Communicating the Results of Scientific Investigations[1]

While many people investigate the world for the pure love of discovery, science is only made complete when discoveries are communicated. Many scientists love to do this as well. Below we describe three ways scientists convey ideas to their colleagues: scientific papers, posters, and oral presentations. Each has distinct forms and conventions, although the similarities among them should also become clear. We describe how to approach each type of communication, their conventions, and our methods of evaluating them. As in all courses, it is important that you check your instructor's expectations.

The Scientific Paper

What is a scientific paper and why do we write them?

A scientific paper is a formal way for working scientists to report the results of original investigations in a public and permanent fashion. Papers appear as articles in scientific journals published in print and online. Due to the importance of this "primary literature" in informing new investigations, articles published in journals undergo rigorous peer review for clarity, accuracy and importance. We want you, as a working scientist, to understand this process and contribute to the primary literature through your own investigations.

General advice

Like papers in non-science courses, your scientific papers should be well written, creative, and thoughtful. The purpose of a scientific paper is similar to other academic writing. It is a narrative of your investigations and an argument about their meaning. In many ways, the principles of scientific writing are the same as academic writing in other disciplines:

Audience -- Knowledge of audience will help you decide what terms or ideas you need to define and how formal to make your language. Assume the audience consists of peers, i.e., unknown readers with a similar background in the subject matter as your classmates.

Brevity -- Scientific writing is often described as concise and non-ornamental. This does not mean it has to be boring.

> Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that every word tell. (Strunk and White 1979)

Structure -- The structure of writing helps convey your narrative and arguments clearly. The *Advice to Authors* (below) discusses the purpose of specific sections of a scientific paper. However, the careful construction of your writing should be apparent at all levels: sections, paragraphs and sentences.

Conventions -- As in most disciplines, scientific papers need to conform to particular stylistic conventions; in journals these rules are given in the editors' *Advice to Authors* (see below). It is important to understand the similarities and differences in the conventions and to inquire about specific expectations and requirements of individual professors.

There are three aspects of scientific writing conventions that bear special mention:

Voice -- . Discuss the following passages with your instructor to make sure you understand the conventions and expectations for use of passive and active voice for papers for a particular class.

From Alley's (1996) *The Craft of Scientific Writing:*

> Many scientists and engineers hold the misconception that scientific documents should be written *in the passive voice*. Not true. Because the purpose of scientific writing is to communicate (inform or persuade) as efficiently as possible, and because the most efficient way to communicate is through straightforward writing, you should use the most

[1] This document consists entirely of direct excerpts of the *Grinnell College Investigations Manual*. The complete manual is freely available at http://www.grinnell.edu/sites/default/files/documents/investigations_fall_12_0.pdf.

> straightforward verbs available. Needless passive verbs slow your writing; they reduce your writing's efficiency. . . . Is passive voice wrong? No. Although the *active voice* ("The oscilloscope displayed the voltage") is stronger than the passive voice ("The voltage was displayed on the oscilloscope"), there are occasions when the passive voice is more natural. For instance,
>
> > On the second day of our wildebeest study, one of the calves wandered just a few yards from the herd and was attacked by wild dogs.
>
> In this example, there is nothing wrong with the passive verb "was attacked" because the passive voice allows the emphasis to remain on the wildebeest calf, which is the focus of the paragraph. The key to choosing between an active and passive verb is to ask which form is more natural. . . .
>
> Some passive voice arises in scientific writing because scientists cling to the misconception that they can never use the first person ("I" or "we"). . . . As long as the emphasis remains on your work and not you, there is nothing wrong with judicious use of the first person. . . . First, you should reserve the use of the first person for those occasional situations in which your role in the work is important – for instance, when you make an assumption. Second, you should avoid placing the first person (either "I" or "we") as the beginning word of a sentence, because that position receives heavy emphasis. Instead, have the first person follow an introductory adverb, infinitive phrase, or dependent clause.

From Day and Gastel's (2006) *How to Write and Publish a Scientific Paper*:

> Let us now talk about *voice*. In any type of writing, the active voice is usually more precise and less wordy than is the passive voice. (This is not always true; if it were, we would have an Eleventh Commandment: "The passive voice should never be used.")
>
> As noted in Chapter 11, the passive voice sometimes functions well in the Methods section. Elsewhere in the scientific paper, however, it rarely should be used.
>
> Why, then, do scientists use so much passive voice? Perhaps this bad habit results from the erroneous idea that it is somehow impolite to use first-person pronouns. Because of this idea, the scientist commonly uses verbose (and imprecise) statements such as "It was found that" in preference to the short, unambiguous "I found."
>
> Young scientists should renounce the false modesty of their predecessors. Do not be afraid to name the agent of the action in a sentence, even when it is "I or "we." Once you get into the habit of saying "I found" you will also find that you tend to write "*S. aureus* produced lactate" rather than "Lactate was produced by *S. aureus.*

Quotation -- **Never use quotation without consulting your instructor.** Quotation is extremely rare in scientific primary literature articles and used only when the author is trying highlight the *exact words* used by another investigator. Compare articles in biology and chemistry journals with those in the social sciences or humanities to appreciate how different these practices are between disciplines. Paraphrase your sources carefully, and cite your sources according to the conventions of the particular journal (see below). **Please remember, however, that this rule does not grant permission to use verbatim language from sources without quotation marks!**

Authorship -- Instructors expect students to work together to discuss the results of laboratory work and other group assignments. However, all work handed in to the instructor (quizzes, exams, problem sets, lab data analysis, papers, peer reviews, etc.) should be the work of the individual student *unless the instructor gives written permission for submission of group work.*

Specific Advice -- Investigations "Advice to Authors"

Identify the author(s) on the first page, use double-spacing with 1 inch margins, and number each page. If your instructor asks for an electronic submission, name the file with your name and an indication of the subject of the paper (e.g., RWeasley_Chemotaxisassay.docx).

Scientific papers usually contain sections in order: Title, Abstract, Introduction, Methods, Results, Discussion, Acknowledgments, and References.

Title

The title tells *what* the paper is about, so the best time to determine it is after you have completed your paper. A title should be informative, specific and concise. Since you are not writing a murder mystery, it is all right to tell the "ending" in the title. It is often this information that helps a reader decide if the paper is something s/he wants to read.

Under the title, place your name and "professional address," which here is your specific course and laboratory section. This information should either be placed alone on a *title page*, or at the top of the first page in order to save paper (ask your instructor).

Below are examples of titles that (1) tell the reader very little about the investigation (**Bad)**, (2) give specific information about the type of investigation, though they fail to inform the reader about the nature of the results (**Better)**, and (3) indicate the objective and primary conclusions of the investigation in a concise manner (**Very Good)**.

Bad: "Lab 1: Heart Lab"
Better: "The function of frog hearts"
Very Good: "Epinephrine Increases the Strength but not the Rate of Contraction of Frog Hearts"

Bad: "Laboratory exercise: Water analysis"
Better: "Drinking water quality in four samples"
Very Good: Source influences drinking water calcium content

Bad: "Laboratory Exercise: Greenhouse Gases"
Better: "Infrared Spectroscopy of Greenhouse Gases"
Very Good: "Molecular motion influences greenhouse gas properties"

Abstract

The abstract is a summary of each major part of the paper; it includes a brief introduction to the problem being studied, a brief statement of how the study was conducted, a brief summary of the major results, and a brief statement of the significance of those results. An abstract is usually between 100-200 words. Make every word count, so you can convey the most information in these few words. Clearly, it is best to write this section after you have written each of the four sections summarized in the Abstract.

Introduction

The introduction should briefly describe the background information for the reader to understand *why* the investigation was done. This should include the reasons for choosing the question being asked (why is it interesting?), some background on the system under investigation, and, if applicable, justification for hypotheses. A good introduction will mention the major issues that will be considered in the *Discussion* section, and that is why it may be helpful to write it, and particularly revise it, after finishing the other sections.

There are many ways to organize an introduction depending on its length and audience, but one principle is to begin by developing the general importance of your question, then move to the ideas leading to your specific study and question. Assume that the reader is at least moderately familiar with the general subject of the paper. If you are using a particular experimental method, provide a rationale for having selected it. If your study tests a particular hypothesis, you might end your introduction by stating your hypothesis (with justification, of course) and describing in the most general terms how your investigation addressed it.

Methods

This section should carefully explain *how* the research was done. The level of detail should allow the reader to know exactly what you did and be able to repeat your study. Organize the sections logically, and not necessarily chronologically; the Methods section is not a diary of what you did every day. Use subheadings if there are more than a few paragraphs. Include all materials used, *but do not make lists.* Describe the exact conditions employed, how you gathered the data, and how you analyzed it precisely enough that someone else could repeat it. You may cite the lab manual or other sources for common techniques. If you develop your own technique, explain it in sufficient detail that another person could replicate your work. If you are doing a field study, indicate the location of the study and the dates on which it was carried out (since this may be important to the results). Do NOT do this for a laboratory study.

Fatal flaws: Do not present your Methods as a diary or the materials as a list. Write in complete sentences and organized paragraphs.

Below are some examples of good and bad Methods section practices:

Bad:

- “We measured growth rates and wrote down the data.” How did you measure growth rates? You don’t need to tell the reader that you recorded the data or entered it into the computer.

- “The data were entered into Excel for manipulation.” Likewise, graphical or spreadsheet programs do not need to be mentioned.

- “The cells were washed in saline and resuspended in medium.” What solution did you use to wash the cells?

- “Student t-tests are based on the principle…” Commonly used statistical tests generally need no explanation or citation. You should mention, however, what techniques were used to test which predictions.

Good:

- "We used a t-test to determine whether mean photosynthetic rates differed between the two light environments."

- “We prepared 5 solutions ranging in concentration from .0050M to .010M, by serially diluting a solution of .050M silver nitrate.”

- “We pelleted cells at 5000 x g for 5 minutes and then washed them in 0.05 M NaCl. Cells were pelleted again and resuspended at a concentration of 108 cells per ml in peptone-glycerol broth.”

Results

Raw data you have collected should not appear in your paper. Rather, the *Results* section should summarize your findings and present your data for the reader to evaluate. One good way to approach the text of the Results section is to develop a set of questions about the data you gathered. Do not use questions that begin with “Why” -- these necessarily involve interpretation and should be addressed in the *Discussion* section. Write your Results section by answering each of these questions in a logical order. Refer to Figures and Tables as you describe the results.

Graphs and tables help the reader understand complicated data more easily than a written description. Note, however, that if the data can be easily summarized in the text, a figure or table is not necessary. The text should tell the reader the important points trends shown on the graphs or tables. Obviously the same data should not be presented in two different forms (e.g., a table should not contain data also summarized in a graph), so decide which format best informs your reader. Refer to graphs of any kind, as well as other pictorial materials, as “Figures” in the text. Call rows and columns of numbers and text “Tables” and number them separately from figures. Number tables and figures in the order in which you refer to them in the text. Call out each figure and table in the text. Ask your instructor whether tables and figures should be imbedded in the text, or placed in order at the end of the paper.

Discussion

The role of the *Discussion* section is to interpret the meaning of your results. Proceed in this section from the specifics of your study to the general question that motivated the study (just the opposite from the Introduction!). Consider addressing the following points in order:

1. Remind the reader of important trends in your data and how those results relate to your hypothesis or goals.
2. Provide an explanation for the most interesting or relevant results. This might include references to other studies that showed similar or different results. Include references that help support your explanations.
3. Discuss the relevance of your results and their interpretation to the larger questions that motivated the study.
4. End the discussion with a summary, the “take home lesson” that you want your reader to remember about your work. Indicate interesting future directions for study, rather than simply summarize (again) your results. In other words, build on the interpretations you have just provided, so that those arguments in the previous paragraphs matter. Some papers have this summary as a *Conclusion* section.

The length of the Discussion section depends on the scope of your study. A good way to approach the writing of this section is to consider each of the above points as the subject of a short paragraph. You can later expand or combine these after laying out your ideas.

Here are some tips on common errors in Discussion sections:

- Do not infer that because your hypothesis wasn't supported, you made a mistake. "Negative" results can be important too, since they may suggest that your hypothesis was incorrect. What would be the benefit of testing hypotheses, if you could never reject them? If you did make an error somewhere in your investigation, acknowledge it and move on.
- Do not omit or minimize discussion of findings that you did not expect. Such results are often the most interesting.
- Do not center your discussion around a proposal to repeat your experiment with a larger sample size! This is often true and not as interesting as suggestions for new investigations that arise from your findings.
- Do not end the paper with the phrase, ". . . but of course more work needs to be done." Describe what *kind* of work would be the most interesting extensions of the study and why.

Acknowledgments

In this section, thank any persons who contributed any significant help during the study. Such contributions include help in experimental design, collection of data, preparation of graphs, drawings or the manuscript, critiquing a draft of the manuscript, and financial or physical support of the work. Always acknowledge your partners in group projects!

References

Standards for citation vary somewhat among journals. When scientists submit a paper for publication, they read and adhere to the guidelines set for each particular journal. In the same manner, you should think of each paper you submit as needing to adhere to the guidelines set by each particular professor.

List only the papers or other publications that were *directly cited* in your paper. A References section is not a bibliography. Citing a paper means you read it -- reading the abstract is NOT sufficient, unless specifically allowed by your instructor.

Cite references in one of two ways in the text of your paper:

1. Mention the authors' names as part of your sentence followed by the year of publication in parentheses. When there are three or more authors, give the first author's last name, followed by "et al." (Latin for "and others"):

Sullivan et al. (1998) described the use of delta-crystallin as a marker of lens induction during differentiation.

2. Place authors' names and the year of publication in parentheses following ideas or results from the article:

Experimental studies of several species indicate that tradeoffs between growth and male function may not be predicted by resource allocation models alone, unless meristem availability is also considered as a resource (Eckhart and Seger 1999).

List references alphabetically according to the first author. Standards for the reference sections vary widely among journals, primarily in details of punctuation. Please use the appropriate form for each type of reference below:

Journal article:
Author(s). Year. Title. *Journal* Volume:pages.

Sullivan, C.H., P.C. Marker, J.M. Thorn, and J.D. Brown. 1998. Reliability of delta-crystallin as a marker for studies of chick lens induction. *Differentiation* 64: 1-9.

If you cite more than one paper by the same author(s) the papers should be listed chronologically (earliest first).
If a paper has more than five authors, use "et al" list the first five.

Book chapter of edited volumes
Author(s). Year. Title of chapter. *In* Editors names (eds.). Title of book. Publisher, Place of Publication, pages.

Eckhart, V.M., Seger, J. 1999. Phenological and developmental costs of male sex function in hermaphroditic plants. *In* Vuorisalo, T.O. and Mutikainen, P.K. (eds.). Life history evolution in plants. Kluwer, Dordrecht, pp. 195-213.

Book
Author(s). Year. Title. Publisher, Place of Publication.

Voyles, B.A. 1993. The biology of viruses. Moseby, St. Louis.

Web pages (use sparingly!)
Author. publication date. Page title. Site title. URL. date you accessed it.

Harr, J. 2002. Plants of Cedar Creek – Asteraceae. Cedar Creek LTER. http://cedarcreek.umn.edu/plants/narratives/asteraceae.html . 7 January 2004.

Evaluation of Scientific Papers

Evaluation and revision is the key to better writing. This means you must start writing early, finish a complete draft well before the due date, seek out reviewers, and revise. Scientists never send manuscripts to journals without having several people not associated with the study read and evaluate it. A good reviewer reads critically, i.e., s/he lets the author know both the strengths and weaknesses of the writing. People who just like to tear things (and people) apart, or who are afraid or unwilling to point out problems, are equally useless as reviewers. So who should review your manuscript? The candidates:

The author -- Take some time away from your paper and then come back to it as a reviewer. Read it aloud. How does it sound? Does one sentence flow to the next? Is there needless repetition? Do your explanations make sense? This may sound foolish, but it is a tested method. It may also help you learn to recognize your own bad writing habits.

Other students -- Since other students are your intended audience, why not test out the paper on one of them? You may want to pick someone NOT in your class, particularly if all members of the class are writing a paper on a similar topic. Your reviewer should be thanked in your *Acknowledgments* section.

The professor -- Your instructor may be willing work with you on your paper. Make an appointment well ahead of time (professors have busy schedules) and come in well prepared to discuss *specific* aspects of the paper. Don't expect your instructor to read a full draft at a moment's notice to screen for problems.

Do you get the sense that all this can't be done the night before the due date?
You got it.

The Scientific Poster

What is a poster and why do you do it?

Professional scientists regularly present the results of their work at local, national, and international meetings. At most scientific meetings, posters are the primary means by which scientists exchange information about their work. The poster, although a smaller unit than the published journal article, is thus a fully professional entity, and almost always the first form in which your story is made public. It is also the most egalitarian form of presentation in that tenured researchers and students alike use it. Its principal advantage is that it promotes extensive two-way communication between the presenter and the audience. Not only are results and conclusions presented to the audience, but also the presenting scientist usually receives ideas and suggestions that help in planning future experiments.

What is a poster? A poster is a visual way of presenting scientific results. A good poster is virtually self-explanatory; it will contain the elements of a paper (Title, Abstract, Introduction, Materials and Methods, Results, Discussion, Conclusions, and References), but it is a distinct form in which different elements are emphasized.

Contents of a Scientific Poster

Title and Author Panel

The title should be descriptive but short, in **boldface** letters 1.5 inches high. The authors' names may be somewhat smaller.

Abstract

This is a short (50-100 word) summary of your research. It should be completely self-contained (that is, independent of the rest of the poster). This is the one portion of a poster that is commonly published.

Introduction

Here you introduce the topic of the work, briefly summarize any relevant background information, including a short review of the work of other investigators, and succinctly state the objectives or hypothesis.

Methods

Unless the primary focus of the poster is the novelty of its experimental methods, this section should be kept to a minimum. There must, however, be sufficient detail to permit the reader to understand what was done and evaluate the appropriateness of the experimental design and technique.

There is some disagreement, both within biology and between biologists and chemists, over how long this section should be and what it should contain. Some alternatives:

- Include relevant methods within the text associated with figures in the Results section, and don't include a separate Materials and Methods section at all.
- Include a Materials and Methods section, but make it extremely brief and heavily larded with citations (including the lab manual); additional methodological details may be included in figure legends when necessary.
- Use bulleted lists of procedures; sketches, figures, diagrams, or photos of equipment; and a listing of conditions. If detailed materials and methods are required, they may be appended in smaller type.

Check with your instructor to find out what s/he prefers.

Results

This is a **summarized** report of your observations, not your interpretation of the results. Present your results in a logical sequence, not the sequence in which they were obtained. Remember that this is primarily a visual, rather than verbal, presentation. Graphical representation of data is almost always more effective than tables or text. Use text only to explicate the figures and, if necessary, to make transitions between figures. Number all figures and tables consecutively (e.g., Fig. 1, Fig. 2, Table 1, Table 2, etc.). Raw data should be included only when <u>absolutely</u> necessary; if in doubt, ask your instructor.

Discussion
Here you analyze and discuss your findings, though less expansively than in a paper. Summaries such as numbered or bulleted items may be used. You should point out the general meaning and importance of your results, and relate them to those of other investigators (be sure to cite their work appropriately!). You should also include a description of further work that could be done in this area.

Conclusions
This includes a few brief and concise statements summarizing your work.

References
Here you should list sources that were cited in your poster.

Acknowledgments
You can acknowledge funding sources, individuals, facilities, and personal conversations that aided you in your research.

Presenting a poster
Be ready with a short oral summary of the main points of your poster. A concise synopsis of the purpose of your experiments, the results you achieved, and the conclusions you draw is very useful. Also, prepare brief explanations of the important features of each panel, particularly for those including tables or figures. This preparation will allow you to "walk through" the poster with anyone who expresses interest.

The Scientific Presentation

What is the role of a 15-minute oral presentation?
Scientific presentations, like posters, are ephemeral. You have only a brief interval in which to convince others of the significance of your data and leave a lasting impression. Every effort must be made to make it easy for the audience to comprehend and remember the main points of your talk.

How should a scientific presentation be organized?
As with a paper or poster, one way to ensure that people will remember your main result is to include it in the title. Repetition is also important, both within the structure of the talk and in reinforcing the main points on a figure or slide with what you say. In the words of an old adage, first you should tell people what you are about to tell them, then you should tell them, and in conclusion you should repeat what you told them.

Many students prefer to use PowerPoint, a computer program that permits electronic versions of slides to be projected onto a screen, while others are more comfortable with overheads. Ask your instructor what s/he prefers.

Here are a few tips for talks:

- A talk should include an Introduction, Materials and Methods, Results, Discussion, and Conclusions. A talk is therefore structured much like a paper or poster. A talk is unlike a paper in that it is advisable for you to offer a brief interpretation of your results immediately after describing the results to the audience, while the relevant figure is still being shown.

- A common problem is running over the time allotted for a. A good rule of thumb is to allocate about a minute per slide. If you have 30 slides or overheads to squeeze into a 15-minute talk, chances are you won't make it. Keep in mind that you should allocate 2-3 minutes for questions at the end of your talk, which means that only 12-13 minutes of a 15-minute talk should be taken up by you.

- Try to maintain a high information-to-ink ratio. That is, don't include any information that is not relevant to your point. It is often especially difficult to cleave to this rule in PowerPoint presentations, where it's easy to get caught up in the glitz and gimmicks! Focus on content and clarity, rather than flash. Often, flash not only is irrelevant, but also actively prevents the viewer from perceiving content. For example, while it is fun for you to play with presentations that move around on the screen, an audience will be sufficiently distracted that it will be unable to hear anything you say while the movement is being visually tracked.

- Limit the amount of information on each slide. A good slide will include no more than 5 points. If slides include figure or data tables, they should also include a line of text identifying the main point. If you feel that you need to make more than 5 points, make another slide.

- You cannot include more points by talking faster! The audience will not hear what you have to say unless you are speaking at a rate of about 100 words per minute or slower.

Giving group presentations

Usually the easiest way to give a group presentation is to assign responsibility for particular sections of the talk to particular members of the group. While this may streamline production, it results in a poor talk unless the entire group gets together to discuss everything before and after working on each section. You need to know what will happen in the other sections of the talk in order to do a good job on your section. This is especially important because poor transitions between segments can lose an audience.

Handling questions from the audience

- Wait for the questioner to complete his or her question before you begin to answer, and then repeat the question so that everyone in the room can hear.
- Never interrupt unless the question is extremely vague and rambling. If you must interrupt, do so tactfully, and attempt to rephrase the question.
- Take a moment to think before answering, and don't be afraid to ask for clarification if you aren't sure what the question means. Questions that arise during the course of the talk should be answered immediately if they resolve ambiguities in the presentation, and postponed if they will interrupt the flow of the talk and distract the audience.
- If you don't know the answer to a question, you should just say so. You can use this as an opportunity to query the audience, suggest sources where the questioner might find the answer, or offer to find out the answer and get back to the questioner at a later time.

An excellent website where you can get more tips on preparing talks:
http://www.kumc.edu/SAH/OTEd/jradel/effective.html

Scientific Paper Evaluation Form (1)

Name _________________

Your grade on this paper reflects my evaluation of how you've done in 5 major areas, as listed below. The "bottom line" is an integration of these factors expressed in a fashion similar to how journals evaluate manuscripts.

Explanation of logic and design of study

1. Question or design not evident.
2. Both question and design stated, but not developed effectively.
3. Question clearly stated and design appropriately described.
4. Significance of question clearly stated and design elegantly described.

Data Analysis and Presentation

1. Inappropriate or inadequate.
2. Adequately analyzed and presented.
3. Efficiently and clearly analyzed and presented.
4. Elegantly analyzed and presented.

Data Interpretation

1. Conclusions inadequate and/or inappropriate.
2. Conclusions are explained and justified.
3. Conclusions are clearly related to the question.
4. Demonstrates intellectual creativity by putting conclusions in a larger context and/or proposing *interesting* directions for future research.

Use of the primary literature

1. No citations or inappropriate citations.
2. Citations used perfunctorily.
3. Citations used appropriately.
4. Significant synthesis and integration of citations.

Overall quality of writing

1. Unacceptable.
2. Acceptable.
3. Well-written.
4. Elegant.

ACCEPTED NOT ACCEPTED ACCEPTED WITH MINOR REVISION ACCEPTED WITH MAJOR REVISION

Scientific Paper Evaluation Form (2)

Title

___ Does the title give an accurate preview of what the paper is about? *(i.e. Is it informative, specific and precise?)* *3 pts*

Abstract

___ Are the main points of the paper described clearly and succinctly? *3 pts*

Introduction

___ Does the Introduction have a logical organization? *Does it move from the general to the specific?* *5 pts*
___ Has sufficient background been provided to understand the paper? *How does this work relate to other work in the scientific literature* *5 pts*
___ Has a reasonable explanation been given for why the research was done? *Why is the work important? What is its relevance*? *5 pts*
___ Is the final paragraph a brief description of the hypothesis/goals and findings of the paper? *5 pts*

Materials and Methods

___ Could the study be repeated based on the information given here? *4 pts*
___ Is the material organized into logical categories? *4 pts*

The materials and methods should be a source of detail about the experimental approaches of the authors. Procedures that have been repeated by the authors should only be listed once. Variations to the procedure should be briefly summarized. *(The M&M should not read like a recipe).*

Results

_____ Is the content appropriate for a results section? *10 pts*

- Simple introduction to the scientific question
- Brief description of the methods
- Clear description of the results for each experiment
- Analysis of those results

___ Are the results/data analyzed well? *5 pts*

- Given the data in each figure, is the interpretation accurate and logical?
- Is the analysis of the data thorough or are some aspects of the data ignored?
- Does the author make connections between different sets of data within the text?
- Are the data interpreted in a larger context?

___ Figures *5 pts*

- Are the figures appropriate for the data being discussed?
- Are the figure legends and titles clear and concise?

Note: The entire experimental findings of a paper should be apparent from reading the results section. It should be possible to understand the question the authors are asking, the experimental approach they use to answer the question, the results of those experiments, and basic analysis of the data. Larger issues of what the research means, how it relates to other work, etc should be included in the discussion.

Discussion

___ Does the author clearly state whether the results answer the question? *(i.e. support or disprove the hypothesis?)* *5 pts*
___ Were specific data cited from the results to support each interpretation? *Does the author clearly articulate the basis for supporting or rejecting the hypothesis* *5 pts?*
___ Does the author make connections between data sets within the paper? *5 pts*
___ Does the author adequately relate the results of the current work to previous research? *10 pts*

References

___ Are the references appropriate and of an adequate quantity? *5 pts*
___ Are the references cited properly (both within the text and at the end of the paper)? *5 pts*

Writing Quality

___ Is the paper well organized? (Paragraphs are organized in a logical manner) *7 pts*
___ Is each paragraph well written? (Clear topic sentence, single major point) *7 pts*
___ Is the paper generally well written? (Good use of language, sentence structure) *7 pts*

Scientific Poster Evaluation Form (1)

1. Scientific merit:
   - Is the hypothesis stated clearly and is it discussed in light of what is already known about the question?
   - Is sufficient background material presented to adequately understand the rationale for the experiment?
   - Are the methods appropriate for answering the experimental question and carried out accurately?
   - Is the Materials and Methods section sufficiently clear so that someone else in the class could repeat the experiment?

2. Presentation and discussion of results:
   - Are the data clearly and accurately presented in the tables and/or figures?
   - Are the results discussed clearly in the context of the hypothesis? That is, do they indicate an answer to the experimental question?
   - Are the results discussed in relation to other published findings?
   - Are the statements and results of others referenced properly?

3. Overall quality of the poster presentation:
   - Is the visual quality of the poster adequate?
   - Are the sections of the poster organized in an appropriate and meaningful manner?

Scientific Poster Evaluation Form (2)

1. Does the poster have adequate background information allowing you to understand why the investigation was done?
   strongly disagree / disagree /agree / strongly agree
   Explain:

2. Does the poster have a clearly stated hypothesis or question?
   strongly disagree / disagree /agree / strongly agree
   If so, what is it? If not, explain.

3. Does the methods section adequately detail how the investigation was carried out?
   strongly disagree / disagree /agree / strongly agree
   Explain:

4. Does the poster present the results in figures and tables that are easy to understand and appropriate for the data?
   strongly disagree / disagree /agree / strongly agree
   Explain:

5. Did the presenter do a good job explaining the investigation?
   strongly disagree / disagree /agree / strongly agree
   Explain:

6. Summarize the major conclusions and relate these conclusions back to the original hypothesis or question.

Oral Presentation Evaluation Form

Presenter(s): Reviewer:

Comments on scientific merit of the project

Comments on depth of understanding

Comments on team work

Introduction. The study's rationale was **Comments**

1. not clearly evident
2. evident, but not developed
3. clearly stated and appropriately developed
4. stated and developed elegantly

Materials and Methods. The study's design was

1. inappropriate and/or inadequate
2. evident, but not developed
3. stated clearly and efficiently
4. stated elegantly

Results. Data analysis and presentation were

1. inadequate and/or inappropriate
2. adequate
3. clear and efficient
4. elegant

Discussion & Conclusions. Data interpretation was

1. inadequate and/or inappropriate
2. explained and justified
3. clearly related to question
4. intellectually creative, in placing conclusions in larger context and/or proposing *interesting* directions for further research

Visual aids were

1. not clear and/or not helpful
2. adequate
3. clear and efficient
4. elegant

Overall quality of speaking (eye-contact, volume, clarity, organization) was

1. unacceptable
2. adequate
3. clear and articulate
4. elegant and entertaining

Responses to questions were

1. unacceptable
2. adequate
3. clear, respectful, and informative
4. exceptionally insightful