Fall 2003)

### Results

#### *Water Quality*

Water quality testing revealed a mean pH of 6.67  $\pm$  0.07 pH units (Table 1). Mean dissolved oxygen and dissolved carbon dioxide were 3.4  $\pm$  0.4ppm and 55  $\pm$  3ppm respectively. Also, the total phosphorus was measured as 0.51  $\pm$  0.5mg/L and conductivity, measured in microsiemens, was 1,063  $\pm$  17 $\mu$ S. All means were computed with n=45. Both conductivity and phosphorus fall far out of range of optimal water quality levels for a healthy aquatic ecosystem (Table 1). The measured phosphorus level is an order of magnitude larger than what is recommended by the EPA. Conductivity is twice as high as the ideal level in a freshwater ecosystem. **[RESULTS TEXT]**

Table 1. Water quality data obtained from the University Bay marsh in 2003. Each value represents the mean of 45 trials. The error margin is + or - 1 standard error. Optimal data ranges for a healthy aquatic ecosystem are shown for comparison. **[TABLE LEGEND]**

Parameter	2003 data	Optimal data ranges
pH	6.57 $\pm$ 0.07	6.9 – 7.1
Conductivity ( $\mu$ S)	1,063 $\pm$ 17	150 – 500
Dissolved O <sub>2</sub> (ppm)	3.4 $\pm$ 0.4	5 – 6
Dissolved CO <sub>2</sub> (ppm)	55 $\pm$ 3	> 20
Phosphorus (mg/L)	0.51 $\pm$ 0.04	0.005 – 0.05

**[TABLE]**

#### *Macroinvertebrate Diversity*

Macroinvertebrate species in the University Bay marsh were catalogued and presence or absence of each species was noted. Figure 3\* depicts the calculated frequency of each species per 500mL. The species are approximately organized on the chart from left to right with increasing pollution tolerance as described on North Carolina State University's water quality webpage (2003). The highest frequency in both 2002 and 2003 exists among organisms around the mid-range of pollution tolerance. Orb snails, scuds, backswimmers, copepods, seed and clam shrimp, nematodes and tubifex worms were present in over half of our samples in either 2002 or 2003. Species indicative of very high water quality or very low water quality were less frequent compared to species indicative of the mid range. Nonetheless, the data show an increase in the variety of species present from 18 species in 2002 to 26 in 2003. **[RESULTS TEXT]**

\*Figure 3 not shown in this Writing Manual

## TABLES AND FIGURES:

Tables and figures are key elements of a scientific paper.



- **Tables** are organized lists of numbers, ideas, or other data.
- **Figures** are graphs, charts, diagrams, or photos.

Why use tables and figures? First, they offer a concise way to present a large amount of information. Second, they carry the bulk of the experimental evidence needed to support your conclusions. Third, they offer the reader a chance to assess your data and determine whether or not your conclusions are valid. Finally, the values in them can be used by other scientists who wish to build on your work. Usually, **summarized** (e.g., averages and measures of variation) rather than raw data are included in a paper. Always make it clear whether you are presenting actual data or averages. (In some cases we will ask you to include raw data as an appendix.) Please refer to the Biocore Statistics Primer for directions on producing figures in Excel.

Each table or figure should be referred **to in the text of your paper** at least once. If you have nothing to note about a particular table or figure, leave it out. Identify and number tables or figures according to the order they appear in the text (Table 1, Table 2, Figure 1, Figure 2, etc.). This way the reader will know exactly what data you are discussing.

Tables and figures should be neat, logically organized, and informative. If properly prepared, they can stand independently of the paper. Always remember that readers are not familiar with your data. A table or figure that seems self-explanatory to you may not seem so to a reader.

#### Here are some rules for presentation of graphs and tables:

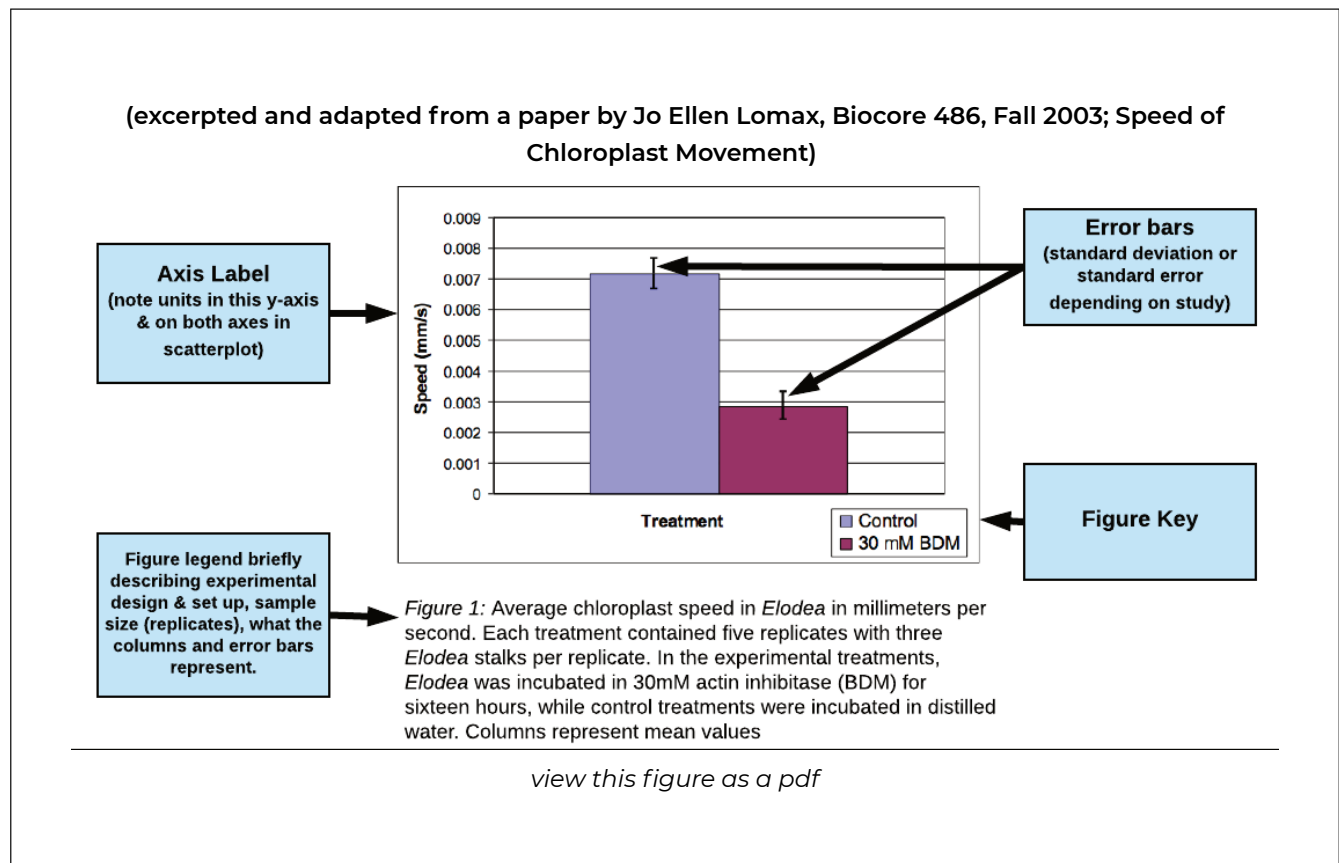
- Present your final data in table or graphical form. The choice of table or figure should be based on the type of data you have. If you are trying to show trends or simple comparisons it may be best to use a figure. If you have long lists or many comparisons to be made across groups a table may be more appropriate. [**DO NOT** present the same data in both table and graphic form.]
- The most common way to present graphical data is either an XY scatterplot for continuous data or a bar chart for categorical data/ results of statistical comparison of the means of two or more groups.
- **Keep it simple!** The amount of time it takes a reader to interpret a figure is inversely proportional to how well those data are presented. Do not overuse transformations or ratios if they are unnecessary for accuracy and clarity of your results.
- Clearly label all axes or columns including units (e.g. Time (min.), Concentration (mM), Mass (mg)). Describe any symbols you use in your graphs using a **KEY** (see figures below for examples of keys).
- Table and figures should always have a brief text description called a **LEGEND** that fully describes them so that they can stand alone. (See figures below for examples of figure legends.)
  - **POOR LEGEND:** Enzyme activity vs. salt (*Avoid using the term vs*)
  - **BETTER:** Average alkaline phosphatase activity for concentrations of NaCl from 0.1 to 1 mM. The substrate for the reaction was ATP at a concentration of 2 mM for a total reaction time of 3 minutes. Columns represent mean values (N=3) with error bars representing  $\pm 1$  SE.
- Put table legends **above** a table. Put figure legends **below or to the side** of a figure.
- Do **NOT** create titles for figures or tables. Instead of a title, use a simple legend numbering each table and figure consecutively is sufficient. Do not use titles like "Chart 1" that are automatically generated by Excel.
- For graphs that present an average value as a single point or bar, include error bars and state what they represent. Usually, this will be 1 standard deviation (SD) or 1 standard error (SE) on either side of the mean (see figure 1 below for an example).
- For tables presenting means, include some measure of variation (SD or SE). (See Table 1 above for an example of this).
- State the number of samples used to calculate an average. If you measured the height of 12 purple cone

flower plants and reported an average height of 0.82m, indicate the number of samples used to generate that statistic as n=12.

- Do not connect the points on a line graph unless you really mean to say that the values in between the points shown should follow the line drawn. Trend lines have very limited predictive value or validity when connecting 3 points or less.

**Drawing a diagram or presenting a photomicrograph:** Drawn diagrams or photographs taken from a microscope and their legends should contain enough information that a reader can understand (as near as possible) what you actually observed and the conditions surrounding the observation. Diagrams must be large enough to show significant details of what you observed. In practice, this generally means that each diagram should cover **at least a quarter of an 8.5×11" page**. Indicate the type of microscopy used and the total magnification in your legend. Include a scale on your drawing. Define the experimental conditions and include notes on the process of your investigation. See Figures A-7, A-13, and A-14 in the World of the Cell's "Principles & Techniques of Microscopy" for examples of good figure legends.

## Example of Good Results bar graph



## Example of Good Results scatterplot

(excerpted and adapted from a presentation by Jennifer Rowland, Beth Rollmann, Simona Rosu, and Christopher Luty, Biocore 384, Spring 2003; Gramicidin Decreases CO<sub>2</sub> Consumption in *Elodea*)

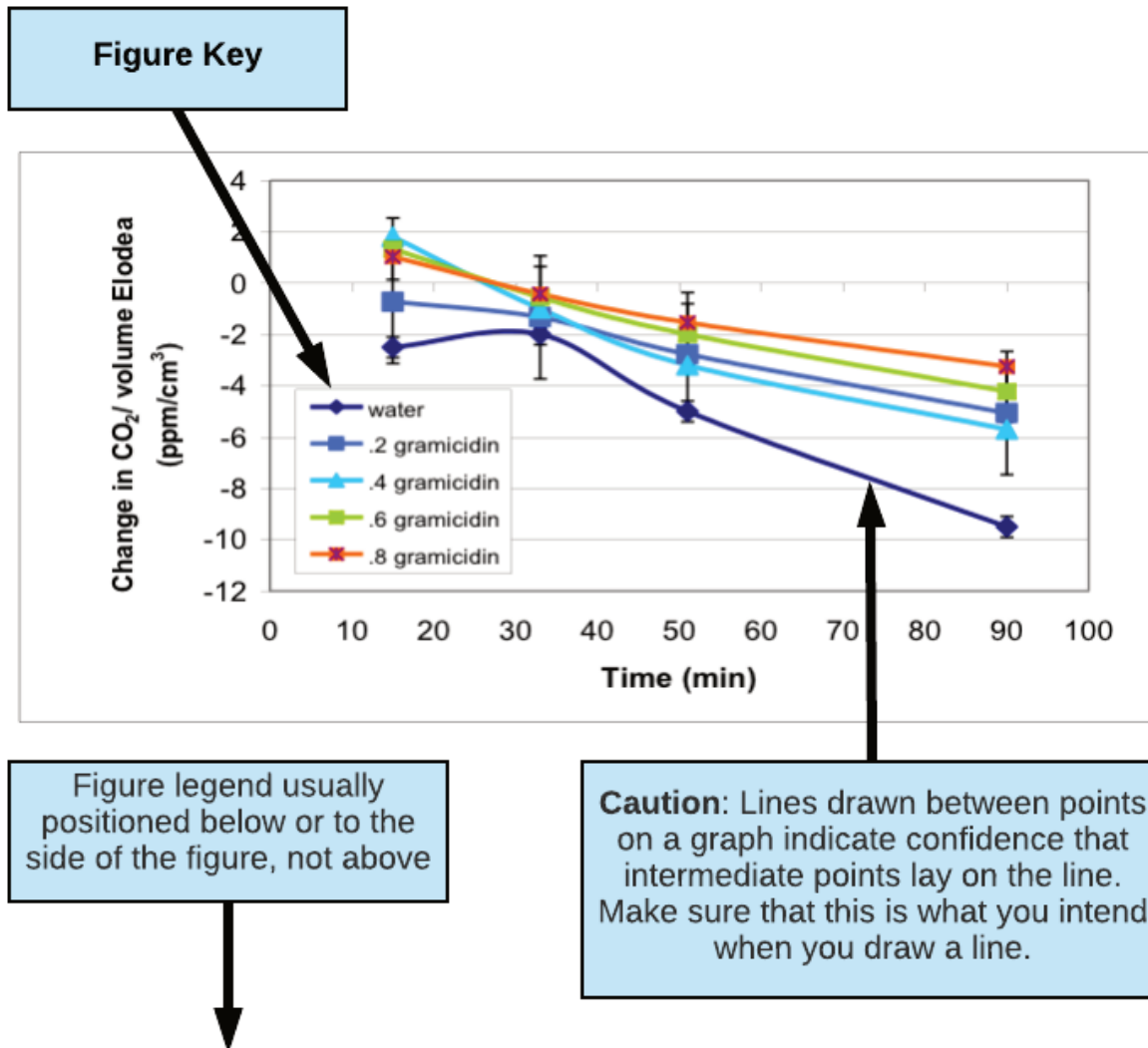


Figure 2: Change in dissolved CO<sub>2</sub> levels in water surrounding six *Elodea* sprigs (6 cm in length) in 75 ml culture tubes over 100 minutes of light exposure. Dissolved gramicidin concentrations ranged from 0 to 0.8  $\mu$ M. Each data point represents the mean of N=11-15 culture tubes for each gramicidin concentration plus/minus one standard error.

*view this figure as a pdf*

## Example of Good Table

(adapted from Jenna Voegelé paper on water quality in Willow Creek, Biocore 382, Fall 2004)

Table 1. Mean values of water chemistry tests from upstream and downstream sampling locations during a three day study period, Sept 14-16, 2004. Variation is shown as  $\pm 1$  SE next to each mean value, followed by sample size (in parentheses) in which varied for each test and sampling location. Note the smaller sample size for the nitrate-N test.

Water Quality Test	Sampling Location	
	Downstream	Upstream
Turbidity (NTU)	32.2 $\pm$ 9.7 (16)	23.6 $\pm$ 5.9 (13)
PH	6.99 $\pm$ 0.1 (16)	6.97 $\pm$ 0.12 (14)
Dissolved Oxygen Saturation (%)	77.1 $\pm$ 1.7 (32)	81.5 $\pm$ 1.9 (26)
Biochemical Oxygen Demand (mg/L)	2.6 $\pm$ 0.5 (20)	3.3 $\pm$ 0.7 (18)
Total Phosphorus (mg/L)	0.44 $\pm$ 0.09 (15)	0.58 $\pm$ 0.12 (14)
Nitrate-N (mg/L)	8.6 $\pm$ 1.4 (4)	11.0 $\pm$ 0.7 (4)
Water Temperature ( $^{\circ}$ C)	20.8 $\pm$ 0.3 (17)	20.6 $\pm$ 0.3 (14)
Fecal Coliform (colonies/100ml water)	414 $\pm$ 185 (29)	684 $\pm$ 201 (24)

### Writing a figure legend for a drawing or micrograph:

If you are including an image (drawing or photomicrograph) in your paper, highlight attributes of the image that are important for your paper and to your reader. If the reason for including the image is to highlight anatomy, you may want to label structures and include a description of movement or other important observations in the figure legend. When writing a figure legend to accompany a photo or drawing, include enough information so that a reader can understand (as near as possible) what you **actually observed and the conditions surrounding the observation**. This means that you should indicate the type of microscopy used (phase contrast, bright field, fluorescence, etc.) and any notes regarding the preparation (e.g., mounted in ProtoSlow, water or saliva, with coverslip, types of stains used, etc.). Also **indicate the total magnification** in your legend. Diagrams must be large enough to show significant details of what you observed. It is important to **include a scale** on your drawing.

*Click on the three purple icons in the diagram below for more information about each element.*

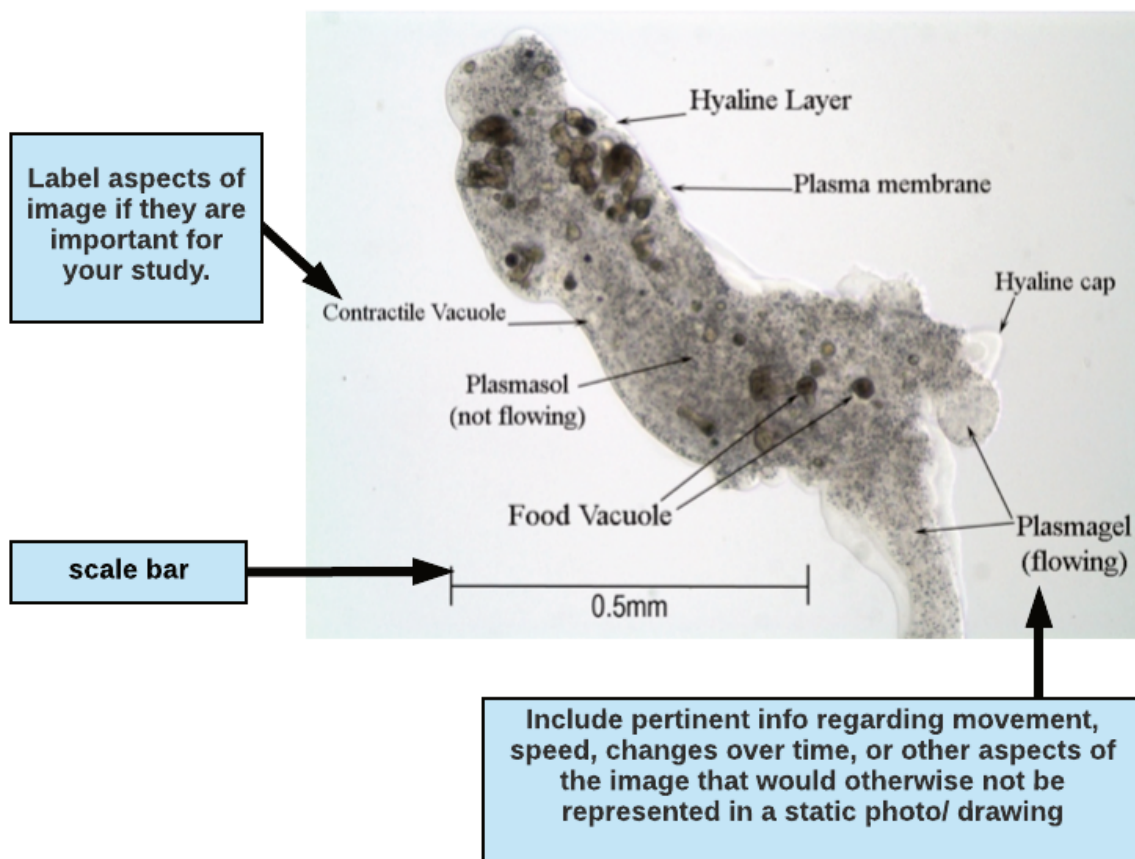


Figure 1.1 Micrograph of the protozoan *Pelomyxa carolinensis* viewed under phase contrast microscopy, magnification 100X. The specimen is mounted in ProtoSlow and coverslip to reduce its movement. Plasmagel streams readily into pseudopodia (seen at the bottom right of the photo) allowing the amoeba to slowly crawl across the field of view.

*view this figure as a pdf*

In the figure description above, the writer has indicated the type of microscopy (phase contrast microscopy, magnification 100X) and the total magnification (100X).

**How will results (including text & figures/tables) be evaluated?** To see our expectations for your Results, see the Biocore Research Paper Rubric in this Writing Manual.

# Discussion

This is where you **interpret your results for the reader**. It is the most important part of your paper and often one of the most difficult to write. The discussion section is NOT a restatement of your results, but rather where you provide your insight on the investigation through logical analysis. Key elements of your discussion section include:

- BROAD STUDY QUESTION that your research is trying to address
- SUPPORT/REJECT HYPOTHESIS
- INTERPRET the dependent variable measured (if multiple variables are measured you interpret each variable independently and then INTEGRATE variables for overall interpretation of data)
- Formulate argument for your conclusions, emphasizing how your data do or do not support your biological rationale & by comparing with relevant findings in the literature
- NEW KNOWLEDGE that your investigation has generated: highlight the knowledge gap that your data help address, and the implications of your work. Introduce at least one new paper from the scientific literature to help you discuss or support your findings.
- EVALUATE confidence in experimental design and reliability of data
- NEW QUESTIONS and FUTURE STUDIES that the new knowledge inspires
- UNEXPECTED OBSERVATIONS are unique observations not collected in rigorous way but still intriguing and could inspire new investigations
- CONCLUSION brief statement as summary.

The organization of your discussion section is not fixed but rather it is driven by the reliability of the data you collect. The discussion should complement the logic set up with your biological rationale in the Introduction.

The following is **not** an appropriate discussion section: “Our data supported the hypothesis. The results were what we expected (see Results section).” Instead, state specifically what you observed in your data, and the conclusions you feel confident you can make based on the evidence you gathered. The Discussion should **formulate and support a logical argument**, leading the reader through the specific conclusions drawn from the data to their more general implications beyond the experiment.

## ELEMENTS IN THE DISCUSSION SECTION

### Broad Study Question

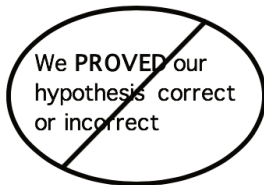
What is the broad question that your research is trying to address? State your question clearly in the opening paragraph.

### Support or Reject Hypothesis:

- If you have conducted a manipulative study, **restate your hypothesis** and whether you **support or reject your hypothesis referencing appropriate data**. (Note that finding no difference between two treatments is a result).
- Critically evaluate your biological rationale, experimental design, data collection, and explicit/implicit assumptions throughout. After this evaluation, you should be able to support or reject your hypothesis....OR you may feel that you did not fully test your hypothesis after all. A key step here is to look at your controls and variation in your measurements. How much variation surrounds your controls? How

reliable and accurate are your measurements?

- **Special Note about Inconclusive results:** You may find that you have very **LOW RELIABILITY** of results because of malfunction, error or confounding variables. In this case, you may still feel your hypothesis is true, but you were not able to test it as expected. Instead, report your results as inconclusive, describing why you could not test your hypothesis and how you would revise your investigation in future studies.
  - IMPORTANT NOTE: finding no difference between treatments is NOT an inconclusive result—No difference is a very valid result that contributes to a conclusion for either supporting or rejecting a hypothesis!



- **Philosophical Note:** DO NOT USE THE WORD **PROVE**. You cannot “prove” your hypothesis correct or incorrect. **Science cannot prove anything**, it can only provide evidence to support or reject your hypothesis. Without getting too philosophical, the role of science is not to find proof but rather to move closer to truth by eliminating hypotheses that are not true. Therefore, you will not be ‘proving your hypothesis’, but rather supporting or rejecting your hypothesis given the construct of your experiment and the data you have gathered. If you have carried out a **systematic observation** and may have not posed a formal hypothesis but you can provide answers to the general questions you posed about the system, or describe the system more precisely based on the data you collected.

**Interpreting Data:** If you feel that your protocol allowed you to test your hypothesis,

- Interpret each piece of data presented in the results independently and evaluate the reliability of the data.
- Discuss how these data are similar (confirm) or contrast with what is reported in literature you presented in the introduction OR new literature you discovered after you completed your experiment. **Explain the trends you feel are important to support your conclusion(s)** and evaluate how this supports or contradicts the biological assumptions you outlined in your biological rationale. Be prepared to detach yourself from your original biological rationale in explaining or being critical of your results.
- Combine and integrate the multiple types of *reliable* data you collected and discuss how together they inform the broad question (only combine data you are confident in).

### **Generating New Knowledge**

Describe how your experiment contributes to the knowledge gap you identified in your introduction. Cite similar, contrary and/or supportive literature.

- **If your data supported your hypothesis:** guide your readers through the steps in your reasoning referring back to your biological rationale to provide context. Present the arguments that explain how your experimental approach and the pieces of evidence (data) convince you of your conclusion. Explain how do your findings add to those that others have observed. **Compare your findings with information from the literature (this often requires a post-experimental literature search)**, citing appropriate references that support for your results. These references include many that you cited in your Introduction section; briefly summarize them but avoid redundancy.
- **If your results are contrary to your hypothesis,** you need to speculate the reasons for this difference, continue your literature search to explain your alternative results. Are your results consistent or inconsistent with others findings—why or why not? Distance yourself from the project while writing and

be reasonably critical of your data. What evidence do you have that your biological rationale is acting? Is the mechanism you propose in effect? Evaluate the key biological assumptions in your biological rationale which were not correct.

- **Implications** of your findings- How does your experiment add to the current body of knowledge? Speculate on the implications of your findings. It is essential that you **refer back to your biological rationale**. Implications are specific, reasonable extensions of your results or the meaning of your results for the larger picture. Be careful, however, with your choice of words: state implications as logical possibilities rather than as fact. Your results may lead to new insights about relationships in nature. An unexpected result (if it holds up on repeating the experiment) may yield insight to guide a more effective experimental approach.

### **Evaluate Confidence in Experimental Design and Data Reliability/Quality**

- Evaluate the strengths and weakness of your experiment and your confidence (or lack of) in your experimental design. Explain how these factors allow you to gauge the strength of your conclusion(s). **Always address whether your protocol allowed you to truly test your hypothesis** (see special note about inconclusive results in 'support or reject hypothesis' section above). In some cases you may discover unexpected inaccuracies in your data or that the methods you used were not appropriate or precise enough to address your question or test your hypothesis. Address the errors, unresolved issues and speculate how the experimental approach might be improved. Inconclusive results may show that you weren't asking a relevant question in the first place or that the experiment was not able to test the question you posed. This, in turn, can generate specific new questions and experimental approaches. **Avoid making a laundry list of mistakes you made in carrying out your experiment.** Only mention errors if they help explain unexpected data values and/or lead you to conclude that your methods did not allow you to test your hypothesis.
- **Evaluate reliability of data** – Once you have established that your experimental design was appropriate to address your original question, you must also **evaluate how well you carried out your intended design** and what that means to your **data reliability** (e.g. evaluating whether the variation you see between samples is natural variation or experimenter's error). How good are your data? Consider the variability in your data (variance, standard deviation, standard error). Did you have enough replicates? Did you have a large degree of experimental error? What are the implications of variability? **Do not over-interpret your data.** Recognize the magnitude of the variation within your data and the level of departure you would need to conclude true differences. In most cases you are trying to attach meaning to a group of numbers generated by some procedure. Help your readers make sense of these numbers by explaining how the patterns and relationships you observed reflect the biological concepts or issues you set out to explore. How do your data fit with your biological rationale?

**New Questions and Future Studies:** Science is built on an iterative cycle of questions, experiments, results and conclusions. Often it is appropriate to suggest the next step in the investigation. Be sure to include **the reasoning that leads to your insights**. Your experiment will likely provide many opportunities to ask new questions and suggest future studies.

**Final Conclusion:** End your paper strongly with a clear, brief conclusion that relates directly to the question, hypothesis, or knowledge gap you stated in the Introduction.

**If you get stuck:** The hard work of making meaning of data will be easier if you have a clear idea of what it was that you set out to do in the first place. Re-read your question and biological rationale. Do your results allow you to answer the question you posed in light of your biological rationale? A second reading of your BR after examining your data will often solve much of the confusion you may be experiencing. Be sure to discuss your



results thoroughly with your research team. They may have some insight, intriguing literature for comparison, or thoughts about the data that could benefit your interpretation.

**Other things you can do:**

- Take a look at the example of good discussions on the next pages.
- Make a conceptual diagram for yourself or with your team. This is especially useful for seeing new connections, structuring ideas, and finding interactions at multiple levels.
- Explain the experiment and its significance to a friend who knows nothing about it. If you understand the full content, context, results and relevance of your experiment, you should be able to explain what was done and what it means. This should help provide some organization to your paper.

**How will discussions be evaluated?** To see our expectations for your Discussion, see the Biocore Research Paper Rubric in this Writing Manual.

## EXAMPLE OF GOOD DISCUSSION

**Adapted from a paper by Jeremiah Wilke, Biocore 382, Fall 2003 Practice Paper entitled “Queen Anne’s Lace (*Daucus carota*) Species Frequency Suggests Rototilling as Most Effective method for Control of Invasive Weeds in Prairie Restoration Projects**

The results suggest that rototilling is the most effective method as mulching and mowing yielded frequency values approximately 5 fold greater. The greater effectiveness of rototilling over the other methods coincides with previous knowledge of Queen Anne’s lace as it is known to favor habitats in no-till fields (Rose and Sheaffer, 2003) and re-sprout stems even after being cut (Biocore 382, class 2001, unpublished data) . **(setting up logical argument: referring back to biological rationale and comparing findings with the literature)**. The frequency means suggest mowing to be slightly more effective than mulching; however, the distribution of the frequencies indicates little difference as the methods share common values. **(Data interpretation- part of logical argument; Add re-statement of hypothesis and clearly state whether it was supported or rejected based on data interpretation)**

Through rototilling seems to be the most efficacious for Queen Anne’s lace, several factors prevent us from making a definitive conclusion, most notably a small sample size. **(Evaluating the validity and reliability of data)** Frequency calculations can suggest patterns in the treatment, but they give no sense of the species density (number of a give species per quadrat). Examinations of the species frequency of Queen Anne’s lace in a control would also allow us to be more conclusive by gaining a sense of the improvement the methods made over untreated plots. **(evaluating experimental design)** Beyond our inability to decisively say which treatment is the most effective for Queen Anne’s lace, further work by the University of Wisconsin-Madison Biocore class of 2001 suggests we cannot generalize to other non-native species (Batzli, 2003). In their research, none of the methods demonstrated an appreciably greater capacity for weed control when tested on a variety of species. **(discussion of other data makes our interpretation and argument more convincing)** Species density calculations, measurements against a control, and the effectiveness of treatments on the

other invasive plants therefore all necessitate future research. Mixing treatments has also been proposed (Batzli, 2003), while engineering novel methods deserves further study. **(next steps)**  
**(Final conclusion and brief discussion of implications of this research would help here)**

## EXAMPLE OF A GOOD DISCUSSION THAT ENUMERATES ASSUMPTIONS AND HOW VIOLATING ASSUMPTIONS CHANGES CONCLUSIONS

Adapted from a poster by Beth Gausden, Katie Gielissen, Emily Gurnee, Jordan Mollet, and Carley Zeal, Biocore 384, Spring 2006

**Addition of colchicines to MATa *S. cerevisiae* in vivo does not inhibit budding in the absence of  $\alpha$ -factor but reduces shmooing and  $\beta$ -gal activity in response to  $\alpha$ -factor**

The results in Fig. 2 do not support our hypothesis (**rejection of original hypothesis**) that yeast exposed to colchicine in the absence of  $\alpha$ -factor show a drastic decline in the incidence of budding as compared to controls. Our original hypothesis was based on the assumption that inhibition of mitotic division would prevent budding. (**clear statement of key assumption in biological rationale**) Although nuclear division is mediated by microtubules, pinching action and subsequent cytokinesis (budding) is controlled by actin filaments<sup>1</sup>. The tubulin-colchicine complex inhibits karyogamy; however, bud formation can occur independently of nuclear division.<sup>1</sup> Budding was still observed microscopically after three hours of incubation with colchicine (Fig. 2)- approximately two generations. These results indicate that bud formation was not inhibited by colchicine; (**summary of how results do not support biological assumption**) however, later generations incubated in colchicine may show complete cessation of budding as a result of aneuploidy, an irregular number of chromosomes.<sup>1</sup> This occurs when a yeast cell undergoes successful cytokinesis but unsuccessful karyogamy; if this process is continuous or prolonged, cells will be unable to bud.

The results in Fig. 1 and Fig. 2 do not support our hypothesis that colchicine does not affect shmooing or the transcription of mating genes. We expected no change in the incidence of mating gene transcription as reported by the  $\beta$ -gal assay and percent of shmooing yeast in the yeast treated with colchicine compared to untreated yeast. The  $\beta$ -gal assay, Fig. 1, indicates a large decrease occurred in the transcription of mating genes in the presence of colchicine. Similarly, we observed a lower percentage of shmooing cells in the presence of colchicine. If nuclear division were inhibited by colchicine, then the portion of cells experiencing aneuploidy would be unable to respond to  $\alpha$ -factor by shmooing or transcribing mating genes.

### *Conclusion*

Our results suggest that colchicine does not inhibit bud formation (in the absence of  $\alpha$ -factor) after 3 hours. We also observed decreased shmooing as well as  $\beta$ -galactosidase activity in yeast cells

treated with colchicine and  $\alpha$ -factor. The consistency of our results provides reasonable confidence in the methods. In future studies, longer incubation times, differing concentrations of colchicine, and chromosome and microtubule staining could be used to investigate the mechanism more thoroughly.

## EXAMPLE OF GOOD DISCUSSION

### **Adapted from a paper by Beth Theusch, Biocore 384, Spring 2003 Inorganic Phosphate Competitively Inhibits Alkaline Phosphatase-Catalyzed Hydrolysis of p-Nitrophenylphosphate**

We hypothesized that inorganic phosphate (Pi) would act as a competitive inhibitor of the alkaline phosphatase-catalyzed pNPP hydrolysis reaction. Our data support this hypothesis. **(re-statement of hypothesis and whether it was supported or rejected)** As expected, we found that addition of inorganic phosphate increased the  $K_m$  of the alkaline phosphatase-catalyzed pNPP hydrolysis reaction while the  $V_{max}$  remained relatively unchanged. **(setting up logical argument)** After the addition of a concentration of Pi inhibitor approximately equal to the uninhibited  $K_m$  substrate concentration, the apparent  $K_m$  became 6-7 times as large (from 0.038 mM to 0.253 mM) as the uninhibited  $K_m$ . Therefore, pNPP substrate molecules had to be almost 7 times as numerous as inhibitor molecules to access alkaline phosphatase's active site and produce product equivalent to an initial uninhibited reaction velocity of  $1/2 V_{max}$ . These data indicate that Pi is quite an effective competitive inhibitor. One reason for its effectiveness as an inhibitor could be that the molecular weight (MW) of inorganic phosphate is about 96 g/mol, while the MW of pNPP, with its bulky nitrophenyl group, is almost 217 g/mol. Temperature is a measure of average molecular kinetic energy and is proportional to  $mv^2$ . This means that lighter molecules have to move faster than heavy ones at 37°C in order to have the same kinetic energy as the large molecules. Molecules that move faster have more collisions, so it is likely that each Pi molecule had a greater chance of colliding with the alkaline phosphatase (AP) active site than did each pNPP substrate molecule during our experiment. **(constructing new knowledge: references would help a lot here to show that the differences in molecular weight mentioned could significantly change kinetic energy)** In addition, AP may have had a greater affinity for Pi than it did for the pNPP substrate, since alkaline phosphatases have a high affinity for inorganic phosphate (McComb *et al.*, 1979). The bulky phenyl group on pNPP may have sterically hindered the hydrolysis reaction more than the hydrogen on Pi, depending on the specific geometry of the active site. As we mentioned previously, AP generally hydrolyzes Pi at a slower rate than it hydrolyzes phosphomonoesters (Schwartz, 1963), and so it may be that Pi occupies the AP active site longer per hydrolysis and thus excludes available pNPP from subsequently binding. **(constructing new knowledge: referring back to biological rationale and comparing findings with the literature)**

At first glance, it might appear that some of the increase in apparent  $K_m$  could be attributed to a slight change in pH, since the  $K_m$  value is pH dependent. Dibasic Pi can act as a base by adding a

proton and becoming  $\text{HPO}_4^-$  and as an acid by losing a proton and forming  $\text{PO}_4^{3-}$ , but phosphate is predominantly the dianion at a pH of 8.6. Since the pH of the 0.05 mM  $\text{Na}_2\text{HPO}_4$  salt solution was 7.7, which is close to the targeted value of 8.6, it is reasonable to assume that the buffer counteracted any fluctuations in pH and essentially kept the pH constant. **(evaluating experimental design)**

Although the  $V_{\text{max}}$  did not change dramatically between uninhibited and inhibited reactions, there was some difference between the uninhibited value of 0.056  $\mu\text{mol}/\text{min}$  and the inhibited value of 0.070  $\mu\text{mol}/\text{min}$ . Since  $V_{\text{max}}$  did not decrease, it was clear that  $\text{P}_i$  did not act as a noncompetitive inhibitor. Since  $V_{\text{max}}$  increases in the presence of an activator, it is possible that slight changes in ionic strength resulting from the addition of the salt could have activated AP somewhat. However, previous studies at a pH of 10 have shown that the activities of mammalian alkaline phosphatases are either unaffected or diminished by an increase in ionic strength. Specifically, calf intestinal AP experienced no change in activity following the addition of 1M NaCl, a much higher concentration than the  $\text{Na}^+$  that we introduced in our experiment. In other systems, NaCl addition at a pH of 9.0, close to the 8.6 we used in our experiment, had little effect on maximum velocity and actually inhibited it at low substrate concentrations (McComb *et al.*, 1979). Since other variables in the experiment were held constant, the differences in  $V_{\text{max}}$  values could simply be due to experimental error. **(evaluating data reliability & experimental design)**

The  $K_i$  value of 8.78  $\mu\text{M}$  obtained from this study was comparable to but slightly greater than literature values for the  $K_i$  of *E. coli* AP. The values of 1  $\mu\text{M}$  (O'Brien and Herschlag, 2001) and 0.6  $\mu\text{M}$  (McComb *et al.*, 1979) for  $\text{P}_i$  inhibition of *E. coli* AP were both obtained at a pH of 8.0 and temperature of 25°C, while we used a pH of 8.6, a temperature of 37°C, and bovine intestinal AP in our study. Just like  $K_m$  values,  $K_i$  values are pH dependent. It is generally recognized that competitive inhibitors of AP are more effective at lower pHs (McComb *et al.*, 1979). The pH difference alone could probably explain why our  $K_i$  was slightly larger and our inhibitor was slightly less effective than in the *E. coli* studies. In addition, bovine intestinal AP has a structure that is somewhat different from *E. coli* AP, so it is reasonable that the kinetics of the two enzymes could differ slightly. Some studies in rats have shown that only 1/10 as much  $\text{P}_i$  is needed to inhibit intestinal AP as compared to the amount that is needed to inhibit AP in other rat tissues (McComb *et al.*, 1979). **(evaluating data reliability & experimental design)** Perhaps there are lower  $\text{P}_i$  concentrations in intestinal cells as compared to cells in other tissues. It would be interesting to see if this is true for bovine and other mammalian AP as well. **(New questions/Future Studies)**

The inhibition of AP by  $\text{P}_i$ , the product of AP catalyzed hydrolysis reactions, is a substrate-level regulation mechanism (Becker, Kleinsmith, and Hardin, 2003). This allows the AP enzyme to be responsive to product concentrations, so it is not always functioning at its maximum rate. It is not in the best interest of the cell to convert all phosphomonoesters into  $\text{P}_i$  and an alcohol at once, and the competitive inhibition by  $\text{P}_i$  helps to prevent this. This is precisely why initial reaction velocities are used when studying enzyme kinetics; if products are allowed to accumulate, they are likely to have an inhibitory effect on the enzyme. **(implications of results, referring back to biological rationale)**

Overall, the results of this study indicate that  $\text{P}_i$  is indeed a competitive inhibitor of bovine intestinal AP, as we had hypothesized. Specifically, we found that the  $K_m$  value increased from 0.038 mM to 0.253 mM while  $V_{\text{max}}$  remained relatively constant. We also found that our  $K_i$  value of 8.78  $\mu\text{M}$  was

reasonably similar to that reported previously for this particular enzyme and inhibitor. **(final conclusion)**

## Parenthetical Citations Within Text

- Cite all information that you use from published or unpublished sources in the body of your paper and provide full citations in the Literature Cited section at end of the paper.
- **Parenthetical author-date format** within a sentence or at the end of a block of text. Provide the last name of the author(s) and the date the work was published, both enclosed by parentheses. Example: Global warming is a looming threat to biodiversity (Peters and Lovejoy 1992).
- **More than one source**, list them in chronological order: e.g. (Jones 1992; Smith and Jacobs 1993; Torrez 1995). If a work has **more than two** authors, you may list the first followed by *et al.* (Latin for “and others”) and the date: (Jones *et al.* 1995). However, the names of all of the authors must be included in the list of citations at the end of the paper.
- **Unpublished information:** If you cannot find a published citation you can site personal communication in the body of your text – NOT in the literature cited. The format for **unpublished information** or data communication to you by a colleague is the source followed by “personal communication” or “unpublished data”: e.g. (Maria Rodriguez, personal communication 2002; Biocore 382 class, unpublished data). \*\*\*Use these sparingly as sources usually are not formal and cannot be verified easily. DO NOT base the major foundation of your study on personal communication unless the information gained is unique and not found elsewhere.

## Literature Cited

List all works cited in the text – and no others – alphabetically in the References section at the end of your paper. The specific format used for references *varies* depending on each journal’s conventions, web-site format and the type of source to which you are referring. We would like you to use the format demonstrated below which follows the **Name-Year system**. Each reference should include the names of all the authors, the date the article or book was published and/or the date the website was accessed and its title. Regardless of the exact format used, make sure that you are consistent!

### HERE ARE SOME EXAMPLES TO FOLLOW:

#### *Journal*

Format as follows:

Author(s). year of publication. Title of the article (with only the first word capitalized). title of journal plus volume (issue): Inclusive page numbers.

**One author example**

Vitousek, P.M. 1994. Beyond global warming: ecology and global change. *Ecology* 75: 1861-1876.

**Multiple author example**

Post, W.M., Emanuel, W.R., Zinke, P.J., and Stangenberger, A.G. 1982. Soil carbon pools and world life zones. *Nature* 298: 156-159.

**Internet Sources**

A full discussion of number and types of internet resources is beyond the scope of this manual.

However, the following is a general guide for most articles that are published on the internet. As with all resources, especially those found on the internet, you must be wary of the source and its validity. If it doesn't have an author or publication/ posting date BEWARE!

Format as follows:

Author(s). Year of publication. Title of the work. Title of the complete work or website or on-line journal plus volume (issue) if available/ applicable. Website URL or address (except for online journal or personal email). Date you accessed the web page.

**Email:**

Carbon, J.J. Physiology data. Personal email (7 July 2010).

**Listserv or RSS feed newlist:**

Blystone, R.V. 1994. Setting up a digital classroom and other stuff. [biolab@hubcap.clemson.edu](mailto:biolab@hubcap.clemson.edu) (accessed May 10, 1996).

**World Wide Web:** Basic form is: Author. Date. Title. URL (Access date)

Waterman, M., Stanley, E., Soderberg, P., and Jungck, J.R. 1999 Kingdoms entangled: molecules, malaria, and maize. *BioQUEST Curriculum Consortium*. <http://bioquest.org/case.html> (accessed April 12, 2012)

Macreal, H. 2001. Large Fish, Small Pond. <http://www.bigfish.org/articles> (accessed April 20, 2001)

Splice, G. 2000. Mutations are the Ultimate form of Variation. *University Press Weekly* vol 22. Electric Library. <http://www.elibrary.com/> (accessed October 17, 2011).

**\*Note:** Do not write out a website address (URL) as a parenthetical citation within the text of your paper—instead include the author and year of publication (e.g. Macreal 2001), just as you do with all other publications. Whenever possible, list the author. If you can't find an author, list the organization that provided the information. If you can't find the name of the organization, question the quality of your source.

**Biocore Lab Manual**

You will be citing one of your Biocore lab manuals in many of your research papers. To do this, look at the lab manual chapter to find the author(s) you wish to cite and the example format below. NOTE: This is an example for the Biocore Prairie chapter of the Biocore 382 lab manual.

*Example:* Batzli J. and McGee S. 2017. Biocore Prairie Restoration Project. *In* Batzli, J. M., editor. *Biocore 382 Evolution, Ecology, and Genetics Laboratory Manual*, Fall 2017 University of Wisconsin-Madison.

### **Book Citations**

#### Format as follows:

First author's last name, First initials, subsequent authors' name separated by commas, year of publication, title of book (italicized, with only the first word capitalized), edition number (if it is not the first edition), the publisher, the city of publication, and the state (omit the state for well known cities like New York).

#### **Whole Book**

Kuhn, T.S. 1962. The structure of scientific revolutions. University of Chicago Press, Chicago.

Purves, W.K., Sadava, D., Orians, G.H., and Heller, H.C. 2001. Life, the science of biology, 6th ed. Sinauer, Sunderland, MA.

#### **Chapter in a Book**

Naes, A. 1986. Intrinsic value: will the defenders of nature please rise? *In* Soulé, M.E., editor. Conservation biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, MA. pp. 504-515.

# Structure of a Biocore Research Proposal

In Biocore lab you will write research proposal papers *before* you collect data for your research projects. A research proposal is a very important first step that helps you get familiar with your system and serves as a guide for your entire project. The proposal has many similar attributes as a lab paper (discussed in the previous section) and shares nearly all the same components; **Introduction, Materials and Methods, and Expected & Alternative Results**. We call the final section “**Implications**” rather than a “Discussion” to emphasize the potential impact of the predicted expected and alternative results.

Below we point out how proposals differ from final lab papers and provide guidelines for what should be included in this type of paper. When writing about what you propose to do, **use the future tense**. **No abstract is necessary** for research proposals.

**Make sure to review the Research Proposal Rubric as you are writing!!**

## Title

See Final Lab Report Title section description and examples. How does a proposal title compare to a title for a final paper? **Compare rubrics**.

## Introduction

Include a summary of background information, experimental question, biological rationale, hypothesis, and experimental approach. As you become more familiar with your system during your study, you will likely need to revise this section for your final paper to reflect the greater depth of your knowledge or unanticipated variables that become clear as the study progresses.

## Methods

The methods section is usually quite detailed and may include diagrams or flow charts explaining your experimental design and protocols. Include a description of any pilot studies you plan to do.

## Expected and Alternative Results

Since you have not done the experiment yet, you will not have any data. However, your hypothesis is a clear statement of what you expect and should provide the basis for this section. Provide a graph of the data you expect if your hypothesis is supported, showing actual numbers on labeled axes. This data is ‘dummy data’ – you make it up to represent expected trends and variation based on your current knowledge of the system. It could be based on your own pilot studies and/or published data from similar studies. Text accompanying this section



should point out expected trends and describe pertinent attributes of trend lines. You should also present **biologically plausible *alternative results*** to those you expect, e.g., opposite results or the “no difference” result. (Do not present alternative results that represent flawed mechanical assumptions.) Thinking about alternative results at the proposal stage may help you troubleshoot problems, evaluate the efficacy of your control, or provide a background for your final results since, quite often, these are the ones you actually see at the end of your experiment.

## Implications & Conclusions

In this section, describe the implications of the predicted trend described in your expected results as it relates to the knowledge gap and the broader rationale presented in your Introduction. Remind the reader of the biological and methodological assumptions you are making, and limitations of your experiment. Discuss your alternative results and explain how they might yield from incomplete or alternative rationale or unanticipated variables. Describe limiting factors (e.g. replication, controls etc.), and evaluate your confidence in the experimental design and/or your capacity to make broad conclusions. Finish off with a strong conclusion, with a description of ramifications if your hypothesis is supported. **Special note on avoiding social justifications:** You should **not** over emphasize the relevance of your experiment and the possible connections to large-scale processes. **Be realistic and logical**—do not over generalize or state grand implications that are not sensible given the structure of your experimental system. Not all science is easily applied to improving the human condition (cure cancer or solve climate change). Performing an investigation just for the sake of adding to our scientific knowledge (“basic science”) is important too. In fact, basic science often provides the foundation for applied studies.

### Example of Good Implications

Adapted from a paper by Claire Evensen- Biocore 382 Fall 2017

**Inoculation of *Solidago canadensis* with rust fungus expected to result in higher infection severity on younger, upper leaves as compared to older, lower leaves**

**Knowledge Gap:** Although it is known that rust fungus infects *S. canadensis* leaf tissue (Novander and Smith 1995), it is not known if infection severity is influenced by leaf age, nor is it known if the age gradient across a single plant from older leaves on the lower stem to younger leaves on the upper stem is significant enough to result in differences in infection severity.

**Implications:**

If we see differences in infection severity between older and younger leaves treated with a fungal spray, the study will support the idea that stomatal opening arising from differences in leaf age is an important factor in rust fungus infection. Though it was previously known that infections occur via the stomata, it was unclear whether the variation in stomatal opening associated with leaf age was distinct enough to either hinder or advance the fungal infection process. Although we are not measuring the degree of stomatal opening or closure, if we support our hypothesis that younger

leaves are more susceptible to infection than older leaves, our data would suggest that the age of leaf including lack of open stomata more prevalent in older leaves dramatically lowers the probability of the fungal germ tube finding an insertion site—to the point that a large proportion of spores that adhere to the leaves are unsuccessful in entering the host tissue (Bradley et al. 2007). An alternative explanation for higher infection rate on younger leaves is simply associated with stem height, with fungal spores more easily spread by wind to leaves that are higher on the plant stem as opposed to older leaves that are less exposed and lower on the stem (Novander and Smith 1995). Regardless of the mechanism, our work will provide valuable insight into how the relationship between the rust fungus and *S. canadensis* changes with leaf age. **(Referring back to biorationale and comparing expected results with knowledge gap).**

If our study yields alternative results and we reject our hypothesis, we could conclude that either our assumptions regarding stomata opening and age are flawed or there are unanticipated confounding factors influencing our study. We assume that older leaves would have fewer stomata openings and would, therefore, provide fewer opportunities for fungal infections in the older leaf tissue. However, if the rust fungus germ tube is highly efficient in terms of leaf coverage, or if a robust infection only requires a baseline threshold of a “few” stomata, and if there are enough stomata available to be sufficient for infection even when a leaf has almost completely senesced, we will likely not see statistically significant differences in infection between younger and older leaves. An important additional variable includes the presence of prior infections. In other words, we may spray plants that were already infected with spores that had yet to germinate. Should this occur, statistically significant differences in infection rate? may be masked by a previous rust infection. **(Explaining how assumptions, unanticipated variables, and limiting factors, here and below, could yield alternative results)**

Our study is limited by our inability to control the presence of naturally occurring wind-borne rust spores. We assume that a single wind-borne spore has a low probability of adhering to a *S. canadensis* leaf, however it is possible for natural infection to contaminate and obscure potential differences due to our inoculation treatments. This experiment will be done in a field setting in the Biocore Prairie. As such, we have located a patch of *S. canadensis* with no apparent infection that is isolated from infected patches of other *S. canadensis* plants. We will be creating a spray inoculant at saturating concentration and at a much higher concentration than naturally occurring spores could achieve. Both the treated and control plants will be isolated by dense vegetation and therefore, will be much more likely targets of infection by our treatments than by natural infection. If there is any contamination by naturally occurring wind-borne spores, we will detect it on our control group's extent of infection following the experiment. The extent of infection by non-inoculated control plants will serve as a baseline for comparison to the two treatment groups. **(Reminding the reader of the biological and methodological assumptions you are making, and limitations of your experiment.)**

Finally, we assume that the Tween-20 solution will be a suitable temporary environment for spores. Rust fungus is highly dependent on its relationship with its host plant (Petersen 1974), so it may be weakened or die when it is removed from the host. Should this occur, we will expect to see low levels of infection across all three groups, as manual infection attempts would fail. Nevertheless, we are confident in our design given the timing of our study in mid-Sept when the life cycles of both the host and the fungus align; the ideal germination temperature for the fungus of 37°C will be

achieved; and that previous studies have found success with the 0.01% Tween-20 solution (Stavelly 1983). **(Evaluation of confidence in method)**

In conclusion, we believe our rationale regarding stomatal infection mechanism, and the relationship of stomatal opening and leaf age is sound. Although there is literature describing the mechanism of rust fungal infection through stomatal opening, to our understanding, it is not established that infection by the *S. canadensis* leaf rust fungus is associated with leaf age. If our hypothesis regarding leaf age of *S. canadensis* and rust infection severity is supported, we can better predict incidence and timing of rust infection on *S. canadensis* and can furthermore, support questions about control and spread of *S. canadensis* and this fungal leaf pathogen. **(Ramifications if hypothesis is supported)**

# Formatting Your Lab Paper

Please use the following conventions for your reports:

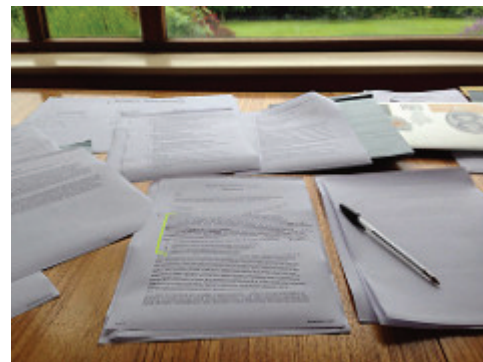
- **Double space** your text. This allows your TA or peer reviewer to write comments between the lines without struggling to squeeze words into the margins.
- Use **11-12 point font**.
- Keep a **1-inch margin** around all of your text. Margins make your papers easier to read and provide room for comments.
- **Use headings and subheadings**. Headings and subheadings help you to organize your paper and provide clear signposts for your readers to follow. Examples of headings are the major sections we described above (Introduction, Methods, etc.). Long sections and those that include distinct parts should have subheadings. For example, the Methods section of an ecology paper might have the following subheadings: Organism, Study Sites, Data Analyses. Use a 2-point larger bold font for headings and a bold font for subheadings.
- **Don't prepare a title page** – save a tree. Simply center the title at the top the first page of your report. Likewise, don't bother with a special folder for the report – a single staple in the corner is sufficient.
- **Target Audience**– Write for readers who are fellow Biocore students but are not in lab.
- **Spell check and proofread every paper before turning it in!**



*Daria Nepriakhina by Epicantus is licensed under CC-BY 2.0.*

# Receiving Feedback

Writing is a process and even very experienced writers spend a lot of time rewriting. Your TAs AND your peers will give you feedback and suggestions on your papers to help you in this process. Note, however, that it is not their responsibility to point out every flaw or to revise your papers for you. Revising is your responsibility. It pays to keep working at this. The feedback we get from Biocore students years later is that one of the most valuable things they learned in Biocore was clear thinking and writing. The two are very connected.



*"Resorting to Paper" by Catherine Cronin  
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## The Big Picture

TA comments (and your grade) will focus much more on "The Big Picture" than on editing details. Here is what we mean by big picture. In evaluating your papers, the TAs ask:

- Did the Introduction convey why the experiment was performed and what it was designed to test?
- Did the Methods clearly describe how the hypothesis was tested/ general predictions were addressed?
- Did the Results clearly and effectively display relevant data?
- Did the Discussion present conclusions that make sense based on the data?

As TAs and instructional staff are reviewing papers we constantly refer to these same four points when making final decisions about individual grades.

## Paper and Proposal Rubrics

All Biocore TAs use a detailed rubric to assess each section of your paper on a 1-4 scale. We use this rubric to clearly state our expectations for your writing. The paper and proposal rubrics are found on the following pages; you should refer to them before, during and after writing your paper and whenever your graded papers are returned. You are also expected to use these rubrics as you peer review your classmates' papers and posters. Note that the four "Big Picture" questions are embedded within the rubric and the final row of the rubric focuses on overall organization, grammar and wording. The goal is for you to use your TA's written comments in tandem with your rubric ratings to *improve your writing* on subsequent revisions or new assignments.

Review the expectations outlined in the Paper and Proposal Rubrics **before** you start writing your paper!

**See Rubrics on the following pages!**

# Biocore FINAL PAPER Review Rubric

## Title

**4 = excellent** Title is concise, conveys main point of experiment, and includes these key components: study system, variables, result, & direction. [With systematic observations, results may be too preliminary to define direction so title should be more general.]

*Show additional rubric tiers*

**3 = very good** Title is concise & conveys main point of experiment but 1 key component is missing

**2 = good** Title could be more concise but still conveys main point of experiment; 2 or more key components are missing

**1 = adequate** Has two or more problems comparable to the following: Title is not concise, point of experiment is difficult to determine by title, most key information is missing

**0 = inadequate** Point of experiment cannot be determined by title

## Abstract

**4 = excellent** Concisely & clearly covers all key components in 200 words or less: biological rationale, hypothesis, approach, result direction & conclusions

*Show additional rubric tiers*

**3 = very good** Concisely & clearly covers all but one key component **OR** clearly covers all key components but could be more concise and/or clear.

**2 = good** Covers all but 2 key components and/or could be done more clearly and/or concisely.

**1 = adequate** Many key components are missing; those stated are unclear and/or are not stated concisely.

**0 = inadequate** Abstract is missing or, if present, provides no relevant information.

## Introduction

**BIG PICTURE:** Did Intro convey why experiment was performed and what it was designed to test?

**4 = excellent** Clearly, concisely, & logically presents all key components: relevant & correctly cited background information, question, biological rationale (including biological assumptions about how the system works and knowledge gap), hypothesis, approach. (There may be a few minor issues with organization/clarity.)

*Show additional rubric tiers*

<b>3 = very good</b>	Concisely & clearly covers all but one key component (w/ exception of rationale) <b>OR</b> clearly covers all key components but could be more concise and/or clear. e.g., has done a reasonably nice job with the Intro but fails to state the approach <b>OR</b> has done a nice job with Intro but has also included some irrelevant background information
<b>2 = good</b>	Covers all but 2 key components <b>OR</b> clearly covers all but 1 key component but could be done much more logically, clearly, and/or concisely. e.g., biological rationale not fully developed but still supports hypothesis. Remaining components are done reasonably well, though there is still room for improvement. Includes information that is extraneous and detracting from the main ideas.
<b>1 = adequate</b>	Covers all but 3 key components & could be more concise and/or clear. <b>OR</b> clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely. e.g., background information is not focused on a specific question and minimal biological rationale is presented such that hypothesis isn't entirely logical
<b>0 = inadequate</b>	4-5 key components are very weak or missing; those stated are unclear and/or not stated concisely. Weak/missing components make it difficult to follow the rest of the paper. Often results in hypothesis that "comes out of nowhere."

## Methods & Materials

**BIG PICTURE:** Did Methods clearly describe how hypothesis was tested?

<b>4 = excellent</b>	Concisely, clearly, & chronologically describes procedure used so that knowledgeable reader could replicate experiment and understand the results. Methods used are appropriate for study. Clearly defines controls and how they will inform the experiment. Briefly describes mathematical manipulations or statistical analyses.
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*Show additional rubric tiers*

<b>3 = very good</b>	Concisely, clearly, & chronologically describes procedure used so that reader could replicate most of experiment with the exception of a few relatively minor details. Methods used are appropriate for study. Minor problems with organization <b>OR</b> some irrelevant/ superfluous information.
<b>2 = good</b>	Procedure is presented such that a reader could replicate experiment only after learning a few more key details <b>OR</b> methods used are reasonably appropriate for study, though a more straight-forward approach may have been taken.
<b>1 = adequate</b>	Procedure is presented such that a reader could replicate experiment but methods are largely inappropriate to test hypothesis <b>OR</b> Procedure is presented such that a reader could replicate experiment only after learning several more key details.
<b>0 = inadequate</b>	So little information is presented that reader could not possibly replicate experiment <b>OR</b> methods are entirely inappropriate to test hypothesis

## Results

**BIG PICTURE:** Did the Results clearly & effectively display relevant data?

**4 = excellent** With a few minor exceptions, contains a concise, well-organized narrative text & tables/figures that highlight key trends/ patterns/output from statistical tests without biological interpretation. Tables & figures have appropriate legends/ labels & can stand on their own.  
If you have problems collecting valid data, state what the problem was that makes your data invalid.

*Show additional rubric tiers*

**3 = very good** Has presented both a concise, narrative text & informative tables/figures without biological interpretation, but has made 1-2 minor omissions or has other relatively small problems. e.g., relevant data & trends are summarized well and without biological interpretation, but tables & figures have very brief legends that leave out some key details.

**2 = good** Has presented findings with a reasonably good narrative text & informative tables/figures, but has 2-3 problems comparable to the following: most relevant data are present but are mixed in with some unnecessary information, trends are shown in figures but are not explicitly noted, tables & figures have very brief legends that leave out key details, variation around mean values is not indicated in figures, conclusions about hypothesis are briefly made.

**1 = adequate** Has 3-5 problems comparable to the following: narrative text and & tables/figures are minimal and mostly uninformative, some relevant data are present but are mixed in with much unnecessary information, trends are not immediately apparent in figures and are not explicitly noted in text, tables & figures lack legends, variation around mean values is not indicated in either text or figures, conclusions about hypothesis are emphasized.

**0 = inadequate** Major problems that leave reader uninformed; narrative text is lacking entirely, tables & figures contain unclear and/or irrelevant information. e.g., "Results" contain no text, raw data are in a table w/ poor legend.

## Discussion

**BIG PICTURE:** Did the Discussion present conclusions that made sense based on the data?

**4 = excellent** With a few minor exceptions, clearly, concisely, & logically presents all key components: supports or rejects hypothesis\*, interprets/integrates data; formulates argument for conclusions referring back to biological rationale & by comparing with relevant findings in literature, introduces new literature to discuss or support findings, evaluates experimental design, evaluates reliability of data, states knowledge generated & implications of results, suggests next investigation steps, includes unique observations, and ends paper with final conclusion.  
\*If you believe error occurred, describe what you believe happened and discuss how this impacts your ability to make conclusions about hypothesis.

*Show additional rubric tiers*



<b>3 = very good</b>	Concisely & clearly covers all but one key component <b>OR</b> clearly covers all key components but could be more concise and/or clear. e.g., has done a reasonably nice job with the Discussion but fails to clearly tie biological rationale from the Intro into the conclusions made <b>OR</b> has done a nice job with the Discussion but has also included an extensive laundry list of experimental problems without discussing their impact on the conclusions. e.g., lacks a discussion of assumptions.
<b>2 = good</b>	Covers all but 2 key components <b>OR</b> clearly covers all but 1 key component but could be done much more logically, clearly, and/or concisely e.g., clearly states that hypothesis is rejected or supported and develops a good argument that refers to biological rationale, but fails to logically and objectively evaluate assumptions and the experimental design and data reliability. Remaining components are done reasonably well, though there is still room for improvement
<b>1 = adequate</b>	Covers all but 3 key components & could be more concise and/or clear. <b>OR</b> clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely. e.g., fails to explicitly reject or support hypothesis and so conclusions are vague and incompletely tied to rationale, literature is minimally cited, presents unranked laundry list of problems instead of logical evaluation of design and data, suggests flashy new experiments that would not clearly shed light on current question
<b>0 = inadequate</b>	4 or more key components are missing or very weakly done. e.g., illogical conclusions made based on data, no ties to biological rationale are made, no literature cited, little to no evaluation of experimental design/data.

## Literature Cited

<b>4 = excellent</b>	References within body of paper are cited appropriately; references in final citation list are formatted appropriately and listed alphabetically by author using WM guidelines.
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*Show additional rubric tiers*

<b>3 = very good</b>	References within body of paper are cited appropriately; references in final citation list are formatted appropriately and listed alphabetically by author using WM guidelines, but there are 1-2 exceptions. e.g., citations are done well except that one or two references listed in text do not appear in the final list <b>OR</b> there are a few minor formatting errors in the final citation list.
<b>2 = good</b>	References within body of paper & references in final citation list are done appropriately for the most part, but there are consistent exceptions. e.g., citations are used sparingly throughout the paper when background information is presented <b>OR</b> there are consistent formatting errors in text and final citation list.
<b>1 = adequate</b>	Very few references are cited in text of paper; final citation list is largely incomplete and/or is not formatted appropriately.
<b>0 = inadequate</b>	Background information is presented but is consistently not cited; final citation list is missing

## Overall grammar, organization, wording

<b>4 = excellent</b>	Excellent organization and paper flow, appropriate word choice, few to no grammatical errors
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*Show additional rubric tiers*

<b>3 = very good</b>	Organization was good with few to no problems, wording awkward in a few places, few grammatical errors
<b>2 = good</b>	Organization somewhat problematic but can still follow thought progression e.g. explanation of methods in the results section; wording awkward at times, some grammatical errors
<b>1 = adequate</b>	Problematic organization of some section resulting in loss of clarity; awkward wording at times; some grammatical errors
<b>0 = inadequate</b>	All poorly organized, interrupted flow to ideas leading to lack of clarity, cannot follow thought progression, many grammatical errors

[Download Biocore rubrics in PDF format](#)

# Biocore Research Proposal Rubric

## Title

**4 = excellent** Title is concise, conveys main point of experiment, and includes these key components: study system, variables, expected result, & direction

*Show additional rubric tiers*

**3 = very good** Title is concise & conveys main point of experiment but 1 key component is missing

**2 = good** Title could be more concise but still conveys main point of experiment; 2 or more key components are missing

**1 = adequate** Has two or more problems comparable to the following: Title is not concise, point of experiment is difficult to determine by title, most key information is missing

**0 = inadequate** Point of experiment cannot be determined by title

## Introduction

**BIG PICTURE:** Did Intro convey why the experiment will be performed and what it is designed to test?

**4 = excellent** Clearly, concisely, & logically presents all key components: relevant & correctly cited background information, question, biological rationale (including biological assumptions about how the system works and knowledge gap research addresses), hypothesis, approach. (There may be a few minor issues with organization/clarity.)

*Show additional rubric tiers*

**3 = very good** Concisely & clearly covers all but one key component (w/ exception of rationale) **OR** clearly covers all key components but could be more concise and/or clear.

e.g., has done a reasonably nice job with the Intro but fails to state the approach **OR** has done a nice job with Intro but has also included some irrelevant background information

**2 = good** Covers all but 2 key components **OR** clearly covers all but 1 key component but could be done much more logically, clearly, and/or concisely.  
e.g., biological rationale not fully developed but still supports hypothesis. Remaining components are done reasonably well, though there is still room for improvement.  
Includes information that is extraneous and detracting from the main ideas.

**1 = adequate** Covers all but 3 key components & could be more concise and/or clear. **OR** clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely.  
e.g., background information is not focused on a specific question and minimal biological rationale is presented such that hypothesis isn't entirely logical

**0 = inadequate** 4-5 key components are very weak or missing; those stated are unclear and/or not stated concisely. Weak/missing components make it difficult to follow the rest of the paper. Often results in hypothesis that "comes out of nowhere."

## Methods & Materials

**BIG PICTURE:** Did Methods clearly describe how hypothesis will be tested?

**4 = excellent** Concisely, clearly, & chronologically describes procedure to be used such that knowledgeable reader could replicate experiment and understand expected results. Methods used are appropriate for study. Clearly defines controls and how they will inform the experiment. Briefly describes mathematical manipulations or statistical analyses to be used.

*Show additional rubric tiers*

**3 = very good** Concisely, clearly, & chronologically describes procedure to be used such that reader could replicate *most* of experiment with the exception of a few relatively minor details. Methods used are appropriate for study. Minor problems with organization **OR** some irrelevant/ superfluous information.

**2 = good** Procedure is presented such that a reader could replicate experiment only after learning a few more key details. **OR** methods used are reasonably appropriate for study, though a more straight-forward approach may have been taken.

**1 = adequate** Procedure is presented such that a reader could replicate experiment **but** methods are largely inappropriate to test hypothesis. **OR** Procedure is presented such that a reader could replicate experiment only after learning several more key details.

**0 = inadequate** So little information is presented that reader could not possibly replicate experiment **OR** methods are entirely inappropriate to test hypothesis.

## Expected & Alternative Results

**BIG PICTURE:** Did the Results clearly & effectively display expected data that are relevant?

**4 = excellent** With a few minor exceptions, contains a concise, well-organized narrative text & tables/figures that highlight anticipated key trends/ patterns/output from statistical tests without biological interpretation. Figures should present data that would support hypothesis as well as present alternative results. Tables & figures have appropriate legends/ labels & can stand on their own.

*Show additional rubric tiers*

**3 = very good** Has presented both a concise, narrative text & informative tables/figures without biological interpretation, but has made 1-2 minor omissions or has other relatively small problems. e.g., tables & figures have very brief legends that leave out some key details.

**2 = good** Has presented expected findings with a reasonably good narrative text & informative tables/figures, but has 2-3 problems comparable to the following: most relevant expected data are present but are mixed in with some unnecessary information, trends are shown in figures but are not explicitly noted, tables & figures have very brief legends that leave out key details, variation around mean values is not indicated in figures, conclusions about proposed hypothesis are briefly made; alternative results are scarcely mentioned.

**1 = adequate** Has 3-5 problems comparable to the following: narrative text and & tables/figures are minimal and mostly uninformative, some relevant expected data are present but are mixed in with much unnecessary information, trends are not immediately apparent in figures and are not explicitly noted in text, tables & figures lack legends, variation around mean values is not indicated in either text or figures, conclusions about proposed hypothesis are emphasized; alternative results are not mentioned.

**0 = inadequate** Major problems that leave reader uninformed; narrative text is lacking entirely, tables & figures contain unclear and/or irrelevant information. e.g., figures are not accompanied by text, expected raw data are in a table w/ poor legend; expected results do not support proposed hypothesis.

# Implications

**BIG PICTURE:** Did the Implications present explanations of expected & alternative results that made sense based on the 'dummy' data presented?

**4 = excellent** With a few minor exceptions, clearly, concisely, & logically presents all key components: describes relevance of predicted trend as it relates to knowledge gap and rationale, explains assumptions made, evaluates confidence in experimental design, discusses alternative results in light of incomplete biological rationale or flawed biological assumptions, and discusses ramifications of experiment.

*Show additional rubric tiers*

**3 = very good** Concisely, clearly, & logically covers all but one key components **OR** clearly covers all key components but could be more concise and/or clear.  
e.g., has done a reasonably nice job with the Implications but fails to clearly tie biological rationale from the Intro with the predicted trend **OR** has done a nice job with the Implications but has also included an extensive laundry list of potential flaws in experimental design without discussing their impact on the predicted trend or alternative results.  
Covers all but 2 key components **OR** clearly covers all but 1 key component but could be done much more logically, clearly, and/or concisely.

**2 = good** e.g., clearly describes relevance of predicted trend that refers to biological rationale, but fails to logically and objectively evaluate assumptions & confidence in the experimental design **OR** has done a nice job with all the components but only briefly mentions alternative results without discussing their implications. Remaining components are done reasonably well, though there is still room for improvement.  
Covers all but 3 key components & could be more concise and/or clear **OR** clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely.

**1 = adequate** e.g., relevance of predicted trend is incompletely tied to rationale, literature is minimally cited, presents unranked laundry list of potential problems instead of logical evaluation of design and data, suggests far-reaching/ illogical ramifications of experiment.  
4 or more key components are missing or very weakly done.

**0 = inadequate** e.g., illogical conclusions made based on predicted trend, no ties to biological rationale are made, alternative results are not mentioned, no literature cited, little to no evaluation of confidence in experimental design.

# Literature Cited

**4 = excellent** References within body of paper are cited appropriately; references in final citation list are formatted appropriately and listed alphabetically by author using WM guidelines.

*Show additional rubric tiers*

**3 = very good** References within body of paper are cited appropriately; references in final citation list are formatted appropriately and listed alphabetically by author using WM guidelines, but there are 1-2 exceptions. e.g., citations are done well except that one or two references listed in text do not appear in the final list **OR** there are a few minor formatting errors in the final citation list.

**2 = good** References within body of paper & references in final citation list are done appropriately for the most part, but there are consistent exceptions. e.g., citations are used sparingly throughout the paper when background information is presented **OR** there are consistent formatting errors in text and final citation list.

**1 = adequate** Very few references are cited in text of paper; final citation list is largely incomplete and/or is not formatted appropriately.

**0 = inadequate** Background information is presented but is consistently not cited; final citation list is missing.

## Overall grammar, organization, wording

**4 = excellent** Excellent organization and paper flow, appropriate word choice, few to no grammatical errors, consistently uses future tense.

*Show additional rubric tiers*

**3 = very good** Organization was good with few to no problems, wording awkward in a few places, few grammatical errors; a few switches between present/past/future tense.

**2 = good** Organization somewhat problematic but can still follow thought progression e.g. explanation of methods in the results section; wording awkward at times, some grammatical errors; several switches between present/past/future tense.

**1 = adequate** Problematic organization of some section resulting in loss of clarity; awkward wording at times; some grammatical errors.

**0 = inadequate** All poorly organized, interrupted flow to ideas leading to lack of clarity, cannot follow thought progression, many grammatical errors.

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# Research Proposal and Final Paper Rubric Conversion to Letter Grade

The TAs use the following rubric conversion key along with the four Big Picture Questions to assign final grades to your papers. (For proposal papers, the “Results” section is replaced by the “Expected and Alternative Results”, and the “Discussion” section is replaced by the “Implications” section.) Final papers include abstracts while research proposals do not.

Letter Grade	Minimum Criteria
A	“4” in at least 3 of the main sections (Intro, Methods, Results, Discussion); “4” in overall grammar, organization, wording; no less than “3” in remaining sections
AB	Does not meet minimum criteria for an “A”, but has “3” or better in each of the four main sections (Intro, Methods, Results, Discussion) and in overall grammar, organization, & wording. Has a “2” or better on Title, Abstract, and Literature Cited.
B	Does not meet minimum criteria for an “AB”, but has “3” or better in at least two of the four main sections (Intro, Methods, Results, Discussion) and in overall grammar, organization, & wording. Has a “2” or better on Title, Abstract, and Literature Cited.
BC	Does not meet minimum criteria for a “B”, but has “2” or better in at least two of the four main sections (Intro, Methods, Results, Discussion) and in overall grammar, organization, & wording. Has a “1” or better on Title, Abstract, and Literature Cited.
C	Does not meet minimum criteria for a “BC”, but has “1” or better in all four main sections (Intro, Methods, Results, Discussion) and in overall grammar, organization, & wording. Has no more than one zero in remaining sections.
D	Does not meet minimum criteria for a “C”, but has “1” or better in at least two of the four main sections (Intro, Methods, Results, Discussion) and in overall grammar, organization, & wording. Has no more than two zeros in remaining sections.
F	Does not meet minimum criteria for a “D”.

[Download Biocore rubrics in PDF format](#)

# Group Effort Analysis & Tips for Writing a Group Paper

## Tips for Writing a Group Paper

Most papers that scientists write result from the collaborative efforts of two or more researchers. There is a clear expectation that **all authors** listed on primary literature have made **significant and equitable contributions** to carrying out the research and in writing the paper itself. In other words, all authors listed should be able to independently answer “big picture” questions (e.g., justification for study, conclusions about hypothesis) raised by reviewers about the work presented. We model this collaborative nature of science in Biocore by requiring students to work in teams to carry out lab research projects. We also provide a few opportunities for you to get experience writing a collaborative group paper. Here are our expectations and tips for writing group papers:



*“Group Study Room, Leiden University Library” by Libr~CommonsWiki is licensed under a CC-BY 3.0 unported license.*

- **Group papers take longer** – Organize your team to begin writing as soon as possible.
- **Communicate regularly** -make sure everyone has the information they need and understands the scope of the task.
- **Each team member must make an equivalent contribution** – One person should not shoulder the burden of writing for the team.
- **Agree upon a common outline for the paper** – The entire team should **agree on the conclusions** made based on data collected and on **the logical argument** that will be made to support these conclusions.
- **Shoulder to Shoulder OR Divide and Conquer?** – Some teams can sit shoulder to shoulder and compose a paper together. Others find it efficient to assign **one to two people per section** (Intro, Methods etc..) followed by a **peer review** by each teammate. If you choose the latter, you need to agree as a team on the final structure and content of the paper.
- **Make it flow-** Once sections of paper have been combined and edited, the draft needs to be reviewed and revised so that it flows logically. Before submitting to your TA each person should have a final review for approval.

You will evaluate your group experience using the following Biocore Group Effort Analysis rubric.



## GROUP EFFORT ANALYSIS (GEA) RUBRIC

Criteria	Poor	Good	Excellent
<b>Attendance and punctuality at meetings</b>	Member frequently absent or late, and did not inform or contact team about absence or tardiness	Member present and on time at most meetings/lectures. When absence necessary, often informed team members and worked to resolve issues associated with absence.	Present and punctual at all meetings/lectures and communicated if any extenuating circumstances or irregularity occurred.
<b>Participation in data collection, data analysis</b>	Member did not actively participate in discussion and did not contribute to group progress.	Most of the time made an attempt to understand the assignment and participates in the discussion.	Meaningfully participated in all discussions, anticipated future needs of the group, and took initiative in monitoring group progress.
<b>Preparedness for meetings</b>	Did not prepare prior to class/group meeting.	Most of the time prepared prior to meeting time with ideas/questions to discuss.	Came prepared for all meetings with ideas/questions to discuss.
<b>Ability to listen to ideas/concerns of others</b>	Did not listen to or attempted to ignore ideas or concerns of others. Consistently dominated or withdrew from discussions.	Patiently and actively listened to ideas and concerns of others most of the time	Helped develop an atmosphere in the group where everyone's ideas and concerns are heard by modeling patient and active listening.
<b>Ability to cooperate and/or compromise</b>	Practiced competitive, uncooperative group behaviors that inhibited the group from achieving goals.	Worked cooperatively most of the time and compromised to help group achieve goals.	Welcomed discussion and critique of ideas in a supportive, cooperative positive environment. Worked to overcome negative, competitive group dynamics if necessary. Encouraged group to maintain high standards of group conduct.
<b>Participation in project planning</b>	Member did not actively participate in discussion and did not contribute to planning project.	Made an attempt to understand the assignment and participate in the discussion.	Contributed meaningfully and participated in all discussions to plan the project.

## Peer Review

Another way you will be working in groups or pairs is through peer review, which is an opportunity for you to give and receive peer feedback on your papers before you turn them in to be graded by your TA. Writing is a form of communication and a peer can tell you whether or not your paper makes sense. It is to your advantage to **take seriously your responsibility to review a peer's paper**. We find that the review process benefits the reviewer as well as the author because it gives you practice evaluating a paper applying the same criteria your TA will use to evaluate your paper.

Note that you do not need to wait for us to assign a formal review to take advantage of the peer review process. You can always get together with another student and act as reviewers for each other's papers even when it is not required as part of an assignment!

Peer review is a skill that takes practice. Use the following criteria when you are learning how to peer review. In order to help you become a more skilled peer reviewer, we will ask you to hand in your peer review comments to be evaluated by your TA. Your TA will use these same criteria to evaluate your peer review.

## Peer Review Rubric

Criteria	Adequate	Good	Excellent
<b>Focus on “Global Concerns” (larger structural, logic/ reasoning issues) rather than detailed “Local Concerns” (spelling, grammar, formatting)</b>	<p>Does not identify missing components.</p> <p>Comments are restricted to spelling, grammar, formatting and general editing.</p>	<p>Identifies most components as present or absent.</p> <p>One or two global concerns comments on a paper that required more focus there. Major comments are focused at the local concerns/ editing level.</p>	<p>Can identify all components of paper as present or absent. Provides logical and well reasoned critique. Recognizes logic leaps and missed opportunities to make connections between parts of paper. Provides a good balance of comments addressing 'global concerns' together with minor comments addressing 'local concerns'</p>
<b>Thorough constructive critique including a balance* of positive and negative comments</b>	<p>Review is entirely positive or negative with little support or reasoning provided.</p>	<p>Good comments, but not balanced as positive and negative or not supported with reasoning</p>	<p>Supports author's efforts with sincere, encouraging remarks giving them a foundation on which to build for subsequent papers. Critical comments are tactfully written.</p>
<b>Evidence of thorough reading and review of paper</b>	<p>Comments focused on one or two distinct issues, but not on the overall reasoning and connectedness of all sections in paper. Obvious that reviewer did not read the entire paper or skimmed through to quickly to understand.</p>	<p>Evidence that the reviewer read the entire paper, but did not provide thorough review.</p>	<p>Comments on all parts of paper and connections between paper sections. Comments are clear, specific, and offer suggestions for revision rather than simply labeling a problem. Appropriate comment density demonstrates the reviewer's investment in peer review, while not overwhelming the writer.</p>
<b>Outlines both general and specific areas that need improvement and provides suggestions</b>	<p>Review is too general to guide authors revision or too specific to help author on subsequent papers</p>	<p>Provides both general and specific comments but no suggestions on how to improve.</p>	<p>Supplies author with productive comments, both general and specific, for areas of improvement. General comments are those that authors may use in subsequent papers, whereas specific comments pertain to the specific paper topic and assignment. Comments come with suggestions for improvement.</p>

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# Presentations

We want to give you practice orally communicating your research to others. We have several types of presentations in Biocore labs:

- **Informal Feedback presentations**, where teams present their research plans and receive input from classmates and instructors on experimental design questions, data analysis questions, etc. Informal feedback presentations allow your peers and instructors to critique your proposal so that you can make necessary changes *before* carrying out the experiment.
- **Formal Final presentations**, featuring either posters or PowerPoint slides which summarize completed research.

## Informal Feedback Proposal Presentations

We expect all group members to have **equal involvement** in the study and in preparing and delivering PowerPoint presentations and posters. **Come to class ready to receive feedback**, with paper and pencil in hand.

Informal PowerPoint feedback presentations should be 8-10 minutes long and have 7-8 PowerPoint slides.

They should have the following components:

### QUESTION

What question do you wish to address with your experiment?

### BACKGROUND INFORMATION

This is the pertinent background information that you used to support the rationale and to develop your hypothesis. The references you gathered should be mentioned here including relevant data/conclusions from other studies.

### BIOLOGICAL RATIONALE

How is this experiment related to what we know and how will this experiment add to our knowledge? What are the biological mechanisms you think are likely to be operating? In short, the rationale could be stated as follows: –the purpose of our experiment is ..... because we think .....is occurring. State any biological assumptions you are making. Use a graphic or visual model for your biological rationale slide.

## HYPOTHESIS

Single sentence, specific, **testable**, based on your biological rationale. Recall that you need to identify an independent variable, dependent variable, and a direction in your hypothesis.

## METHODS

Clearly define:

- How you will set-up the experiment. Tables would be handy here and/or graphics such as flow charts.
- What data you will record and why these are appropriate
- your controls
- How many experimental units you will use and which you will replicate, including controls. State why you think these numbers are appropriate.
- The assumptions for how you think your methods will work.
- Your pilot study- if you are planning one. And contingency plans if it doesn't work.
- How you will analyze your data (e.g., means? standard deviations?)

## EXPECTED/ALTERNATIVE RESULTS

- Begin by describing the axis of your figure or components of data table. Be sure to include units on all of your axes!
- Then present the controls- describing the predicted behavior of both the positive and negative controls (if applicable).
- Describe the trends apparent in the graph or **what your data should look like if your hypothesis is supported**. Explain why these results might occur or might be reasonable (refer back to biological rationale and assumptions met).
- Include an additional slide or overlay of **biologically plausible alternative results** (i.e., data that doesn't fit your expectations, such as no significant difference or effect). Explain what biological assumptions that, if not met, would explain these alternative results. (Do not present results that would occur if errors were made in carrying out your protocol.)

## IMPLICATIONS

- Describe how your research will contribute to the existing understanding of the system and inform next steps, questions or decisions.
- As you present your implications refer back to your biological rationale and knowledge gap. If your hypothesis is supported, does this also supported the mechanism proposed in your BR? Keep your implications at the level of your rationale—and balance your introduction and implications like two bookends for your proposal. There is no need for social justification.

## SAFETY

What safety concerns exist if you are adding a chemical or applying a physical treatment (e.g. electrical current, UV radiation)? How should your chemical be safely stored, handled or treatment done safely to limit exposure? How will your treatment chemicals be safely/properly disposed of? If you perceive risk of any kind, you need to thoroughly research the risks, safety procedures and communicate those risks to your peers and instructors (who may also be at risk). A safety slide is not necessary if there is no apparent risk.

## DATA MANAGEMENT PLAN (DMP)

- What kinds of data are you collecting? Numerical (numbers requiring manipulation), images, observational descriptions
- How will you name your data files (lab section, independent variable, initials of researchers, date)? E.g. lab2\_burn\_jbsm\_20170904.xlsx
- How will you protect and share your data among your team? Take a photo of your data if collected without access to computer; enter into a spreadsheet, in a shareable file, and distributed to all group members.

## QUESTIONS YOU STILL HAVE

Use this last slide to pose questions you haven't found answers to yet, but would be good to answer before you begin your experiment. Have a pencil/paper ready to receive feedback!

## Formal Final Presentations

Final PowerPoint presentations are **graded assignments**. We will use the **oral presentation rubric below** to grade your team presentations. They have the same components as informal PPT's except that "Expected Results" are replaced by "Results" and a "Discussion" section, and there is no "Questions You Still Have" section. Final PPT's are necessarily more detailed yet still very concise and are modeled after talks given at scientific meetings. Final presentations should **take 15 minutes to deliver**. Each member of your team should contribute equivalently to the presentation and to the question/answer session following your presentation. **Practice, practice, practice** your talk as a team beforehand!

## HERE ARE SOME FIELD-TESTED TIPS FOR PREPARING POWERPOINT SLIDES.


### KEEP IT SIMPLE

- Think of your PowerPoint slides as 'billboards' conveying the major points of your presentation. Present only one to two major ideas per slide. You can provide clarification or transitions in your verbal

presentation.

- The **least** effective visuals are crowded, complex lists of numbers or words. They strain the eyes and attention of your audience. By the time you get to your point, the audience may no longer care what it is. Bulleted key ideas, simple graphs, charts or tables are much more effective because they quickly communicate your major ideas. You can include important details in your oral narrative. Below at the top is an example of a slide with too much text. The same information is conveyed with the concise, visually appealing slide below.


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## Keep it simple

Only use summary bullets. If you write too much, people will become distracted. This information should be presented verbally to supplement to bullets. Try to avoid lists of numbers and words. Using graphs or charts will help make ideas more effective and easy to understand.

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## Keep it simple

- Only use summary bullets
- Too much = Distraction!
- Avoid lists of numbers and words.
- Use graphs or charts

- If your methods are complicated, show a **concrete illustration** of it in a visual diagram, flow chart, concept map, or table rather than a lengthy list of procedures.

## DESIGN EVERY SLIDE FOR THE BACK-ROW VIEWER

- Fill the slide with the statement/diagram/chart/graph. Use sharp bold lines and print clearly with characters large enough to be read by the people in the back row.
- Choose colors of high contrast (black on white is much easier to read than red on black).
- Use large font sizes to label all parts of graphs, charts and tables (e.g., column headings, units of measure, axes of graphs, etc.) so that the audience clearly understands what they are looking at.
- Design using a consistent background and color scheme throughout presentation (a background of your own creation or pre-made template). This gives your presentation continuity, providing a visual thread or theme for your viewers. Avoid busy-looking backgrounds which distract your audience.

## USE COLOR, SLIDE TRANSITIONS, AND ANIMATION FOR EMPHASIS OF YOUR SCIENCE, NOT ORNAMENT

- Thoughtfully planned use of color can emphasize relationships and organization throughout your presentation.
- Use only simple slide transitions which do not distract the audience from the contents of your slide.
- Use animation only if it helps to emphasize an important point you want to make. Flashing words or endless animation loops are distracting and draw the audience away from your point.
- In summary, **use color, transitions, and animation** that engage your audience rather than distract them!!

## A WELL EXECUTED VISUAL AID IS SIMPLE, INFORMATIVE, AND PLEASANT TO VIEW

Have a friend look over your slides before your presentation. If she/he can grasp the key points without extensive explanation from you, you have probably prepared effective visual aids.

## FIGURE LEGENDS

There is usually no need for figure legends in a PowerPoint presentation. The words are usually too small to read. Instead, use a **large descriptive title for your figures** and a **well-displayed key** for your different treatments.

## INSERTED PICTURES

If you grab a picture from an online article, scanned text figure, etc., you must cite the website and/or publisher appropriately below the picture.

## LAST PRESENTED SLIDE

End your talk with a simple slide that summarizes your conclusions. Prepare a slide that lists your references, but don't show it to your audience as part of your formal presentation. This reference list is important for your instructors in evaluating your presentation, but usually is not interesting to your audience. You may, however, be asked about your information sources immediately after your presentation, and so you could refer to your reference slide on such an "as-needed" basis.



# Preparing Oral Presentations

Here are some questions that your team should be prepared to answer:

- What was the research question? Is the hypothesis testable given the research design?
- Why was this question interesting to the group? Is the biological rationale an appropriate basis for the hypothesis?
- Was the experimental design appropriate to the research question?
- Are the figures and tables appropriate for the type of data? Are they easy to interpret, properly labeled with informative legends (for posters)?
- **Discussion:** Do your results support your hypothesis as stated? Did your methods allow you to test your hypothesis? Are the conclusions logical given the data? How do the results impact what is known about this phenomenon? Are the arguments easily followed? If your data do not support your hypothesis, what biological assumptions were likely inaccurate?
- What new directions would the group like to take with this research?

Check out this informative and entertaining YouTube video “*Talking Science: The elusive art of the science talk*” for excellent tips on delivering effective science presentations:



A YouTube element has been excluded from this version of the text. You can view it online here:  
<https://wisc.pb.unizin.org/biocore/?p=231>

# Delivering Your Presentations and Oral Presentation Rubric

We list specific tips below, but perhaps our most important advice is to **PRACTICE, PRACTICE, and PRACTICE** before you present your research!!!

## INTRODUCTION

Always introduce yourself and your collaborators, or let teammates introduce themselves.

## MAKE THE MOST OF YOUR FIGURES

Verbally present figure axes- both the label and units. Although you strive to make your figures easy to interpret, explaining axes allows the presenter to slow down and define the variables of interest and also clarifies the data manipulations for the audience. **Do not rush** through slides showing your data; allow your audience time to process all of the information shown. Direct their attention to trends/differences that you used to make a decision about your hypothesis or research question.

## SPEAK LOUDLY

...and project toward your audience instead of facing your slides! Many of us do not have booming orator voices. Therefore, we need to sound obnoxiously loud to ourselves at the front of the room in order to be heard in the back. The quickest way to lose your audience is by speaking too softly, looking only at the laptop computer on which your PPT slideshow is loaded, or by addressing your shoes.

## SPEAK IN A NARRATIVE STYLE

If you need notes use them only as queues. Do not read your “speech.” Speak it from memory. You are the expert- you know your work better than anyone else!

## BE SELECTIVE ABOUT WHAT YOU SAY IN A SHORT TALK

Resist the temptation to explain every detail, or every thought you have about your experiment. Focus on your most important points to fill in important details that allow for clarification and transitions between slides.

## GUIDE YOUR AUDIENCE ATTENTION

Put up a PowerPoint slide or point out a particular section of your poster only a moment before you want to

refer to it. Give the audience time to read it or you read it to them. Remove the slide, use a black slide, or stand in front of your poster if you want the audience to focus all their attention on your words.

**\*\*\*Some suggestions are paraphrased from Gordon H. Bower's "Do's and Don'ts of Brief Research Talks" Courtesy of the Writing Across the Curriculum Program, UW-Madison.\*\*\***

Although you will be doing presentations throughout your experience in Biocore labs, in Biocore 382, 384 and 486 you will be asked to do a formal graded oral presentation and will be given feedback on your oral presentation skills. All Biocore instructors will use the following detailed rubric to assess your presentation. **If you would like specific feedback on your presentation skills** (over and above the feedback given on your experimental design and your science) before doing a "formal" **please ask!** This is a skill that develops over time and with practice. We understand that many (most!) people do not immediately enjoy public speaking. However, we hope that you gain confidence as you improve within a supportive classroom environment.

**See the following pages for Oral Presentation Rubric and the Conversion to Letter Grade chart. Please consult this rubric as you and your group practice your presentation.**

# Biocore Oral Presentation Rubric

## Content

4=excellent	With a few minor exceptions, the team clearly, concisely, & thoroughly conveyed their research project such that the audience could grasp & evaluate the work. The presentation contained all of these key components: 1. a clear, logical biological rationale summarizing research goals, key concepts, unfamiliar terminology, & knowledge gaps to be addressed, referencing appropriate literature; 2. concise, complete hypothesis statement; 3. clear explanation of methods, particularly those unfamiliar to audience; 4. comprehensible graph(s) of results (or expected results); 5. clear & logical conclusions based on data (or expected data) & implications; 6. summary of assumptions that were supported or incorrect and any relevant problems/errors. 7. Audience questions after the presentation were answered logically and fully.
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### *Show additional rubric tiers*

3=very good	Team clearly, concisely, & thoroughly conveyed all but 1 key component OR clearly covers all key components but could be more concise and/or clear. e.g., clearly & thoroughly conveyed all key components but could have been more concise.
2=good	Team clearly, concisely, & thoroughly conveyed all but two key components OR clearly covers all but one key component but could have been presented more clearly, concisely and/or thoroughly.
1=adequate	Team clearly, concisely, & thoroughly conveyed all but 3 key components and could be more concise and/or clear OR clearly covers all but 2 key components but those presented could have been done much more clearly, concisely, and/or thoroughly.
0=inadequate	Team's presentation was missing 4-5 key components; those stated were unclear and/or were not stated concisely.

## Organization

4=excellent	With a few minor exceptions, the presentation content was logically organized in a way that facilitated the audience's comprehension.
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### *Show additional rubric tiers*

3=very good	The presentation content was logically organized so that only a few minor clarifications were necessary after the presentation.
2=good	Most of the presentation content was logically organized, but some key clarifications were necessary after the presentation.
1=adequate	Only some of the presentation content was logically organized, and so many key clarifications were necessary after the presentation.
0=inadequate	The presentation content was not logically organized and so did not facilitate the audience's comprehension.

## Teamwork

4=excellent	Effective teamwork contributed to the success of the presentation because it met these criteria: 1. each team member's contribution to the presentation was equivalent; 2. each team member contributed answers to questions asked after the presentation, to the best of their ability; 3. teammates were respectful of each speaker and did not interrupt them.
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### *Show additional rubric tiers*

- 3=very good      Teamwork was largely effective; 2 of the 3 criteria were fully met.
- 2=good            Teamwork was somewhat effective; 1 of the 3 criteria was fully met.
- 1=adequate      Teamwork was not effective because none of the three criteria was fully met.
- 0=inadequate    No teamwork was evident.

## Visuals

- 4=excellent      With a few minor exceptions, the visuals accompanying the oral narrative very effectively conveyed the research project because they satisfied these criteria: 1. content was relevant; 2. overall appearance was pleasing to the eye but did not distract from the research; 3. font size, graphs, & figures were large enough to be viewed easily; 4. font, graph, & figure \*colors contrasted well against background & so were easy to see; 5. content (text, graphics) filled with just enough information to be informative without looking overcrowded; 6. graphs and figures were clearly labeled, had titles (no legends necessary), and effectively displayed relevant data/trends; 7. organization & formatting emphasized pertinent points. \*colors optional

### *Show additional rubric tiers*

- 3=very good      The visuals used satisfied all but one of the key criteria.
- 2=good            The visuals used satisfied all but 2-3 of the key criteria.
- 1=adequate      The visuals used satisfied all but 4-5 of the key criteria.
- 0=inadequate    The visuals used satisfied only 1-2 of the key criteria.

## Presentation Mechanics

- 4=excellent      With a few minor exceptions, the presentation mechanics allowed the research project to be very effectively conveyed because they satisfied these criteria: 1. the rate, flow, and clarity of delivery by each speaker was appropriate; 2. all speakers were introduced; 3. each speaker's voice was loud enough to be heard in the back of the room; 4. each speaker spoke to the audience in a narrative style, avoiding distracting mannerisms; 5. transitions between speakers were smooth and helped audience follow the presentation; 6. graph & figure axes labeling were explained clearly before trends/results were emphasized; 7. content was presented long enough to allow audience to follow easily; 8. presentation ended with final conclusion statement(s); 9. presentation took 15 +/- 1 min. (varies w/ assignment).

### *Show additional rubric tiers*

- 3=very good      The presentation mechanics satisfied all but one to two of the key criteria.
- 2=good            The presentation mechanics satisfied all but 3-4 of the key criteria.
- 1=adequate      The presentation mechanics satisfied all but 5-6 of the key criteria.
- 0=inadequate    The presentation mechanics satisfied only 1-2 of the key criteria.

## Rubric Scores to Letter Grade Conversion Guide

Letter Grade	Minimum Criteria
A	Team earned a “4” in Content and Organization, earned a “3” or better in Teamwork, Visuals, and Presentation Mechanics.
AB	Team did not meet minimum criteria for an “A”, but earned a “3” or better in Content and Organization. Earned a “2” or better in Teamwork, Visuals, and Presentation Mechanics.
B	Team did not meet minimum criteria for an “AB”, but earned a “2” or better in Content and Organization. Earned a “2” or better in Teamwork, Visuals, and Presentation Mechanics.
BC	Team did not meet minimum criteria for a “B”, but earned a “2” in Content and a “1” in Organization OR vice versa. Earned a “1” or better in Teamwork, Visuals, and Presentation Mechanics.
C	Team did not meet minimum criteria for a “BC”, but earned a “1” or better in Content and Organization. Received no more than one zero in Teamwork, Visuals, and Presentation Mechanics.
D	Team did not meet minimum criteria for a “C”, but earned a “1” or better in either Content or Organization. Received no more than two zeros in Teamwork, Visuals, and Presentation Mechanics.
F	Team did not meet minimum criteria for a “D.”

[Download Biocore rubrics in PDF format](#)

# Preparing Posters

Posters are a commonly used form of scientific communication that is used to share information and generate dialog with other scientists at scientific meetings and symposia. Posters are either one page or one slide/canvas of text and graphics that summarize your science as either a proposal, final data, or an infographic in a concise and visually pleasing way. In Biocore we make use of posters as a means to communicate research proposals and final research reports that replace papers or oral slide presentations. Before preparing your own poster, observe some made by other Biocore students hanging in Noland hallways or by scientists in other research buildings on campus.

See the **Writing Center handbook for creating and presenting posters**

<https://writing.wisc.edu/Handbook/PosterPresentations.html>

Developing a scientific poster is quite different from writing a paper or creating a PowerPoint presentation.

## Tips to start with

- **Easy to read and visually appealing:** In class, you will be presenting your poster to peers and instructors, primarily in digital form but sometimes in print. You want the most important aspects of your poster to stand out (e.g. results figures and BR diagrams). Use large font to allow for easy reading. During a scientific meeting, there may be as many as 200 posters in a room, and you do not want your poster to be ignored. Use large font and lettering (larger for titles, headings and subheadings) so that the information can be read easily from at least **5 feet away (or at arms-length without enlarging if viewed on a computer screen)**.
- **Emphasize the science:** Although the poster should be visually appealing, don't get carried away with this – put your efforts into **substance over form**. In evaluating the posters, we pay much more attention to the poster's scientific soundness and ability to tell an integrated story than we do to its glitz.
- **Save Space and Graphic Design:** The poster is a summary of your research, in a graphically rich and informative graphic design. To save space, 1.) introduce acronyms that shorten long chemical names or biological terms that describe independent or dependent variables used repeatedly in throughout your poster (e.g. rather than repeating anthocyanin pigment intensity, introduce and use API to save space), 2.) use smaller font for literature cited, 3.) diagram your biological rationale, your methods and the reasoning in your discussion, 4.) use numerical citations in the body of your text (see below).
- **Numerical Citations:** In papers or oral presentations you are used to seeing parenthetical citations within the body of the text (e.g. Smith et al. 2018) which is helpful for reference in a multiple paged document or slide set, however, in a one-page document such as a poster this takes up a great deal of space. Therefore, we recommend using numerical citation format where use of a superscript number in the text or in a graphic is keyed to the number in your literature cited section.

## Components of your poster

### INFORMATIVE TITLE

Gives the reader the take home message of your experiment stating the **organism** (or general system) you are studying, the **independent variable**, and the **direction of your results**. Titles are a critical component of posters since they draw people in to talk with you during a crowded scientific meeting.

**TITLE THAT NEEDS WORK:** The Effects of n-Butanol on mating in *Saccharomyces cerevisiae*

**IMPROVED TITLE:** Increasing Concentrations of n-Butanol Inhibits the  $\mu$ -mating Response in *Saccharomyces cerevisiae* MATa cells

### AUTHOR'S NAMES IN ALPHABETICAL ORDER

Order of authors' names generally indicates the researchers' level of involvement in the study. However, we expect all group members to have equal involvement in the study and preparation of the poster, therefore authors should be listed without indication of hierarchy, in alphabetical order. \*Underline or bold your name when handing the poster as an individual assignment.

### DEPARTMENT AND INSTITUTION AFFILIATION WHERE THE WORK TOOK PLACE

In this case, Biology Core Curriculum, University of Wisconsin-Madison. Affiliations are generally placed directly under the author/ co-author list.

### INTRODUCTION

Be *brief*, but include;

- **Question:** What question did you address with your experiment?
- **Background:** key issues, concepts, or terminology needed to understand the reason for the experiment.
- **Biological rationale:** Often a diagram or conceptual model illustrating how the background information on the independent and dependent variable leads to knowledge gap, and provides reasoning for the hypothesis. The BR is the heart of your introduction and provides the logical, biological reason for doing the experiment and your predicted hypothesis. This is NOT a social justification. Remember your audience: gear your poster to classmates in Biocore who are not taking lab.
- **Hypothesis:** It is of particular importance that you define and present a clear hypothesis that is testable given your experimental design. In general, your hypothesis should indicate your independent variable



(what you are manipulating), your dependent variable (what you are measuring), your study organism or system, and the direction or trajectory of your predicted result(s). This is the only place in your poster that requires full sentences.

## METHODS

There is not room for a lot of details, but you should give your readers enough information that they can **evaluate your claims**—not necessarily repeat your experiment. We strongly recommend using a **chart or annotated diagram** to convey your experimental design, sequence of events, timeline and tools.

## RESULTS (OR EXPECTED & ALTERNATIVE RESULTS FOR PROPOSALS)

Organize your poster such that your data are presented in large and prominent figures or tables (use large font for your axes and numbers). It is appropriate to use **titles** to label your tables and figures. Figures and tables need legends which are often more lengthy, “beefy legends”, than in a paper since you are trying to tell your story with graphics. Briefly state your results in the legends or in a short bulleted list, referring to a series of figures/graphs displaying your data.

## DISCUSSION AND CONCLUSIONS (OR IMPLICATIONS FOR PROPOSALS)

Your discussion should clearly **restate or represent your hypothesis** and state whether you **support or reject** it with supporting evidence from your results. In a proposal, describe the implications of the predicted expected results as it relates to the knowledge gap and the broader rationale presented in your introduction. Sometimes use of a diagram or conceptual model here (similar to that used in your BR) is helpful for explaining the implications of both the expected and alternative results. Avoid over interpretation (particularly if your design or protocol had weaknesses, flawed rationale, or suffered from excessive experimental error) and stick to what you can or cannot say about the system given your data. If your data supported your hypothesis, connect your final conclusion with the knowledge gap and biological assumptions embedded within the biological rationale presented in the Introduction. If your data did not support your hypothesis, describe how they might be the result of alternative rationale, new or unanticipated variables/ interactions that you had not considered previously, or other biological assumptions you made. If possible, briefly describe literature that would help explain your alternative results.

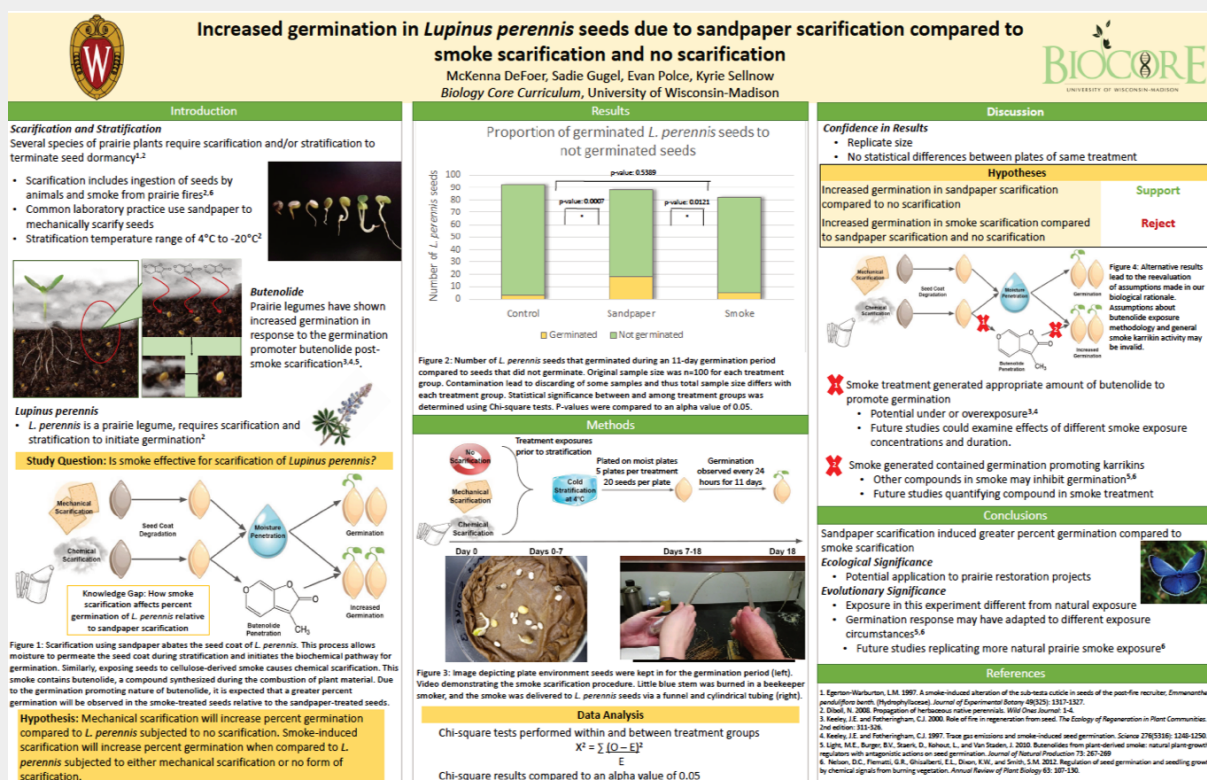
## OVERALL CONCLUSION STATEMENT

End with a clear conclusion statement that is based on your results– the take home message from your research. This final conclusion statement will likely be very similar to your poster’s title.

# LITERATURE CITED

Follow guidelines in this manual. Use numerical citations rather than parenthetical citation format to save space within the text for posters. The literature cited can be done in smaller font than the rest of the poster in order to save space.

## Example Poster



(Click on image for an enlarged version of this poster)

Example Poster contributed by McKenna DeFoer, Sadie Gugel, Evan Polce, and Kyrie Sellnow from the plant physiology unit in Biocore 486.

## FEATURES OF NOTE:

- the use of graphics to illustrate background information
- the paired set of visual diagrams with 'beefy' figure legends for the biological rationale and to illustrate reasoning in the discussion—the pair serve as 'bookends' to clearly communicate the proposed mechanism for the response observed
- large figure displaying results prominently in the center top
- numerical citation in text saves space
- not more than two major colors (green and yellow) carry a theme, contrast nicely and complement the photographs and diagrams

# Creating Printable Posters (Technical Details)

Sometimes Biocore teams choose to produce electronic posters and print them using large format printers. See this College Library website for a link to more important information and tips on creating posters in PowerPoint and Photoshop:

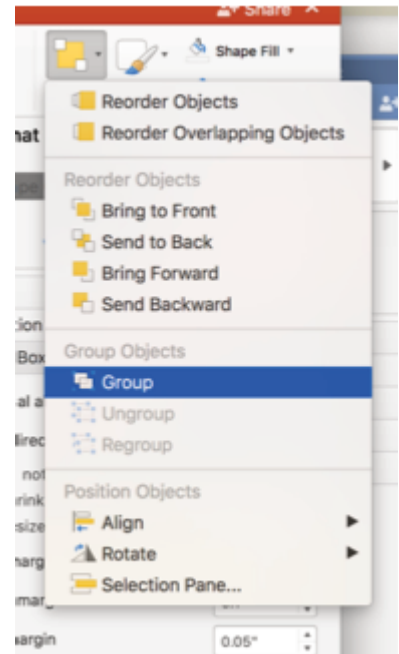
<http://www.library.wisc.edu/college/services-at-college/computer-lab/poster-printing/>

## Essential Tips for creating posters in PowerPoint

- Open Power Point– Open a new document – chose the “blank” layout (no pre-existing boxes)
- Size your poster for:
  - *Mini-poster*– Go to “File”, then “Page Setup”. Adjust the scale to Letter Paper (8.5×11 inches). If you print this document, the width will be 10 inches and height will be 7.5 inches allowing for a 0.5 inch margin.
  - *Large format printer* – Go to “File”, then “Page Setup”. Adjust the scale to a print size of 48” width x 36” height.
- Create your Title box. Go to your drawing toolbar and click on the text box. Type your title, then adjust font size (refer to font size guidelines below). In the same box you can also add the author names and separately adjust the font size for names and institutional affiliation.
- After that, the process will be mostly about choosing the types of boxes and lines you want to define the areas, orientation and structure of your poster. You have three main types of boxes:
  - Textbox
  - Shape box
  - Figure, table boxes.

Which ones you chose, and how many, will depend on the type of poster you are creating and the parts you will include.

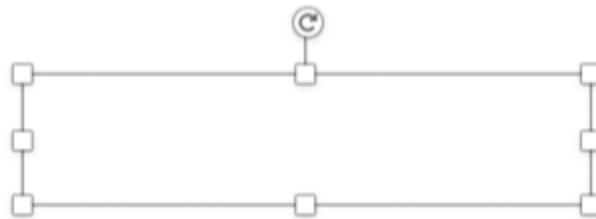
- Align & Group your boxes! Because you'll have lots of boxes floating around on your slide, sometimes it's hard to see how well they line up. Make sure your boxes are lined up by holding the shift key while you drag boxes- this will make the red dotted alignment line show up so you can see the alignment of one box in relation to others). Once you have several boxes/ shapes aligned, then group them by selecting Arrange>Group objects from the main menu bar or use the menu icons and select Group as shown to right. Grouped objects can be moved together and will stay aligned relative to one another.



## TEXT BOX

Click on the textbox symbol in the drawing toolbox and then click on the part of the poster where you want the words (you'll be able to move it around later so it does not need to be exact). Just start typing. There are two 'phases' of the textbox:

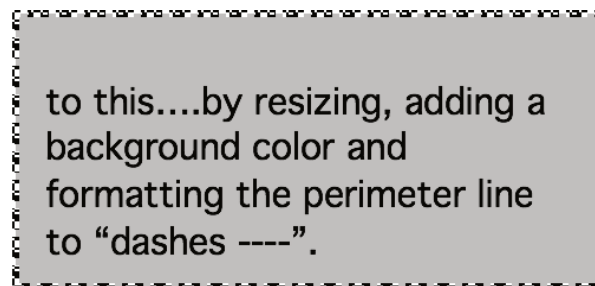
- The formatting phase:** you can change the entire contents of the box (font, size, centered, rotate, color fill or line color etc.) and move it around. It will look something like this:



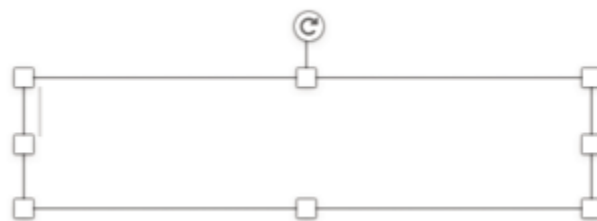
You will be able to click on the boxes on the edge to reshape and resize the box. If you want to move the entire box without reshaping/resizing, just click anywhere else on the perimeter. In addition to changing what's inside the box you can also change the **perimeter and interior**. For instance, if your default is set to be white with a black line around it...



You can change to this, without a line, to...



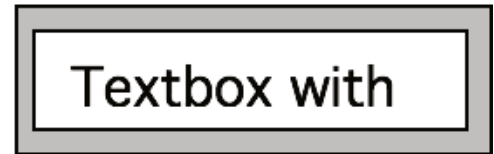
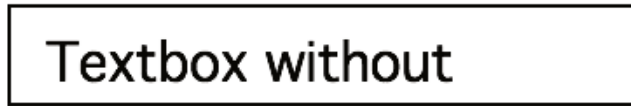
- **The editing phase:** the computer lets you change what's highlighted on the inside of the box. It will look something like this:



Note there is an active cursor inside. In this phase you can highlight and change the style of specific subset of words as in the example above if you have the title and the authors in the same box you could highlight the author names and make them a smaller font.

## SHAPE BOX

This is a very versatile tool. You can use it for highlighting other boxes, making circles, or making concept maps or graphic models, etc., here's an example:



And, if you chose to have a textbox (no fill, no line) in a circle (with gradient fill options), you can do this:



## ALIGNMENT

All boxes will be automatically positioned on the page along a 'grid'. This can be good because it can help you line everything up. To manipulate alignment, select Format>Alignment>More Options to reveal a formatting pallet of vertical and horizontal alignment options. Once you have aligned boxes or shapes, group them by selecting the Arrange>Group option from the menu bar (see below).

## ARRANGE/GROUP FUNCTION

**Really useful for creating visual diagrams and graphics!** When you have multiple levels of boxes (the textbox in front of the shape box) you need to choose which shape will go in front so that your text is not hidden behind the shape. You can do this by clicking on one of the shapes, and right click, then go to "Arrange" or "Order" menu and "bring object front" or 'send object back'.

If you get a collection of boxes or objects together and you want them to stay together, you can use the **"Group"** function by highlighting all the boxes (either shift and click on all of them, or go to the arrow in your drawing toolbox and use it to highlight all of them), right click, go to "Group". You have the option of ungrouping as well.

## INSERTING FIGURES AND GRAPHS

If you're using data and have a graph from Excel, or another program, you have two options.

- **Importing:** Directly bringing the figure into PowerPoint from the other program. You can import a figure or table from Excel by "copying" the figure within Excel and "pasting" it into the poster. Sometimes this

works. If not, you may have to recreate your figure using the 'chart' option provided.

You can also “paste” in several ways. If you will not need to modify your graph you can choose to paste as a screenshot or picture. This will be more likely to paste the graph as it looks in Excel, but you won’t be able to modify colors or numbers. This is also great for tables you don’t want to redo in PowerPoint. To do this, “copy” as usual in Excel, but when in PowerPoint, go to “edit”, “paste special”, then “Picture (TIFF)”.

- You can create a table for graph using PowerPoint’s software: Go to “insert”, click “chart” or “table”. You will have a spreadsheet pop open for the chart, and a dialogue box asking how many rows and columns. You can either enter the values by hand, or, it’s possible to copy and paste your spreadsheet data from Excel into the PowerPoint. The chart function works very similarly to Excel.

## General Font Tips

Font size will depend on the font chosen, length of text, AND the size of the poster. Below are for standard Calibri font for a Mini Poster (8.5×11” Letter sized) and Large Format poster 4’ wide by 3’ high that can be viewed from 5’ away.

Section Component	Font Size Guidelines	
	Mini-Poster	Large Format Poster
Title	24	85+
Author names	14	50
Section headings (Introduction, Methods etc.)	14	36
Subheadings	12	
Section text	9-10	24-28
Figure/ Table legends	8-9	16-18
Literature cited	6-7	12-14

*\*Note: Fonts vary in legibility. For mini-posters, adjust your font sizes to be large enough for your instructor to read comfortably from arms-reach, about 24 inches away.*

**Generally use sans serif rather than serif font for posters.** Times New Roman (what most of this manual is written in) is a serif font – it means that the font style has little connectors between the letters – designed to aid the eye as it flows from one letter and word to the next in paragraph form. Sans serif fonts, like Calibri, Arial and Helvetica, do not have these connectors. Below is a phrase in 20 point font for sample serif and sans serif fonts:

and the cow jumped over the moon
(Times New Roman- serif font)



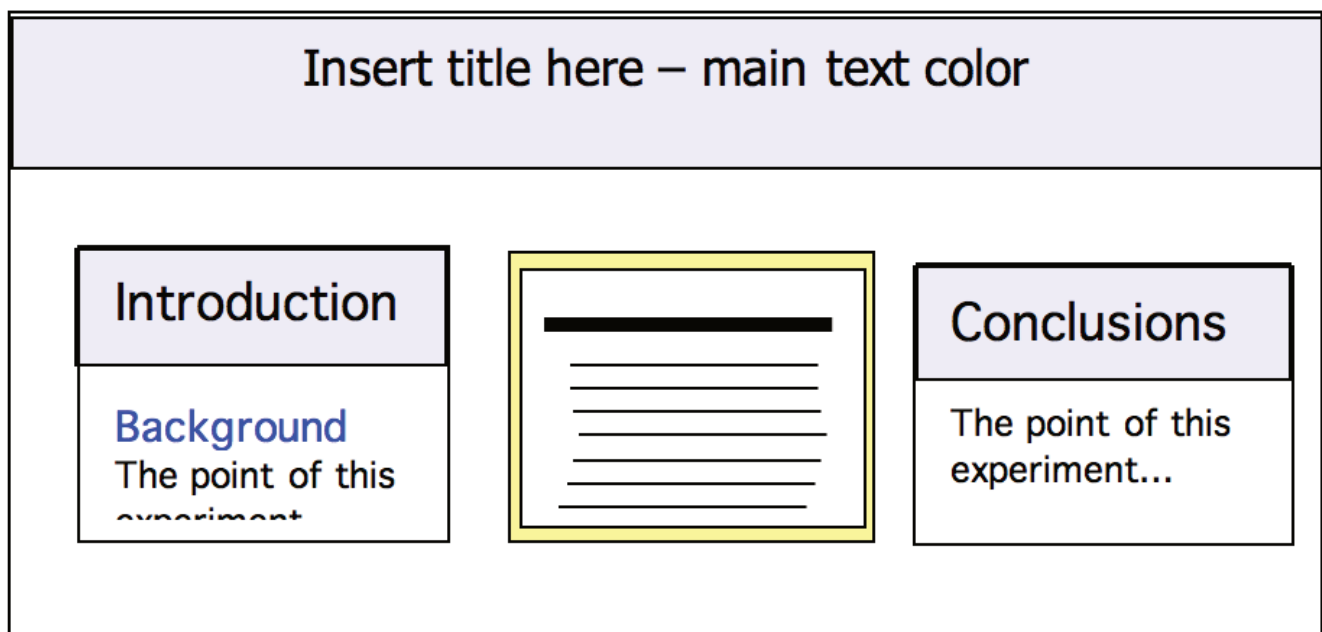
and the cow jumped over the moon (Calibri- sans serif font)

For reading lengthy documents, **serif fonts** are appropriate, but for posters many people feel that, especially for titles and headings, that **sans serif fonts** are easier on the eye.

## General Style Tips

We suggest you chose a light-colored background and dark-colored text, however light (white) text on dark background works well too. Regardless of color choice, make sure your text stands out and is of **high contrast** from the background. There are many other ways to integrate colors besides the background. You can add pictures, or use colors in your figures, or create colored boxes around different part to emphasize the layout.

**Stick with a simple color scheme.** Keep it to a maximum of **three to four main colors**. With four you have a good combination because you have your background, main text color, special text color (– and a variant for your main color), and emphasis color. See below.



**Background color**

Light – in this case, white

**Main text color**

Dark – black

**Special text color**

Dark – blue

**Main color**

A variant of your special text – light blue

**Emphasis color**

Contrast with your other colors (e.g. yellow), or add another tone of the main color to create a more monochromatic scheme.

**Love your white space.** The blank parts of your poster can offer as much to help with the flow and balance as any of the focal points. Generally, white space can occupy about 20% of your poster space.

**Remove all redundancies.** If you are using logos (e.g. UW seal or departmental logo) only present it once, rather than as bookends for your title or to fill all of your white space.

**Be concise.** Although full sentences may be needed in some parts of your poster (e.g. your hypothesis), in other parts keep only essential words and concepts or replace words with visual models, images, or illustrations. Create appropriate abbreviations, acronyms, and symbols that are clearly defined.

For examples and good poster design tips visit [betterposters.blogspot.com/](http://betterposters.blogspot.com/)

**Your posters will be graded using the rubric on the following page.**

# Biocore FINAL POSTER Review Rubric

## Title

**4 = excellent** Title is concise; gives reader idea of experimental system; states organism/system studied, independent variable, and direction of results.

*Show additional rubric tiers*

**3 = very good** Title is concise & conveys answer to study question, but has problem similar to the following: is missing model system or independent variable.

**2 = good** Title could be more concise but still conveys answer to study question. OR Title is concise & conveys answer to study question but has problem similar to the following: missing model system & independent variable

**1 = adequate** Has two or more problems comparable to the following: Title is not concise, answer to study question is difficult to determine by title, most key information is missing.

**0 = inadequate** Answer to study question cannot be determined by title.

## Introduction

**4 = excellent** Clearly, concisely, & logically presents all key components often in diagram or conceptual model: relevant & correctly cited background information, study question biological rationale (including main biological assumptions about how system works as well as knowledge gap), hypothesis. (There may be a few minor issues with organization/clarity.)

*Show additional rubric tiers*

<b>3 = very good</b>	Concisely & clearly covers all but one key component (w/ exception of rationale) OR clearly covers all key components but could be more concise and/or clear. e.g., has done a reasonably nice job with the Intro but fails to state hypothesis concisely OR has done a nice job with Intro but has also included some irrelevant background information.
<b>2 = good</b>	Covers all but 2 key components OR clearly covers all but 1 key component but could be done more logically, clearly, and/or concisely. e.g., biological rationale not fully developed but still supports hypothesis. Remaining components are done reasonably well, though there is still room for improvement; includes info that is extraneous & detracts from the main ideas; multiple examples of wordy text.
<b>1 = adequate</b>	Covers all but 3 key components & could be more concise and/or clear OR clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely (excessive text, overly wordy). Weak/missing components make it difficult to follow the rest of the poster. e.g., background information not focused on study question & minimal biological rationale presented such that hypothesis isn't entirely logical.
<b>0 = inadequate</b>	4-5 key components are very weak or missing; those stated are unclear and/or not stated concisely. Introduction provides little to no relevant information. Often results in a hypothesis that "comes out of nowhere."

## Methods & Materials

<b>4 = excellent</b>	Concisely & clearly describes procedures used to generate data presented, giving readers enough information to evaluate claims but not necessarily to repeat experiment. Uses brief text and/or annotated diagram(s) and/or charts with detailed legends to convey experimental design, tools, sequence of events, data transformation and statistical tests used.
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### *Show additional rubric tiers*

<b>3 = very good</b>	Concisely & clearly describes procedures used to generate data so that reader could evaluate most claims made. Minor problems with organization OR some irrelevant/ superfluous info.
<b>2 = good</b>	Methods presented such that a reader could evaluate most claims made only after learning a few more key details OR methods are conveyed with a lot of text & would be better explained with more figures/ charts.
<b>1 = adequate</b>	Methods presented such that a reader would have difficulty evaluating claims unless they learned several more key details OR methods are conveyed with too much text & almost no figures/charts.
<b>0 = inadequate</b>	So little information is presented that reader could not possibly evaluate claims.

## Results

<b>4 = excellent</b>	Concise & clearly describes procedures used to generate data presented, giving readers enough information to evaluate claims but not necessarily to repeat experiment. Uses brief text and/or annotated diagram(s) and/or charts with detailed legends to convey experimental design, tools, sequence of events, data transformation and statistical tests used.
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*Show additional rubric tiers*

<b>3 = very good</b>	Uses very concise text to refer to figures/graphs/tables that highlight the data, but has made 1-2 minor omissions or has other relatively small problems. e.g., relevant data are summarized well and without biological interpretation, but tables & figures have very brief legends that leave out some key details.
<b>2 = good</b>	Uses somewhat concise text to refer to figures/graphs/tables that highlight the data, but has 2-3 problems comparable to the following: most relevant data are present but are mixed in with some unnecessary information, key data are shown in figures but are not explicitly noted, tables & figures have very brief legends that leave out key details, conclusions about hypothesis are briefly made; overuse of text paragraphs.
<b>1 = adequate</b>	Has 3-5 problems comparable to the following: excessive narrative text with minimal, uninformative tables/figures /tables; some relevant data are present but are mixed in with much unnecessary information; key data are not immediately apparent in figures and are not explicitly noted in text, tables & figures lack legends and/or titles, conclusions about hypothesis are emphasized; overuse of text.
<b>0 = inadequate</b>	Major problems that leave reader uninformed; narrative text is lacking entirely, tables & figures contain unclear and/or irrelevant information. e.g., raw data are in a table w/ poor legend and no title.

## Discussion

<b>4 = excellent</b>	With a few minor exceptions, clearly & concisely presents an analysis that: supports or rejects hypothesis*, discusses biological meaning and relevance of results & compares with relevant findings in literature, evaluates experimental design, evaluates reliability of data, states implications of results, suggests next investigation steps and unexpected observations. Poster ends with final conclusion that addresses study goal/question. *If you believe some data were invalid and/or biological assumptions were not met, discuss how this impacts your confidence in the data and ability to make conclusions regarding your hypotheses.
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*Show additional rubric tiers*

<b>3 = very good</b>	Concisely & clearly covers all but one key component OR clearly covers all key components but could be more concise and/or clear. e.g., has done a reasonably nice job with the Discussion but fails to clearly tie biological rationale from the Intro into the conclusions made OR has done a nice job with the Discussion but has also included an extensive laundry list of experimental problems without discussing their impact on the conclusions.
<b>2 = good</b>	Covers all but 2 key components OR clearly covers all but 1 key component but could be done much more logically, clearly, and/or concisely. e.g., clearly states that hypothesis is supported and develops a good argument that refers to biological rationale, but fails to logically and objectively evaluate the data reliability or propose next investigative steps. Remaining components are done reasonably well, though there is still room for improvement.
<b>1 = adequate</b>	Covers all but 3 key components & could be more concise and/or clear OR clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely. e.g., fails to conclude anything about the hypothesis and so conclusions about study question are vague and incompletely tied to rationale, literature is minimally cited, presents unranked laundry list of problems instead of logical evaluation of data, suggests flashy new experiments that would not clearly address study question.
<b>0 = inadequate</b>	4 or more key components are missing or very weakly done. e.g., illogical conclusions made based on data, no ties to biological rationale are made, no literature cited, little to no evaluation of experimental design/data.

## Visuals & Organization

<b>4 = excellent</b>	With a few minor exceptions, the organization & visual look of the poster effectively conveyed the research project because: 1. content was relevant & accurate; 2. overall layout was pleasing to the eye but did not distract from the research; 3. font size, graphs, & figures were large enough to be easily read 4. font, graph, & figure *colors contrasted well against background & so were easy to see; 5. poster filled with just enough information to be informative without looking overcrowded and/or text heavy; 6. graphs and figures were clearly labeled and effectively displayed relevant data; 7. organization & formatting emphasized pertinent points; 8. lists, diagrams, or other visuals communicate points instead of wordy paragraphs
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### *Show additional rubric tiers*

<b>3 = very good</b>	The organization & visuals used satisfied all but one of the key criteria.
<b>2 = good</b>	The organization & visuals used satisfied all but 2-3 of the key criteria. Text used instead of relevant, informative visual on 1-2 occasions.
<b>1 = adequate</b>	The organization & visuals used satisfied all but 4-5 of the key criteria. Text used instead of relevant, informative visual on multiple occasions.
<b>0 = inadequate</b>	The organization & visuals used satisfied only 1-2 of the key criteria. Very few visuals presented.

## Literature Cited

**4 = excellent** References within body of poster are cited appropriately; references in final citation list are formatted appropriately and listed alphabetically by author or numerically using Writing Manual guidelines.

*Show additional rubric tiers*

**3 = very good** References within body of poster & in final citation list are done appropriately, but there are 1-2 exceptions. e.g., citations are done well except that one or two references listed in text do not appear in the final list OR there are a few minor formatting errors in the final list.

**2 = good** References within body of poster & in final citation list are done appropriately for the most part, but there are consistent exceptions. e.g., citations used sparingly throughout the poster when background information is presented OR consistent formatting errors in text & list.

**1 = adequate** Very few references are cited in text of poster; final citation list is largely incomplete and/or is not formatted appropriately.

**0 = inadequate** Background information is presented but is consistently not cited; final citation list is missing.

## Overall grammar, organization, wording

**4 = excellent** Excellent concise wording and text flow, appropriate word choice, few to no grammatical errors.

*Show additional rubric tiers*

**3 = very good** Wording was good with few to no problems, wording awkward in a few places, few grammatical errors. A few minor instances of text overuse.

**2 = good** Wording somewhat problematic but can still follow thought progression e.g. explanation of methods in the results section; wording awkward at times (clarity issues), some grammatical errors. A few minor instances of text overuse.

**1 = adequate** Problematic wording of some section resulting in loss of clarity; awkward wording at times; some grammatical errors. Some instances of text overuse.

**0 = inadequate** Poorly worded, interrupted flow of ideas leading to lack of clarity, cannot follow thought progression, many grammatical errors. Multiple examples of text overuse.

## Rubric Scores to Letter Grade Conversion Guide

Letter Grade	Minimum Criteria
<b>A</b>	Earned a “4” in at least 3 of the main sections (Introduction, Methods & Materials, Results, Discussion, and Visuals & Organization) and “3” in the remaining sections; no less than a “3” in Title, Literature Cited, and Overall grammar, wording
<b>AB</b>	Did not meet minimum criteria for an “A”, but earned a “3” or better in Introduction, Methods & Materials, Results, Discussion, Visuals & Organization. Earned a “2” or better in Title, and Literature Cited, Overall grammar, wording
<b>B</b>	Did not meet minimum criteria for an “AB”, but earned a “3” or better in at least two of the main sections (Introduction, Methods & Materials, Results, & Discussion) and “2” in the remaining sections. Earned at least a “3” in Visuals & Organization. Earned a “2” or better in Title, Literature Cited, Overall grammar, wording.
<b>BC</b>	Did not meet minimum criteria for a “B”, but earned a “2” or better in at least two of the main sections (Introduction, Methods & Materials, Results, & Discussion) and “1” in remaining sections. Earned at least a “2” in Visuals & Organization, and Overall grammar, wording. Earned a “1” or better in Title, Literature Cited.
<b>C</b>	Did not meet minimum criteria for a “BC”, but earned a “1” or better in Introduction, Methods & Materials, Results, Discussion, Visuals & Organization, and Overall grammar, wording. Has no more than one zero in Title, and Literature Cited.
<b>D</b>	Did not meet minimum criteria for a “C”, but earned a “1” or better in at least 3 of these sections: Introduction, Methods & Materials, Results, Discussion, Visuals & Organization. Has no more than two zeros in Title, and Literature Cited, and Overall grammar, wording.
<b>F</b>	Did not meet minimum criteria for a “D.”

[Download Biocore rubrics in PDF format](#)



# Biocore PROPOSAL POSTER Rubric

## Title

**4 = excellent** Title is concise; conveys main point of experiment and includes these key components states organism/ system studied, independent variable, and direction of expected results.

*Show additional rubric tiers*

**3 = very good** Title is concise & conveys answer to study question, but has problem similar to the following: is missing model system or independent variable

**2 = good** Title could be more concise but still conveys answer to study question. OR Title is concise & conveys answer to study question but has problem similar to the following: missing model system & independent variable

**1 = adequate** Has two or more problems comparable to the following: Title is not concise, answer to study question is difficult to determine by title, most key information is missing

**0 = inadequate** Answer to study question cannot be determined by title

## Introduction

**BIG PICTURE:** Did Intro convey why experiment will be performed and what it is designed to test?

**4 = excellent** Clearly, concisely, & logically presents all key components often in a diagram or conceptual model:

- relevant & correctly cited background information
- study question
- biological rationale which links treatment to expected results at cellular/molecular level
- hypotheses that are testable given experimental design

(There may be a few minor issues with organization/clarity.)

*Show additional rubric tiers*

<b>3 = very good</b>	Concisely & clearly covers all but one key component (w/ exception of rationale) OR clearly covers all key components but could be much more concise and/or clear. e.g., has done a reasonably nice job with the Intro but fails to state hypotheses concisely OR has done a nice job with Intro but has also included some irrelevant background information
<b>2 = good</b>	Covers all but 2 key components OR clearly covers all but 1 key component but could be done much more logically, clearly, and/or concisely. e.g., biological rationale not fully developed but still supports hypotheses. Remaining components are done reasonably well, though there is still room for improvement; includes info that is extraneous & detracts from the main ideas; multiple examples of wordy text.
<b>1 = adequate</b>	Covers all but 3 key components & could be more concise and/or clear OR clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely (excessive text, overly wordy). Weak/missing components make it difficult to follow the rest of the poster. e.g., background information not focused on study question & minimal biological rationale presented such that hypotheses aren't entirely logical.
<b>0 = inadequate</b>	4-5 key components are very weak or missing; those stated are unclear and/or not stated concisely. Introduction provides little to no relevant information. Often results in a hypothesis that "comes out of nowhere."

## Methods & Materials

**BIG PICTURE:** Did the methods clearly describe how hypothesis will be tested?

<b>4 = excellent</b>	Concisely & clearly describes proposed procedures used to generate expected data, giving readers enough information to evaluate whether protocol is appropriate to test hypothesis but not necessarily to repeat experiment. Uses brief text and/or annotated diagram(s), schedule and/or charts with detailed legends to convey experimental design, tools, sequence of events, data transformation and statistical tests to be used.
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### *Show additional rubric tiers*

<b>3 = very good</b>	Concisely & clearly describes proposed procedures so that reader could evaluate most claims made. Minor problems with organization OR some irrelevant/ superfluous info.
<b>2 = good</b>	Methods presented such that a reader could evaluate most claims made only after learning a few more key details OR methods are conveyed with a lot of text & would be better explained with more figures/ charts.
<b>1 = adequate</b>	Methods presented such that a reader would have difficulty evaluating claims unless they learned several more key details OR methods are conveyed with too much text & almost no figures/charts.
<b>0 = inadequate</b>	So little information is presented that reader could not possibly evaluate claims

## Expected and Alternative Results

**BIG PICTURE:** Did the expected results clearly & effectively display expected data that are relevant?

**4 = excellent** With a few minor exceptions, uses very concise text and/or bullets to refer to series of figures/ graphs/ tables that highlight the expected data. Only relevant expected and alternative data are shown, including the controls. Utilizes images & statistical tests appropriately. Tables & figures have informative legends & titles.

*Show additional rubric tiers*

**3 = very good** Uses very concise text to refer to figures/graphs/tables that highlight expected & alternative data, but has made 1-2 minor omissions or has other relatively small problems. e.g. relevant expected data are summarized well & without biological interpretation, but tables & figures have very brief legends that leave out some key details.

**2 = good** Uses somewhat concise text to refer to figures/graphs/tables that highlight the data, but has 2-3 problems comparable to the following: most relevant expected data are present but are mixed in with some unnecessary information, key data are shown in figures but are not explicitly noted, tables & figures have very brief legends that leave out key details, conclusions about proposed hypothesis are briefly made; alternative results are scarcely mentioned.

**1 = adequate** Has 3-5 problems comparable to the following: excessive narrative text with minimal, uninformative tables/figures/tables; some relevant expected data are present but are mixed in with much unnecessary information, key data are not immediately apparent in figures and are not explicitly noted in text, tables & figures lack legends and/or titles, conclusions about proposed hypotheses are emphasized; alternative results are not mentioned.

**0 = inadequate** Major problems that leave reader uninformed; narrative text is lacking entirely, tables & figures contain unclear and/or irrelevant information. e.g., figures are not accompanied by text, expected raw data are in a table w/ poor legend & no title; expected results do not support proposed hypothesis.

## Implications

**BIG PICTURE:** Did the Implications present explanations of expected & alternative results that made sense based on the 'dummy' data presented?

**4 = excellent** With a few minor exceptions, clearly, concisely and logically presents all key components: describes relevance of predicted trend as it relates to background information, rationale, explains assumptions made, evaluates confidence in experimental design, discusses alternative results in light of incomplete biological rationale or flawed biological assumptions, and discusses ramifications of the experiment. If there are anticipated problems in collecting valid data, stated what the problem is and how it may limit confidence or result in alternative data.

*Show additional rubric tiers*

<b>3 = very good</b>	Concisely & clearly covers all but 1 key component OR clearly covers all key components but could be more concise and/or clear. e.g., has done a reasonably nice job with the Implications but fails to clearly link the biological rationale from the Intro with the expected results OR has done a nice job with the Implications but has also included an extensive laundry list of potential flaws in experimental design without discussing their impact on the predicted or alternative results.
<b>2 = good</b>	Covers all but 2 key components OR clearly covers all but 1 key component but could be done much more logically, clearly, and/or concisely. e.g., clearly describes relevance of predicted data that refers to biological rationale, but fails to logically and objectively evaluate confidence in the experimental design OR has done a nice job with all the components but only briefly mentions alternative results without discussing biological relevance.
<b>1 = adequate</b>	Covers all but 3 key components & could be more concise and/or clear OR clearly covers all but 2 key components but could be done much more logically, clearly, and/or concisely. e.g., relevance of predicted trend is incompletely tied to rationale, literature is minimally cited, presents unranked laundry list of potential problems instead of logical evaluation of design and data, suggests far-reaching/ illogical ramifications of experiment.
<b>0 = inadequate</b>	4 or more key components are missing or very weakly done. e.g., illogical conclusions made based on predicted data, no ties to biological rationale are made, alternative results are not mentioned, no literature cited, little to no evaluation of confidence in experimental design

## Visuals & Organization

<b>4 = excellent</b>	With a few minor exceptions, the organization & visual look of the poster effectively conveyed the research project because: 1. content was relevant & accurate; 2. overall layout was pleasing to the eye but did not distract from the research; 3. font size, graphs, & figures were large enough to be easily read; 4. font, graph, & figure *colors contrasted well against background & so were easy to see; 5. poster filled with just enough information to be informative without looking overcrowded and/or text-heavy; 6. graphs and figures were clearly labeled and effectively displayed relevant data; 7. organization & formatting emphasized pertinent points; 8. lists, diagrams, or other visuals communicate points instead of wordy paragraphs.
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### *Show additional rubric tiers*

<b>3 = very good</b>	The organization & visuals used satisfied all but one of the key criteria.
<b>2 = good</b>	The organization & visuals used satisfied all but 2-3 of the key criteria. Text used instead of relevant, informative visual on 1-2 occasions.
<b>1 = adequate</b>	The organization & visuals used satisfied all but 4-5 of the key criteria. Text used instead of relevant, informative visual on multiple occasions.
<b>0 = inadequate</b>	The organization & visuals used satisfied only 1-2 of the key criteria. Very few visuals presented.

## Literature Cited

**4 = excellent** References within body of poster are cited appropriately; references in final citation list are formatted appropriately and listed alphabetically by author or numerically using Writing Manual guidelines.

*Show additional rubric tiers*

**3 = very good** References within body of poster & in final citation list are done appropriately, but there are 1-2 exceptions. e.g., citations are done well except that one or two references listed in text do not appear in the final list OR there are a few minor formatting errors in the final list.

**2 = good** References within body of poster & in final citation list are done appropriately for the most part, but there are consistent exceptions. e.g., citations used sparingly throughout the poster when background information is presented OR consistent formatting errors in text & list.

**1 = adequate** Very few references are cited in text of poster; final citation list is largely incomplete and/or is not formatted appropriately.

**0 = inadequate** Background information is presented but is consistently not cited; final citation list is missing

## Overall grammar, organization, wording

**4 = excellent** Excellent concise wording, grammar, and flow, appropriate word choice, few to no grammatical errors.

*Show additional rubric tiers*

**3 = very good** Wording was good with few to no problems except in a few places, few grammatical errors. A few minor instances of text overuse.

**2 = good** Wording somewhat problematic but can still follow thought progression e.g. explanation of methods in the results section; wording awkward at times (clarity issues), some grammatical errors. A few minor instances of text overuse.

**1 = adequate** Problematic wording of some section resulting in loss of clarity; awkward wording at times; some grammatical errors. Some instances of text overuse.

**0 = inadequate** Poorly worded, interrupted flow of ideas leading to lack of clarity, cannot follow thought progression, many grammatical errors. Multiple examples of text overuse.

## Proposal Poster Rubric Conversion to Letter Grade

Letter Grade	Minimum Criteria
<b>A</b>	Earned a “4” in at least 3 of the main sections (Introduction, Methods & Materials, Expected & Alternative Results, Implications, and Visuals & Organization) and “3” in the remaining sections; no less than “3” in Title, Literature Cited, and Overall grammar, wording.
<b>AB</b>	Did not meet minimum criteria for an “A”, but earned a “3” or better in: Introduction, Methods & Materials, Expected & Alternative Results, Implications, Visuals & Organization. Earned “2” or better in Title and Literature Cited, and Overall grammar, wording.
<b>B</b>	Did not meet minimum criteria for an “AB”, but earned a “3” or better in at least two of the main sections (Introduction, Methods & Materials, Expected & Alternative Results, Implications) and “2” in remaining sections. Earned at least “3” in Visuals & Organization; “2” or better in Title and Literature Cited, and Overall grammar, wording.
<b>BC</b>	Did not meet minimum criteria for a “B”, but earned a “2” or better in at least two of the main sections (Introduction, Methods & Materials, Expected & Alternative Results, Implications). Earned at least “2” in Visuals & Organization, and Overall grammar, wording. Earned a “1” or better in Title, Literature Cited.
<b>C</b>	Did not meet minimum criteria for a “BC”, but earned a “1” or better in Introduction, Methods & Materials, Expected & Alternative Results, Implications, Visuals & Organization. Has no more than one zero in Title, Literature Cited, and Overall grammar, wording.
<b>D</b>	Did not meet minimum criteria for a “C”, but earned a “1” or better in at least 3 of these sections: Introduction, Methods & Materials, Expected & Alternative Results, Implications, Visuals & Organization. Has no more than two zeros in Title, Literature Cited, and Overall grammar, wording.
<b>F</b>	Did not meet minimum criteria for a “D.”

[Download Biocore rubrics in PDF format](#)

# Writing Style

**Style** refers to the way writing is used to express ideas, distinct from the ideas themselves. Style can also refer to specific guidelines for spelling, punctuation, and formatting established by an instructor or publisher. In this manual we focus on the scientific writing style required by most journals in the sciences as well as by Biocore instructors for lab reports and term papers. Scientific writing is **clear and concise** and uses **correct grammar and spelling**. Clarity demands that you follow the conventions of proper English usage. Two of the best aids available to writers are a style book, such as *The Elements of Style* (Strunk and White, 1979) or *How to Write and Publish a Scientific Paper* (Day, 1994), and a dictionary. These books are good investments for anyone interested in improving his/her writing skills.

## AVOID TRYING TO SOUND “SCIENTIFIC”

Choose the simplest, most precise words you can. They will help you convey information quickly and clearly. Do not write to impress your reader; the task is to explain scientific ideas. If you are using a word that is new to your vocabulary or has uncommon usage, make sure you are using it precisely. Look it up in the dictionary if you have any doubts!

## USE THE ACTIVE VOICE MOST OF THE TIME

In **active voice**, the actor comes before the verb and the object, whereas in **passive voice**, the actor comes last. Active voice is more dynamic and less likely to lead to wordiness and ambiguity.

**POOR:** The bacterial plates were examined by the research team everyday. (passive)

**BETTER:** We examined the bacterial plates daily. (active)

This is your story. It is appropriate to say, “This is what we did, this is what we found, and this is what we think it all means.” However, there are situations where the **passive voice** is appropriate, for example, when the subject of the sentence is irrelevant in the context (e.g., Biocore was founded in 1967). It is common to use passive voice in the Methods section.

## WORD CHOICE AND WORDINESS

Ask yourself, “will this paper read poorly without this word or sentence”? Unless the answer is yes, throw it out! Don’t hesitate to throw out a sentence that doesn’t fit, even if it is well-written.

- Avoid unnecessary phrases and words (*it is interesting that, due to the fact that, at the present time, there is little doubt that*) and verbs into nouns.

**POOR:** It is interesting that at the present time there are many people who like to garden due to the fact that it is relaxing.

**BETTER:** Many people find gardening relaxing.

**POOR:** Many student papers, especially those which consistently exceed 15 pages, are too long. Therefore, in dealing with papers which are not concise, instructors need to resort to drastic measures in order to urge the authors of long papers to edit their papers.

**BETTER:** Many students need to edit their papers to make them shorter.

**POOR:** The sample was subjected to centrifugation.

**BETTER:** We centrifuged the sample at 500 x g.

- Make sure the language you use reflects the scientific activity in which you are engaging. Phrases such as “I believe”, “We would hope”, or “I think that” have little place in scientific writing.
- Avoid using “one” or “you” as the subject of the sentence; put biology in center stage.
- When using a comparative adjective, make sure the object of comparison is clear. Answer ‘lower’, ‘greater’, ‘better’ than what?

**POOR:** The water chemistry made algal diversity lower.

**BETTER:** Algal diversity was lower at high salt concentrations than at low salt concentrations.

- **Read your paper aloud.** You may be able to hear problems you didn’t recognize previously.
- **Ways to prevent awkward or wordy sentences:**
  - Many problems stem from overuse of the verb “to be.” If it does not serve the function of an equals sign in the sentence, try to eliminate it.
  - Put the agent of cause in the subject and the action in the verb. Go for a verb that is interesting and informative.
  - Use “which” and “that” sparingly.
  - If a sentence is more than two lines long, try to break it up into two sentences.
- Avoid the naked *this*. “This” should always precede a noun.

**POOR:** This shows that...

**BETTER:** This behavior indicates...

- In the discussion, it’s not necessary to tell the reader that you are basing a particular conclusion on data presented in the results. If you have presented the data well, the reader will know that you are basing your conclusion on your data.

**POOR:** Based on the results presented in figure 1, one can see that the *Daphnia* grew faster when exposed to higher temperatures.

**BETTER:** Higher temperatures favored *Daphnia* growth.



## AVOID SLANG AND JARGON

**Slang** (got, neat, cool) is highly informal language that is outside of standard or conventional usage.

**POOR:** We **got** all kinds of **neat stuff** from the marsh and **dumped** it in a pickle jar.

**BETTER:** We collected plants from the marsh and placed them in a 1-gallon glass jar.

**Jargon** is highly specialized or technical vocabulary used by those in the same work or profession (e.g., using “chemotherapeutic agent” instead of “drug”). In science writing, jargon frequently consists of nouns modifying nouns and is common when writers use the passive voice.

## DEFINE ANY TECHNICAL TERMS THAT MAY BE UNFAMILIAR TO THE READER

Example, leaf area index (the surface area of leaves in the plant canopy per unit ground area) is often measured in m<sup>2</sup>/m<sup>2</sup>.

## USE INCLUSIVE LANGUAGE

Imprecise word choices may be interpreted as biased, discriminatory, or demeaning. For example, the use of *man* or *men* as generic terms for *humans* is ambiguous and inappropriate.

**POOR:** *Man's* search for answers has led *him* to pursue avenues of scientific discovery.

**BETTER:** The search for answers has led *people* to pursue avenues of scientific discovery.

Use **she/her** as often as **he/his** when referring to a person who may be either gender.

## USE THE APPROPRIATE FORMAT FOR SCIENTIFIC NAMES

The first time you refer to an organism, give the specific epithet (the scientific name- both the genus and species in italics) e.g. *Daphnia magna*. You may subsequently refer to the species with genus abbreviation, e.g. *D. magna*.

If you choose to use common names when discussing particular species, present **the scientific name, in parenthesis and italicized**, after the common name at least once in the paper. Common names are not capitalized unless the name is also a proper noun. Examples:

common goldenrod (*Solidago canadensis*)

Queen Anne's lace (*Daucus carota*)

## LEARN THE CORRECT USAGE OF THE FOLLOWING WORDS AND

## ABBREVIATIONS

- **Accuracy, precision:** *Accuracy* refers to the closeness of a measurement to the true value. *Precision* refers to the repeatability of a measurement. If you measure something with a defective ruler many times and obtain the same length, you will have made a precise but inaccurate measurement.
- **Affect, effect:** *Affect* is a verb that means “to influence” or “to have an *effect* on”; *effect* is a noun that means “result.”
- **Among, between:** *Among* refers to more than two; *between* refers to two of something or indicates geographic location.
- **Amount of, number of:** *Amount of* refers to general quantities of things; *number of* refers to amounts that can be counted.

A small amount of soil can contain a large number of organisms.

- **Cannot:** This is one word.
- **Data, datum:** *Data* is plural; *datum* is singular.
- **e.g., i.e.:** The term *e.g.* (*exempli gratia*) means “for example”; *i.e.* (*id est*) means “that is.” Both should be italicized (because they are Latin terms) and followed by a comma (*i.e.*, like this).
- **Ensure, insure:** *Ensure* is to make certain or guarantee; *insure* is what insurance agents do to protect you from loss.
- **et al.:** This stands for *et alia*, which means “and others.” Note the period after *al.*
- **Few, less:** Use *few* to answer the question “How many?”; use *less* to answer the question “How much?”
- **Hypothesis, theory:** *Hypothesis* is used in everyday language to mean an educated guess; however, scientists use the term *hypothesis* to mean a provisional idea with explanatory power that is consistent with available information. The hypothesis may be rejected if it turns out not to be supported by data generated by further experiments. A *theory* (e.g., the theory of evolution by natural selection) is a well-tested idea that has been supported by multiple observations and experiments over a long period of time.
- **Its, it's:** *Its* is the possessive pronoun (*its* tail); *it's* is the contraction of “it is” (*It's* hot today.)
- **Percent, percentage:** *Percentage* is used when no figure is given (a high *percentage* of students); *percent* is used when a figure precedes it (55 percent or 55%). In science writing, % is more commonly used than *percent*.
- **Prove:** To prove something is to demonstrate it to be a fact. Scientists support hypotheses with data; they seldom prove something. Do not say you “proved” something when you have limited evidence.
- **Significant:** In science writing, *significant* is used for statistical analyses. Do not use *significant* when you mean “important,” “notable,” “distinctive,” or “major.”

- **That, which:** *That* defines and restricts (the book *that* we need has not arrived); *which* is explanatory (an afterthought) and nonrestrictive (the plants, *which* seem bushier than usual, ...).

# Grammar and Sentence Structure

To write effectively, you have to consider not only the substance and style of your paper, but also punctuation and grammar. The following list represents some of the most common errors we have seen in student papers over the years. For others, consult one of the comprehensive style manuals listed in the References on Writing section of this manual. The UW-Madison Writing Center also has a very useful grammar and punctuation website.

## AGREEMENT IN NUMBER

- **Subject and Predicate:** A *predicate* is a verb or verb phrase of a sentence. Predicates should agree in number with their subjects. Units of measure are often used in the collective sense and the verb should be singular.

The **datum** is... (singular)

The **data** are...(plural)

Five milliliters of water was added to the mixture.

- **Pronouns:** Traditionally, the rules of formal academic writing have held that pronouns should agree in number with the noun to which they refer. Following this convention, a sentence might look like this:

**Everyone** (singular) must hand in **his** (not **their**) lab report on time.

This convention is shifting as more people are using the word “they” as a gender-inclusive singular pronoun.<sup>1</sup> In the Biocore program, our goal is to help you understand the traditions you participate in as a writer, and we will expect you to demonstrate that you are engaging with the conventions active in the field in an intentional way. You may use a “singular they” in your work, but if you do so, please include a footnote that indicates that you are using ‘they’ as a singular pronoun. Append this footnote to the **first** instance of the “singular they” in your writing.

## TENSE

Ask yourself whether you did something (past tense), are doing something (present tense), or will do something (future tense).

- Describe your completed observations and procedures (e.g., the Methods and Results sections) and published research in the **past tense**.

We **obtained** samples from three different sites.

1. For more information, see Indiana University's Academic Style Guides on the Singular Pronoun 'They.'

Leaf area **increased** in plants grown under higher light intensities.

McGee (2010) **reported** that taller Biocore students **wore** larger shoes.

- Use the **past perfect tense** when events are repeated or continued from the past to the present.

Gall formation in goldenrods **has been studied** in many geographic locations.

- Describe generalizations, conclusions, and references to conditions that continue to be true in the **present tense**.

Streptomycin **inhibits** the growth of *M. tuberculosis*.

Our data suggest that algae, like all autotrophs, **require** and **may be** limited by light, water, gases, and mineral nutrients.

## PUNCTUATION

- **Comma:** Include commas after each word, phrase, or clause in a series, and before the conjunction separating the last two.

Grasses, legumes, and composites grow in Wisconsin prairies.

Commas should follow *that is*, *for example*, *moreover*, *i.e.*, and *e.g.*

**For example**, most Iron Age graves consist of burial mounds sheltering only one individual.

The Nature Conservancy has completed a preliminary series-level (*i.e.*, dominant plant species) classification for the western United States.

- **Semicolon and Colon:** Use a semicolon between parts of a compound sentence (two or more independent clauses) not connected by a conjunction, such as *and*, *but*, or *or*.

Light consists of energy packets called photons; the shorter the wavelength of light, the more energy in its photons.

Put a semicolon before, and a comma after, each conjunctive adverb, such as **moreover**, **therefore**, **nevertheless**, **consequently**, or **furthermore**, when connecting two parts of a complex sentence. Use commas when these words are used at the beginning of a sentence or when they are part of a simple sentence. (In general, avoid these “filler” words as much as possible!)

The deionized water was not available; *however*, we still completed the experiment.

*Therefore*, the results were significant.

Researchers working in other areas, *however*, failed to document the importance of competition, predation, and disturbance.

Use semicolons when **commas occur within one or more** of the elements of a series.

Familiar examples of species that are extremely vulnerable to human activity are the northern

spotted owl, threatened by logging of old-growth forests in the Pacific Northwest; the red-cocked woodpecker, endangered by logging of longleaf pine forests in the Southeastern Coastal plain; and the desert tortoise, often shot or run over by motorized recreationists.

Three cities I will visit are Madison, Wisconsin; Northfield, Minnesota; and Chicago, Illinois.

Use colons to introduce a part of a sentence that **expands or clarifies** the meaning of what precedes it.

The instructor expects the following students to complete their lab reports early: Anna, Dmitry, Jaafar, and Darla.

- **Quotation Marks:** Place a comma or period inside the quotation marks whether or not it is part of the quotation; place punctuation other than a comma or period outside the quotation marks unless the punctuation is part of the quotation.

We don't label data as "good" or "bad"; however, we can label them "surprising."

- **Parentheses:** Use parentheses (these things) sparingly. If the words you are enclosing within a parenthesis are not important enough to be included in the sentence, they may be superfluous. Use parentheses for comments or explanations that are independent of the sentence.

Solar energy is the basis of virtually all food chains (rare exceptions include chemically based communities in deep-sea vents) and is converted to chemical energy by photosynthetic plants.

Use parentheses to **enclose abbreviations and acronyms** after they are spelled out.

The Global Biodiversity Strategy (GBS) was developed by the World Resources Institute (WRI) and the United Nations Environmental Program (UNEP).

- **Underlining and Italics:** Italicizing and underlining are used for the same purposes. Italics are preferred and are easy to do with a computer. Italicize the titles of books and periodicals.

Curt found the article in the journal *Ecology*.

Italicize **a genus or species name** (and capitalize the genus name).

Poison ivy (*Toxicodendron radicans*) produces a secondary compound which causes an irritating rash on the skin of many people.

Italicize **foreign words and abbreviations** based on them (e.g., the abbreviation e.g.)

- **Dangling Participles:** Participles are verb forms having qualities of both verb and adjective. In the present tense, participles frequently end in *-ing* (*asking*); in the past tense, participles commonly end in *-en* or *-ed* (*asked*, *spoken*). Dangling participles are participles (often acting as adjectives) that modify the "wrong" noun.

**POOR:** A bubble was observed in *the jar using a magnifying glass*. (The jar is not really using a magnifying glass!)

**BETTER:** We used a magnifying glass to observe a bubble in the jar.

- **Abbreviations, Acronyms, Numbers:** Write out a term the first time before abbreviating it.

The enzyme isocitrate dehydrogenase (IDH) catalyzes the oxidation of...

**Express numbers as figures;** do not write out the number name. A sentence, however, should never begin with a figure:

*Twenty-two* gazelles ran past me. Next I counted 10 antelope.

# References on Writing

- Booth, V. 1993. *Communicating in science: writing a scientific paper and speaking at scientific meetings*, 2nd ed. Cambridge University Press, Cambridge, U.K.
- CBE Style Manual Committee. 1983. *CBE style manual: a guide for authors, editors, and publishers in the biological sciences*, 5th ed. Council of Biology Editors, Inc., Bethesda.
- Day, R.A. 1994. *How to write and publish a scientific paper*, 4th ed. Oryx press, Phoenix.
- Knisely, K. 2009. A student handbook for writing in biology 3rd ed. Sinauer Associates Sunderland, MA.
- Kuyper, B.J. 1991. Bringing up scientists in the art of critiquing research. *Bioscience* 41: 248-250.
- McMillan, V.E. 1988. *Writing papers in the biological sciences*. St. Martin's Press, New York.
- Pechenik, J.A. 1993. *A short guide to writing about biology*, 2nd ed. Harper Collins, New York.
- Strunk, W.I. and White, E.B. 1979. *The elements of style*, 3rd ed., Macmillan, New York.
- Turabian, K.L. 1987. *A manual for writers of term papers, theses, and dissertations*, 5th ed. University of Chicago Press, Chicago.
- Weston, A. 1992. *A Rulebook for arguments*, 2nd ed., Hackett, Indianapolis.
- Zinsser, W. 1988. *Writing to learn*. Harper and Row, New York