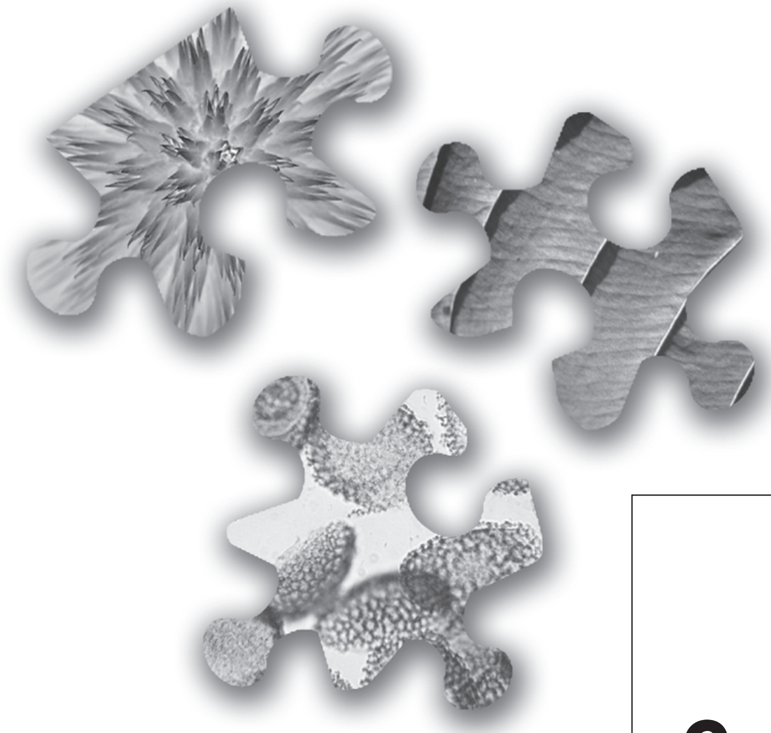


Guide to Success

- What is this lab about?
- What is expected of you?
- How to use this manual
- How does lab fit into the grade for the course?
- How to conduct a laboratory successfully
- How to write a lab report

I. What is this lab about?

A. Reinforcing lecture

This may be the first answer that enters your mind when asked "What is the lab about" and it is probably what you are familiar with from your experiences with science classes. In lecture you learn facts and concepts, in lab you demonstrate these facts and concepts. Ideally, in the morning your instructor talks about some scientific principle and in the afternoon you see it at work through some cleverly written, step-by-step experiment or demonstration. But this is not the case in this course. Yes, we want you to discover things related to lecture, but we want you to go beyond blindly following directions just to get the correct answer and get done. We want you to learn something about how scientific discoveries are made.

B. Learning the process of science

Scientists do science because it is fun. Scientists like solving puzzles and designing experiments to learn how things work the way they do. Scientific discoveries are made when someone thinks about how something works or what causes it to happen, then tests the idea and succeeds in persuading his/her colleagues that there is sufficient evidence for his/her ideas to warrant general acceptance. This is the process of science and it is something you should experience in a science class. This is what should be done in lab. Lab is, above all, learning by doing or, perhaps, learning by doing, doing and failing, thinking, and doing again. In lab, you should learn to draw ideas from what you see and do. In lab, you should learn how to provide evidence to support your ideas and how to critique the evidence provided by others. In lab, you should learn that the right answer is the answer that has the best support.

So, yes, you will learn specific biological facts and concepts in lab. Some will be obvious and, perhaps, be readily learned through a simple lecture. But working through problems in lab should help you learn these more completely and help you retain the knowledge longer. More importantly there will be many other lessons, concepts, ways of thinking, and skills you will learn as a result of inquiry in the laboratory that cannot be learned in lecture alone.

C. What will you be doing in lab?

The labs in this course are different from ones you have previously experienced, or so we hope. Labs are organized around general questions and stories that should inspire you to come up with related hypotheses and experiments. Sometimes you will be given very specific procedures to follow, most of the time you will not. In almost every lab, you will have at least some control over what you choose to do, what you choose to test, how you test, etc. In some cases you will have a very good idea of what the results will be and what they mean before you come to lab. In other cases, the lab will serve as your first introduction to some topic. All of your labs will require data collection, problem solving, and reporting your results.

D. Should we be ahead of or behind lecture?

This is always an interesting debate. When labs precede lectures, then students have experiences to bring to lecture and help them visualize what is being discussed. Students can enter more fully into discussions and have data and observations in their minds. Lectures then help students see how what they did in lab fits together and add terms and explanations to what they have already done and figured out. When lectures precede labs, students have some theoretical knowledge about what is about to happen and lab can be a time to test what is discussed in lecture and to ask questions of their lab instructors.

We are going to try to do both. The labs are designed so that parts of the question under investigation will introduce new concepts that will be discussed later in lecture. Other parts of the question will clearly relate to earlier lectures or earlier labs. Some labs will involve questions posed in lecture. Some labs will require little prior knowledge of the specific topic at hand, others will require a fair amount. Your lecture and lab instructors will have a pretty good idea of what you should know before you go to either lecture or lab.

II. What is expected of you?

A. Be ready to work, explore, and learn

You came to college to learn. We are providing you with the opportunity to do so. To be successful in lab, you have to be ready to work right away, you have to be inquisitive, you have to be willing to ask questions, you have to be ready to try things, you have to be willing to read long sentences spliced together by commas and make sense of them. Many of your questions will be answered by other questions because your lab instructors believe that you can figure out the answers with guidance and will learn better if you do so. If you just come to lab to get it over with, you will be unhappy and be paying for nothing. You get back what you put in.

B. Do the pre-lab assignments (optional—extra credit)

Each investigation includes one or more brief pre-lab assignments that you should complete in the LRC, on the WWW, or at home before attending lab (or even preparing your planning form). Each activity is designed to familiarize you with specific instruments, needed calculations, relevant information, or the type of thinking necessary to complete the lab quickly and successfully. The pre-labs will help you answer questions on the planning forms. The relevant pre-labs are indicated on the planning forms.

C. Come prepared

You have no more than two hours and fifty minutes to complete your work. Can you do it? Sure, if you are ready. There will be pre-lab exercises for the labs, do them! You will have a much better idea what to do and you will have the skills you need when you reach the lab. Read the assigned materials or look up what you think is relevant. Fill your planning form out. These are due the day before lab. Have questions for the instructor.

D. Start immediately

Again, lab is shorter than you realize. The lab instructor will not waste your time with a long introduction. Know what is expected of you before lab and get started right away.

E. Work in groups

All your work in lab will be done as part of a team and you will be required to evaluate each other (see section on Peer Evaluation). Student surveys and interviews, as well as research at other institutions, support the idea that working in groups promotes learning and success. You will most likely be expected to work with others when you graduate from the university—start learning the skill now. Groups ensure that ideas are discussed, plans are reviewed, reports are edited, procedures are followed, and work is performed faster. Working as a team helps individuals because each of you has a talent to share and more minds working on one problem result in a better solution.

What if you don't get along? Or someone slacks off? Or two don't listen to the third who is correct, or…? Learn to negotiate. Learn to persuade. Don't worry if someone appears to be getting by—those who work will learn more and those who don't will not do as well on lecture exams (Did I forget to mention that lab material is fair game for lecture exams?). Your lab instructor will be paying attention and trying to make sure that groups are harmonious, but in the end you must make it work yourselves. This is how it works in the "real" world and how it works here. Better working groups learn more, finish faster, enjoy more, and earn better grades.

F. Write a report

At the end of every lab, each group will hand in a written report. You have the computers and software to do this. You have group members to help you complete it. It should be neat, grammatically correct, and free of spelling and typographical errors. You will not complete it to your or our satisfaction unless you come prepared, start work immediately, and work in groups. This report constitutes the majority of your lab grade.

G. Leave when ready

This lab is competency based. You may leave at any time. To receive credit for the report, you must be there when it is turned in and it must be turned in before you leave. No one will prevent you from leaving, but lab reports will be judged by the highest reasonable standards. So if your group leaves and another announces a finding that improves everyone's reports or negates your findings, well…

III. How to use this manual

This manual is divided into three parts: this introduction to the lab (how to conduct experiments and how to write a lab report); a reference section (how to use the software, how to use the lab instruments, how to analyze data, how to find information, etc.); and an investigations section (lab questions, pre-lab exercises, lab-specific procedures, and planning, grading, and data forms).

Each week you will be assigned a lab question or a hypothesis. Read the corresponding investigation chapter in this manual and begin to plan. Each chapter includes pre-lab exercises. These are designed to help you learn the necessary skills required for completing the lab successfully in the time allotted and to get you thinking about ways to conduct the experiments and analyze the data. Each chapter includes a planning form, which will help you plan for your lab and report; a grading scheme/checklist, which will serve as a guide for the report and the form for your instructor to use in grading; and a lab notes form, which will help you collect data. All of these forms, and any accompanying pre-lab materials, will be turned in each week.

In the reference section of this lab manual, you will find a variety of procedures for measuring, calculating, collecting specific kinds of data, how to use the various pieces of lab equipment, etc. They are not included with the lab procedures or arranged in the same order as the labs. This was done because many of the techniques will apply to more than one lab. It was also done because it is considered part of the course expectations that you learn to plan and select your techniques. That is what researchers do.

Because of the way this lab will run, there will be more than one hypothesis, experiment, test, way of measuring, way of analyzing, etc. for each lab. Thus, there are many ways to succeed. If you come up with an idea that works, or a question to investigate, or a hypothesis to test that we did not think of, great. You are considered successful if you come up with good, relevant, well supported ideas derived from the experiments you conducted.

IV. How does lab fit into the grade for the course?

A. Value

Your grade is based on 1000 total points. You are allowed to earn up to 410 points for lab. Each of the fourteen weekly lab reports is worth 20 points, up to 7 additional points can be earned for each lab for truly exceptional work. Each planning form is worth 10 points. Pre-lab activities earn you up to 3 points "extra credit" each week toward your maximum points. Your lab instructor will grade the planning and pre-lab activities based on the evaluation criteria (grading rubric) that we will provide you (zoology.okstate.edu/zoo_lrc/biol1114/study_guides/labs/pfgrade.htm). You should pay close attention to comments at the beginning of the semester.

You will not be quizzed over material during lab. However, you will be expected to answer questions on the lecture exams pertaining to the labs. While you will not be expected to remember the exact detail of some procedure (how many milligrams of agarose are required to create a gel), you will be expected to be able to relate results or experimental designs to lecture concepts (which of the following graphs of transpiration rate is most likely to reflect a plant placed in a highly humid environment for five minutes?).

B. What if I miss a laboratory?

While we anticipate that this is a rare occurrence, we have developed a system to help students in such situations that does not disrupt their schedules, incur additional costs, or inconvenience other students. We added extra credit opportunities in each lab and in the form of pre-labs that help students learn while they earn points that can be used in the event that planned or unplanned circumstances prevent students from attending labs. There are over 100 extra credit points available if you start early in the semester! These extra credit points serve as "disaster insurance". If you earn the extra credit, you will be prepared if you miss a lab. So if you miss a lab, you do not have to inform the instructor or explain or attend another lab, or anything else. You just use your disaster insurance.

C. Cheating and plagiarism

1. What is plagiarism?

Almost every student will answer "Plagiarism is taking the words or ideas of others and passing them off as your own by not clearly attributing them to the original source" or something like that when asked, yet so many will engage in plagiarism because they are not clear what it means in practice. So here are some examples of the types of writing you will be doing, what plagiarism looks like, and why students might do it. The following are real answers to the first two questions taken from a planning form for one of the investigations (labs):

1. Describe observations in the background material that led to the question under investigation:

   Student A: Large surface area loses heat more easily with a small volume animal: environment effects thermoregulability

   Student B: large surface area loses more body heat w/small volume of the animal

   Student C: large surface area loses heat more easily (with small volume of animal) environment effects thermoregulability

2. What hypothesis (causal explanation) are you proposing to explain the observations and answer the question?

Student A: Animals with a large surface area lose heat easier than a small surface area b/c there is a large surface area for heat to escape.

Student B: Animals that have a large surface area will lose heat easier than those w/ a small surface area b/c there is a larger area for heat to escape.

Student C: animals (volume) with a large surface area lose heat easier than a small surface area because there is a large surface for heat to escape.

So do you see a pattern? We certainly did. The answers are almost identical with a few words changed. They have the same mistakes in them. They are grammatically incorrect and short. The students' typical defense—"We worked together." Well, we encourage collaboration, but not copying.

If the students had truly "worked" together, they would have written better explanations and not made the same mistakes. Why? Because each student should have questioned the statements of the others ("Is 'thermoregulability' a word? I have never heard of it.") and worked to improve them ("Let me look it up"). Because students must show evidence that their planning forms are really their individual work, when these students worked together, they would have taken care to completely rewrite their statements in their own words. Better yet, they would have developed 3 different hypotheses! That way they would have benefited when they went to write their report AND not been cited for plagiarism.

Here is another problem students have. They read a section from a textbook or journal article and they really don't know how to rewrite it because they don't understand it. For example, let's take a look at the following passage:

"A scientist is investigating the alarming rate of disappearance of the largest, most mature, and best breeding *Quattro variegatus*. This species is four-sided in shape and highly dorsoventrally compressed. It lives communally in a highly patterned environment and is extremely cryptic, taking advantage of disruptive coloration. Its major predator is a large, bipedal, ambidextrous mammal with binocular, color vision. The scientist spends time observing predation techniques and examining the stomach contents of the predator and finds that the larger *Q. variegatus* are eaten more frequently than the smaller ones. Unfortunately, there has never been an easy way to determine the gender or age of a *Q. variegatus*. When she samples populations, she does not find equal numbers of all sizes."

And this attempt at rewriting it:

"A scientist was alarmed while investigating the rate that the largest, most mature, and best reproducing *Quattro variegates* were disappearing. These animals are four-sided and highly dorso-ventrally compressed. They live communally and are very cryptic, and so take advantage of disruptive coloration. Their most important predator is a large, bipedal, ambidextrous mammal with binocular, color vision. The scientist found that smaller ones are eaten less frequently than the larger ones. She could not determine their sex or age. When she samples populations, she does not find all sizes in equal numbers."

So would you call this plagiarism—we sure would. Yes, the author changed a few words, but they were trivial changes. The author kept the same paragraph order and most of the key phrases. Why? Well time was once again a likely factor, but here fear of misinterpreting or not sounding as good as the original were also likely factors. Many of the terms are not typical in a student's vocabulary and although students should be learning to use the vocabulary of the field, such use stands out awkwardly when they are just repeated. Did the author look up the definitions of such words/phrases as “dorso-ventrally compressed” or determine what the “large, bipedal, ambidextrous mammal with binocular, color vision” was? If s/he had, then s/he might have chosen other words to describe them. If the author had really taken the time to think about what was being described here, s/he would not have had trouble using different words.

2. How to avoid plagiarism

This sounds like such a simple action to avoid, yet students do it, and get caught, all the time. Why do they do it? Time and fear! To avoid plagiarism takes time—time to read and digest sources of material and time to rewrite the ideas that you glean from those sources in your own words. It takes time to think about what you have read or talked about with someone and to formulate your own statements. It takes time to develop a good planning form or report that will reach or surpass the standards set in the course and if you are afraid you can’t do it, it is so easy to fall into the trap of using others’ words that seem better than yours. So, the first action you must take to avoid plagiarism is to recognize it. The second is to set aside time to spend on your work so you can avoid it. The third is to know and feel confident about the work you are doing and the information you are discussing.

So here are some tips on avoiding plagiarism:

- Allot enough time to write complete, well-written sentences.
- When working together, ask “What else could be the cause? What else could we do?” Don’t just all settle on one idea.
- Before working each student should write a draft of ideas.
- When looking at sources of material (and looking at the work of another student is CHEATING!!), e.g. the pre-labs, lab manual, textbook, or web site, each student should write out notes in his/her own words (don’t copy what was written, write your own short phrases).
- Each student should strive to understand the topic well. There is no such word as thermoregulability; not understanding what ‘thermoregulation’ meant led to trouble. Don’t just parrot back “dorso-ventrally compressed”; look it up.
- To avoid plagiarizing an article or textbook, make notes when you are reading these sources. Read a section, then put down the text and jot down the useful ideas using your own short phrases, not by copying the authors’ words. When it comes time to write your report, summarize the important information contained in what you read with reference to the question you are answering or the section of the report you are writing.
- When possible, read several relevant references and synthesize a paragraph that integrates the information from all of them.
- Remember to still give credit to the source of the ideas if they are not yours, even if the words are.

3. Where can you learn more about plagiarism?

Two excellent sources that discuss plagiarism (and much more) and how to avoid it are:

McMillan, V. E. 2001. *Writing Papers in the Biological Sciences*. 3rd edition. Boston: Bedford/St. Martin’s

Pechenik, J. A. 2004. *A Short Guide to Writing about Biology*. 5th edition. New York: Addison-Wesley Educational Publishers, Inc.

These authors provide more lengthy explanations and examples of the problem and the ways to avoid them. In particular, they focus on the problem of using materials from reference sources and the difficulty students have with rephrasing the information. The standards they set for plagiarism are quite stringent but appropriate and we will hold to them.

4. What are your responsibilities and the consequences for plagiarism?

We take this very seriously. Our assumption is that you have come to college and are taking this course to learn. Earning credit for this course is based on your having learned the material adequately. We are asked to make a judgment of that. To be meaningful, that judgment must be based on your current work. In this course, we encourage students to work together because we think that is how they learn best. When planning your lab, analyzing your data, and writing your lab report, you are free to collaborate with those in your group or with any other group. Sharing your results is encouraged as long as it still reflects productivity and involvement by all. If you are using another group's data in addition to your own, you must clearly indicate that you are doing so, which data they are, and credit your source. Your lab instructor will judge if this was an appropriate use. You are NOT allowed to use any written passages from another's report or even your own from a previous semester either exactly or with minor word changes. **All the members of a group will earn a "0" for a report if any part of it is plagiarized.**

When you use material from other published works (articles, textbooks) you must properly cite the material and must paraphrase it. Direct quotes are unacceptable, even if they are cited. If you are not sure, ask your lab instructor.

Unless you are specifically told otherwise, planning forms and pre-lab activities must clearly show your individual work during the current semester. Does this mean you are not allowed to work with any other students in the LRC or outside class? No, you may. But you must NOT produce identical or highly similar answers. We expect each student to provide his/her own hypothesis, prediction, and experiment. Excuses such as "We were working together and came up with the same idea, so we just both wrote it down the same way" or "I was driving so I had my friend write the planning form out for me" are unacceptable. Nor may you use forms from previous semesters even if they are your own. Asking your friend to complete any part of a pre-lab online for you is also cheating. **Planning forms or pre-lab answers that are identical or judged to be too similar, or that were done by someone other than the student submitting the assignment for credit will result in a "0" for that assignment for all the parties involved** (yes, if someone copies your form, you will be held responsible).

For students receiving a "0" for plagiarizing or cheating in any other way on an assignment for the first time, we will consider this a **Level 1 violation** as described in the OSU Academic Integrity Policy, unless the circumstances warrant further action. A second offense will be considered a **Level 2 violation** as described in the OSU Academic Integrity Policy and will warrant further action, including the possibility of assigning a grade of "F!" for the course. Consult your OSU Student Handbook to be sure you understand the seriousness of these actions and your rights to appeal them (*http://osu.okstate.edu/acadaffr/aa/PDF%20Files/aipp.pdf)*.

D. Peer evaluation

Effective group work requires that students all contribute significantly and equally. For some groups, that might mean everyone does some of everything, every week. For others, different members may agree to perform different tasks for the whole semester. Another group may choose to have each member be responsible for a different task every week. Regardless of the arrangement, everyone needs to contribute equally. So how can we be sure that you have? We follow the procedures outlined in: Herreid, C.F. 2001. When Justice Peaks: Evaluating Students in Case Study Teaching. *Journal of College Science Teaching* 30(7): 430–433, and have you evaluate your peers.

Doing so requires that you follow the directions on the peer evaluation forms that follow. You will fill out quarterly evaluations to provide guidance to your group throughout the semester. Those will NOT affect your grade but will give you a chance to inform your partners about their performances and learn what they think about yours. If anyone is not working satisfactorily, your lab instructor will work with your group to help everyone reach an understanding about expectations and resolve issues.

At the end of the semester, you will evaluate your peers one more time. This one will affect grades. The average score that you receive from your group members. will be used to modify your lab grade. Most students will be in groups where everyone participates equally, and the total lab points they earn will remain the same. However, if your average score is below the expected average of 10, your grade will go down proportionately. If it is above, it will go up proportionately. For example:

> Chris earned 390 points and receives scores of 11 and 9 = average of 10 so Chris' lab score remains 1 * 390 = 390 lab points (or a 95% lab average)
>
> Pat earned 325 points (79%) and receives scores of 12 and 11 = average of 11.5 so Pat's lab score increases to 1.15 * 325 = 374 points (or a 91% lab average)
>
> Jan earned 267 points (65%) and received scores of 7 and 7 = average of 7 so Jan's lab score decreases to .7 * 267 = 187 points (or a 45% lab average)
>
> Sam earned 328 points (80%) and receives scores of 6 and 7 = average of 6.5
> Sam automatically fails the course because the average lab score was below 7!!

You will be expected to assign a score to each of your partners and fully justify any score that you assign them that is above or below a 10. A score of 10 will be substituted for any unjustified or insufficiently justified scores. So you will need to think carefully and document your evaluation. A group member will never be told who assigned a specific score.

The participation-adjusted lab points will be the ones used, along with your points from lecture to calculate your grade in this course. Remember you cannot receive more than 410 points in lab. Excess points do not transfer to the lecture score.

Peer Evaluation Form

Midterm #1 (Practice)

Name ____ Group #__________

This is an opportunity to evaluate the contributions of your teammates to group projects during the semester. Please write the names of your teammates in the spaces below and give them the scores that you believe they earned. If you are in a group of four, you'll have 30 points to assign. In a group of three you'll have 20 points. You don't give yourself points. If you believe that everyone contributed equally to the group work, then you should assign everyone 10 points. If everyone in the group feels the same way, you all will receive an average of 10 points. Be fair in your assessments, but if someone in your group didn't contribute adequately, give him/her fewer points. If someone worked much harder than the rest, give him/her more than 10 points.

There are some rules that you must observe in assigning points:

- You cannot give anyone in your group more than 12 points.
- You do not have to assign all of your points.
- Anyone receiving an average of less than seven points will fail the course.
- Don't give students a grade that they don't deserve.

Group members	Score
1. ____	__________________
2. ____	__________________
3. ____	__________________

Please indicate why you gave someone less than 10 points.

Please indicate why you gave someone more than 10 points.

If you were to assign points to yourself, what do you feel you deserve? Why?

Peer Evaluation Form

Midterm #2 (Practice)

Name ____ Group #__________

This is an opportunity to evaluate the contributions of your teammates to group projects during the semester. Please write the names of your teammates in the spaces below and give them the scores that you believe they earned. If you are in a group of four, you'll have 30 points to assign. In a group of three you'll have 20 points. You don't give yourself points. If you believe that everyone contributed equally to the group work, then you should assign everyone 10 points. If everyone in the group feels the same way, you all will receive an average of 10 points. Be fair in your assessments, but if someone in your group didn't contribute adequately, give him/her fewer points. If someone worked much harder than the rest, give him/her more than 10 points.

There are some rules that you must observe in assigning points:

- You cannot give anyone in your group more than 12 points.
- You do not have to assign all of your points.
- Anyone receiving an average of less than seven points will fail the course.
- Don't give students a grade that they don't deserve.

Group members	Score
1. ____	____________
2. ____	____________
3. ____	____________

Please indicate why you gave someone less than 10 points.

Please indicate why you gave someone more than 10 points.

If you were to assign points to yourself, what do you feel you deserve? Why?

■ Peer Evaluation Form ■

Midterm #3 (Practice)

Name ____ Group #__________

This is an opportunity to evaluate the contributions of your teammates to group projects during the semester. Please write the names of your teammates in the spaces below and give them the scores that you believe they earned. If you are in a group of four, you'll have 30 points to assign. In a group of three you'll have 20 points. You don't give yourself points. If you believe that everyone contributed equally to the group work, then you should assign everyone 10 points. If everyone in the group feels the same way, you all will receive an average of 10 points. Be fair in your assessments, but if someone in your group didn't contribute adequately, give him/her fewer points. If someone worked much harder than the rest, give him/her more than 10 points.

There are some rules that you must observe in assigning points:

- You cannot give anyone in your group more than 12 points.
- You do not have to assign all of your points.
- Anyone receiving an average of less than seven points will fail the course.
- Don't give students a grade that they don't deserve.

Group members	Score
1. ______________________________	______________
2. ______________________________	______________
3. ______________________________	______________

Please indicate why you gave someone less than 10 points.

Please indicate why you gave someone more than 10 points.

If you were to assign points to yourself, what do you feel you deserve? Why?

Peer Evaluation Form

Final

Name ____ Group #__________

This is an opportunity to evaluate the contributions of your teammates to group projects during the semester. Please write the names of your teammates in the spaces below and give them the scores that you believe they earned. If you are in a group of four, you'll have 30 points to assign. In a group of three you'll have 20 points. You don't give yourself points. If you believe that everyone contributed equally to the group work, then you should assign everyone 10 points. If everyone in the group feels the same way, you all will receive an average of 10 points. Be fair in your assessments, but if someone in your group didn't contribute adequately, give him/her fewer points. If someone worked much harder than the rest, give him/her more than 10 points.

There are some rules that you must observe in assigning points:

- You cannot give anyone in your group more than 12 points.
- You do not have to assign all of your points.
- Anyone receiving an average of less than seven points will fail the course.
- Don't give students a grade that they don't deserve.

Group members	Score
1. ______________________________	____________
2. ______________________________	____________
3. ______________________________	____________

Please indicate why you gave someone less than 10 points.

Please indicate why you gave someone more than 10 points.

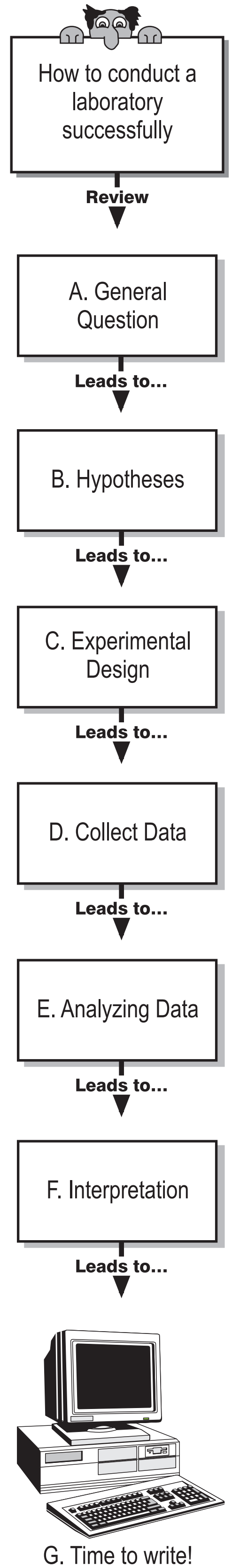
If you were to assign points to yourself, what do you feel you deserve? Why?

V. How to conduct a laboratory successfully

We are pretty sure you want to be successful each week. To do so, you need to design, conduct, and report on your own experiment. But where do you get the ideas for an experiment? What is a good test? What should you consider when designing the experiment? How should you analyze the data? These are all good questions and you will have plenty more. Let's see how this guide will help.

The process you will follow conforms to a general order (sometimes referred to as the scientific method) with which you are probably familiar. This section of the manual will provide you with a review of the process, but add more details that you may not be familiar with yet. In this section you can follow the process visually by observing the diagrams on the right. This first overview is pretty simple and presents the major components of the process. Later diagrams and text will expand on the details.

As you can see, you start with a general question, typically based on a pattern of observations. You then offer an explanation (hypothesis) that answers the question, develop a hypothesis to test your explanation, collect, analyze, and interpret the data in the light of your hypothesis, then write a report that convinces your reader that the hypothesis you proposed is more likely to be "right" or "wrong" (more about this later). On the following pages, you will learn more about the details of each component of this process and what you should do to be successful at each.



A. Review the general question

Research programs and experiments are usually focused around a general question. How does this mechanism work? What affects this rate? What causes this phenomenon to occur? What is the function of this? More specific questions are developed within a general one and these, along with a set of observations, lead to specific hypotheses.

1. Do you understand it?

The questions will be stated as part of the scenario at the beginning of each investigation chapter. Be sure you understand what the question is asking. Remember though that the question is very general and you may want to or need to work on only a small part of the question. Also try to think about questions in terms of mechanisms. In your mind concentrate on words like how, affect, cause, function. When you are not sure about the question and what it means, what are you going to do?

2. Have you discussed it before?

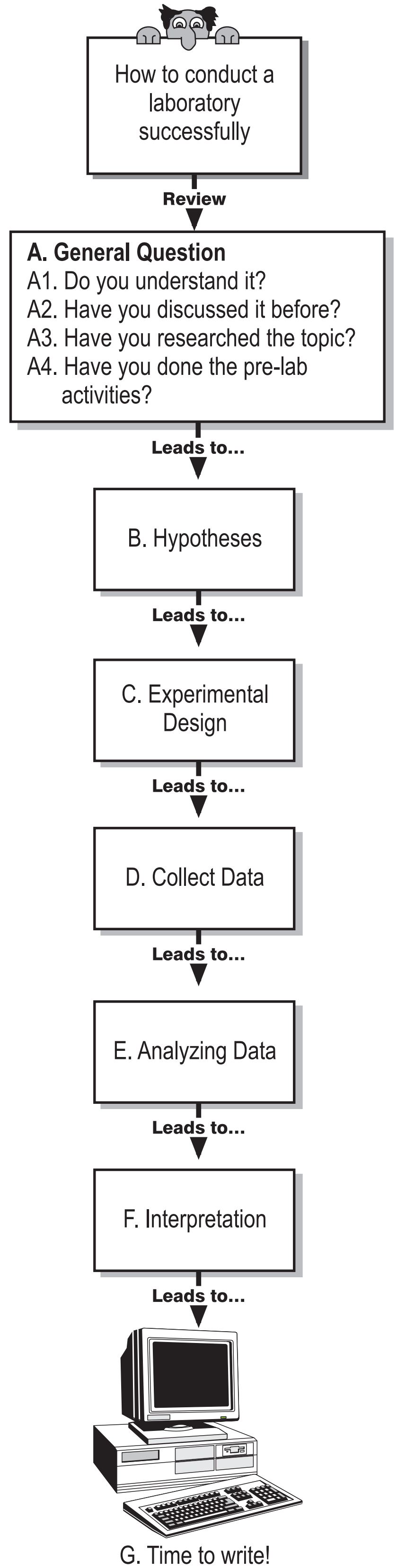
Clearly, if you have discussed the question before, you should have an idea what it is about. Was it discussed in lecture? Then review your notes and/or text. Was it discussed in a previous lab? Then think about how this lab relates to that one. Was it a discussion you had with your colleagues? Then think about what was said and jot it down.

3. Have you researched the topic?

You will be better prepared to do the lab and to write your report if you look through some background material. Was some assigned? Have you looked in your text? Did you carefully read the opening paragraphs for the particular investigation? Have you looked up the terms/concepts listed in section I. B. of each investigation? Have you tried searching the library catalog or the WWW for related information?

4. Have you done the pre-lab activities?

These are designed to give you insight into techniques, hypotheses, analytical methods, and relevant factors. Sometimes, it will not be obvious as to how the pre-lab activity and the lab are related, but it should become clear as you investigate further. These activities should also help you define the question.



B. Hypotheses

This is, of course, the tentative answer to the question you defined based on the general question. Does it fit in? Can you explain how it fits in? Is it a good hypothesis? How could you tell?

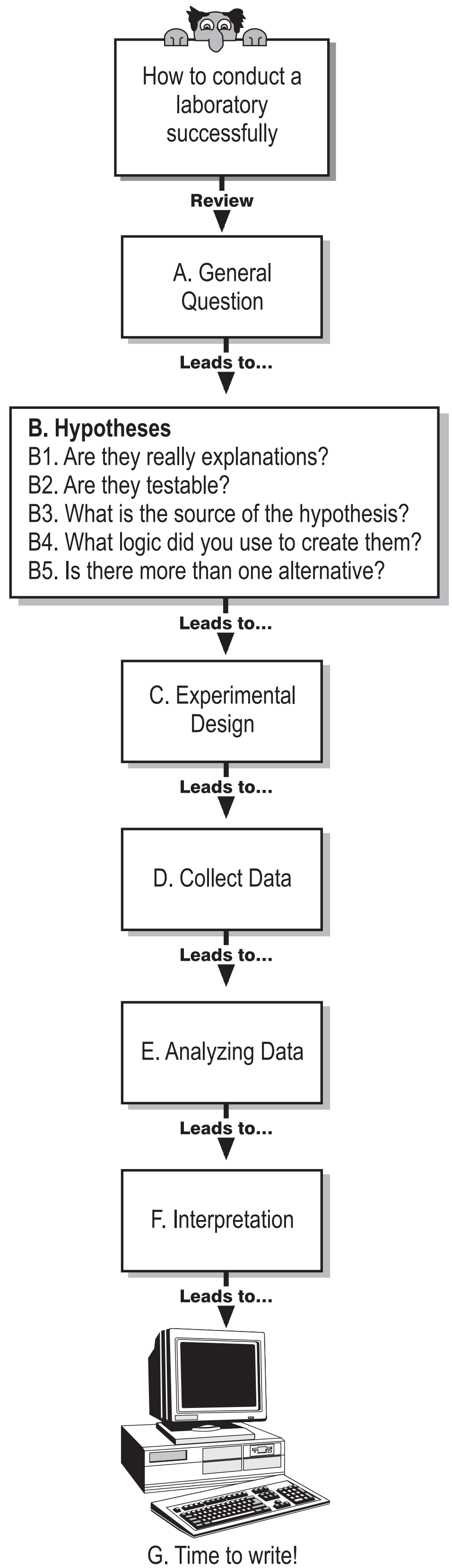
Here are some criteria or considerations:

1. **Are the hypotheses really explanations?**
   You might have a statement or even an educated guess as to what will happen under certain circumstances, but that is not necessarily a good or interesting hypothesis. "Students' grades increase later in the semester" is more of an observation than a hypothesis. "Students' grades increase later in the semester because students spend more time in class" is a hypothesis.

2. **Are the hypotheses testable?**
   Can each hypothesis be tested? Can an experiment be designed that will provide evidence to support or refute each hypothesis? Experiments that require materials beyond what is available in lab are not good choices, and neither are the associated hypotheses. Tests of phenomena beyond science are not good choices—"Ethereal waves alter phytokarma and change the rate of CO_2 production in plants subjected to certain music."

3. **What is the source of the hypothesis(es)?**
   Did you just think of the hypothesis? Did you read it in the lab manual? In another lab manual? In a textbook? In a journal article? Scientists get their ideas from lots of places. It is not unusual for one scientist to test another's model (hypothesis). If you got it from somewhere, the reader of your work should know the source of your hypothesis.

4. **What logic did you use to create your hypothesis(es)?**
   You should be able to explain and/or defend your logic. Hypotheses should be reasonable and have observations (yours or others) to support the idea that they are possibly correct. Know why you came up with the idea. If your group does not think it makes sense, why will anyone else and on what will you base your experimental design? You'll also want to be able to explain this to the reader.



5. Is there more than one hypothesis?

For most research questions there is more than one hypothesis. Typically there are alternatives, such that one or the other, not both, is supported by the results. This is great! You can impress the scientific world (or at least your instructor) with your clear cut logic and an experimental design (see next section) that shows what you know. Sometimes there is more than one hypothesis, but they cannot easily be tested so that both are not supported simultaneously. This leaves you with ambiguous results at best. If you realize this ahead of time you can change your plan. If you realize after, you can explain the limits of your work. If you don't realize at all, but your instructor does while grading your paper, well… .

For an excellent explanation of how to formulate and judge hypotheses, read Lawson, A. 1995. *Studying for Biology*. Benjamin/Cummings: NY, one of our recommended study guides.

C. Experimental design

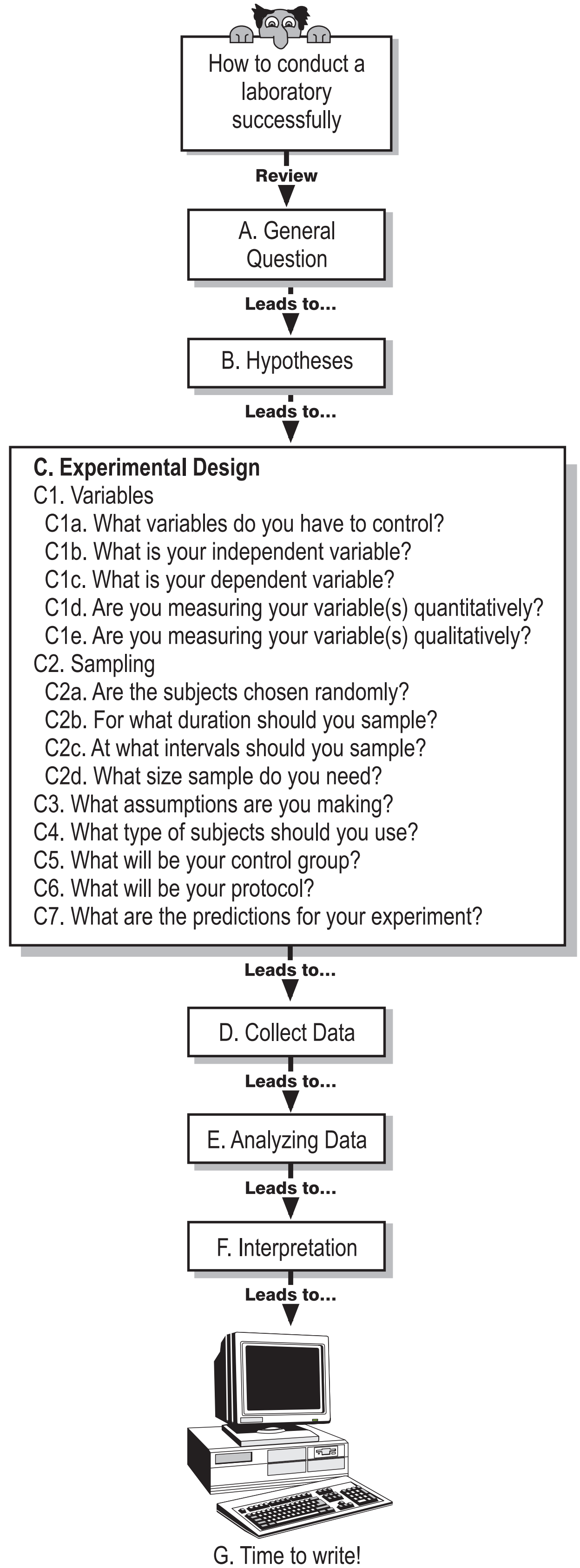
The basics of an experimental design seem simple, but many factors play a role in good design. A good design determines whether or not you actually test your hypothesis. But there are many constraints—cost, time, personnel, subject availability, etc. So you have to compromise and perhaps not test your hypothesis completely. This is actually quite common, especially since one experiment does not typically cover all the possible alternate hypotheses. In many ways your experimental design depends on the question you are asking and the hypothesis you are testing. So try to think of these before lab and talk your design over when you meet your teammates.

1. Variables

a. **Controlled variables—**These are all the things you have to keep constant or measure so that you can remove their effect on the data. For example, if you are measuring volume changes by measuring pressure changes, you have to either keep temperature constant or factor in how much the pressure would change if the temperature changed.

b. **Independent (experimental/manipulated) variable—**This is the one you change, typically, or those that serve as the predictor variables. It is safest to manipulate only one variable at a time, however, you can carefully change more than one at a time if you carefully design the experiment to test several values of each. If that is the case, you have to consider interaction effects (when one experimental variable affects the other's effect).

c. **Dependent (response/measured) variable—**This is the one you measure to determine the effect of the independent variables.



d. **Are the variables measured quantitatively?—**These would result in numerical data including counts, proportions, rates, fractions, dimensions, weights, etc. When you are collecting these, you need to be careful to record the correct units.

e. **Are the variables measured qualitatively?—**These would be items that are not typically quantifiable, such as sex, color, geographical origin, etc. When collecting such data, be sure to make very accurate notes if the item cannot easily be sorted into two to three categories.

2. Sampling

a. **Random sampling—**Not all variables can be taken into consideration and some, e.g., genetic make-up, may not be measurable. To minimize such effects, it is good to place equal numbers of subjects of each type into each group. But this may not be possible if all factors cannot be identified. So subjects are drawn from the pool of subjects and assigned to groups randomly. This is done by drawing numbers, picking cards, using a random number table, etc.

b. **Duration—**How long should you sample? Will a three minute experiment be long enough to detect a meaningful change? Will three minutes be overkill when everything happens in ten seconds?

c. **Interval—**How often should one sample? Once every five seconds is too slow for an insect's wing-beats but too fast for a thermal probe that changes every thirty seconds.

d. **Sample size—**Is one organism enough? Two? Three? Should you sample each one five times? For many investigations, you will be constrained by time and resources to sampling one or a very few individual organisms.

3. Assumptions

What are you assuming? Is it worth mentioning? Every experimenter has to make assumptions when s/he designs an experiment. Does it matter if the subjects are males or females? Does the phase of the moon matter? Do you need to record the temperature always? There are many possible factors to consider. Some you can completely dismiss. Some you might not measure, but might inform the reader that you assumed them to be irrelevant or unimportant and why, e.g., a one hour rest period is sufficient for animals to recover before a second trial. Some factors need to be either measured, controlled, or randomized.

4. Subjects

Choosing subjects, or areas to sample, can be very important. In most of our experiments, the sample size is so limited (e.g., 1) that this is not a factor, but you should be aware of the problem. In general, you want to randomly sample from populations of organisms that are as similar as possible. For some factors, one might want to restrict the sample to one type (e.g., all males, gram + bacteria only, seedlings between 3"– 4" tall) and restrict the range of one's conclusions.

5. Controls

Simply stated, experiments need to include a group of subjects that are treated identically to another group but are not exposed to the experimental treatment. These are the controls or control group. They serve as the benchmark against which the experimental group or treatment is compared. You need to always think about this. The question will always arise, "How do you know what you manipulated is what actually caused the effect?" You need to be able to point to a control or another group for comparison. Sometimes you will need to control for different factors, so multiple controls are necessary.

6. Protocols (steps)

What steps are you following? How do they differ from the reference module procedures? You need to decide who of your team will be performing which task. Be sure to collect the right tools. Be sure to have timers if they are needed. Record these notes on your lab notes page. This will help you write your report. Before you can use the table in your lab notes page, you need to set it up. What do the columns represent? What do the rows represent?

7. Predictions

You need to know whether the results of your experiment support or refute your hypothesis. You need to know that your experiment will yield meaningful results. Look at your hypothesis. Look at your experiment. If your hypothesis is correct, what results do you expect? If your hypothesis is incorrect, what results do you expect? These are your predictions and this is the format in which to state them (If... then...). Make sure your team agrees on what you expect. If you don't, ask yourselves why not. Could it mean that you don't all understand your experiment or hypotheses? You should—they're yours. Write your prediction(s) on your lab notes page. This will help you write your report.

D. Collecting data

This could be a few minutes, a couple of hours, or a couple of days. Your data are important. When reading your report, your lab instructor will be looking to see if you have data to support your conclusions and if they really do. Without data to support your statements they will be discounted. Those are the rules of science. So be careful, collect well and collect completely.

1. Quantitative data

This can be recorded by hand or by computer. You need to make the choice based on the tools available, the amount of data to be collected, the sampling regime, etc.

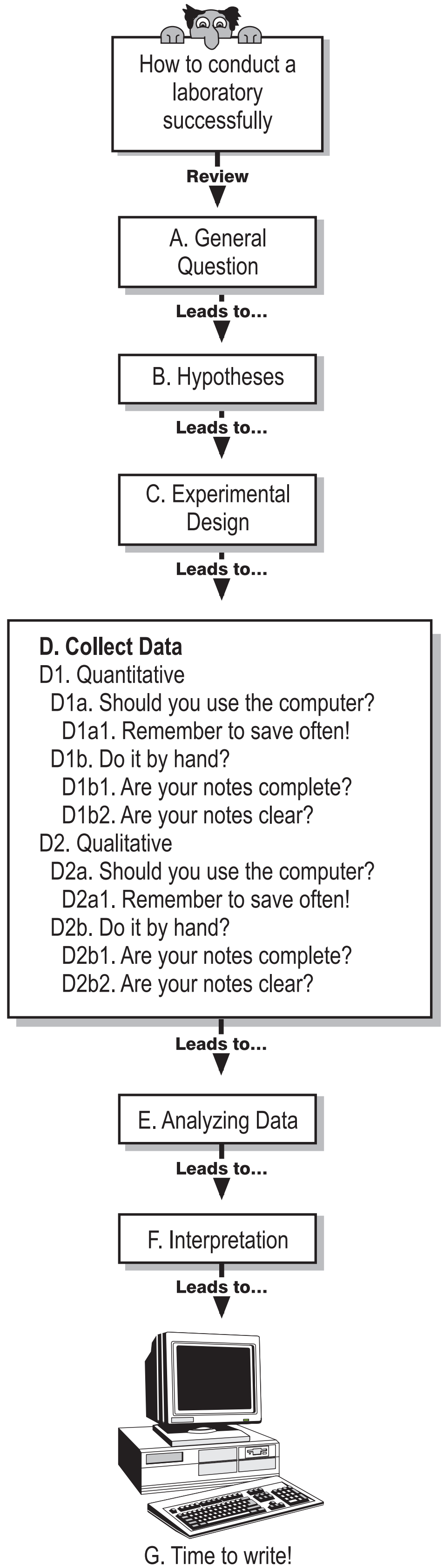
a. By computer—This will allow unattended and continuous data collection. It will make data analysis and graphing easier. It requires time to learn to operate and set-up, so you will need to practice. Certain types of probes used in the lab can only be used with the computer.

1) Did you save it? Don't trust technology! Be sure to save your data until your report is complete. Your team will have a special spot for your data. Remember, without data you have no results or discussion in your report.

b. By hand—This requires very little preparation or training. It is flexible, but it is slow and can be inaccurate. Data must be entered into a computer for graphing and analysis and transcription errors can occur. Above all be sure to check:

1) Are your notes complete? Don't forget to sample when it is time. Don't forget to write everything down.

2) Are your notes clear? If you cannot decipher your notes, they are worthless to you. Indecipherable scribbling or abbreviations can cost you later. Use the table on the lab notes page whenever possible. Decide on abbreviations before you get started.



2. Qualitative data

This is descriptive data or observations. You will most likely record these by hand. Use the lab notes page. Write down as accurate and complete a description as you can. You should do this even if you record quantitative data using the computer. Your notes will help you make your report much better. Don't just rely on your memory, even though the time is short. Beginning students don't write enough of the right things down. Learn by doing—and do it now!

E. Analyzing data

You got it—now what? You need to summarize your data so you can see what is going on and show it to others.

1. Did you graph your data to look for a trend or pattern?

You need to! Graphs help you see the trends in your data. Does the dependent variable increase over time? Decrease? Increase, then level off? Is the rate (slope) under one set of conditions different from another? These graphs can go in your report.

2. Descriptive statistics

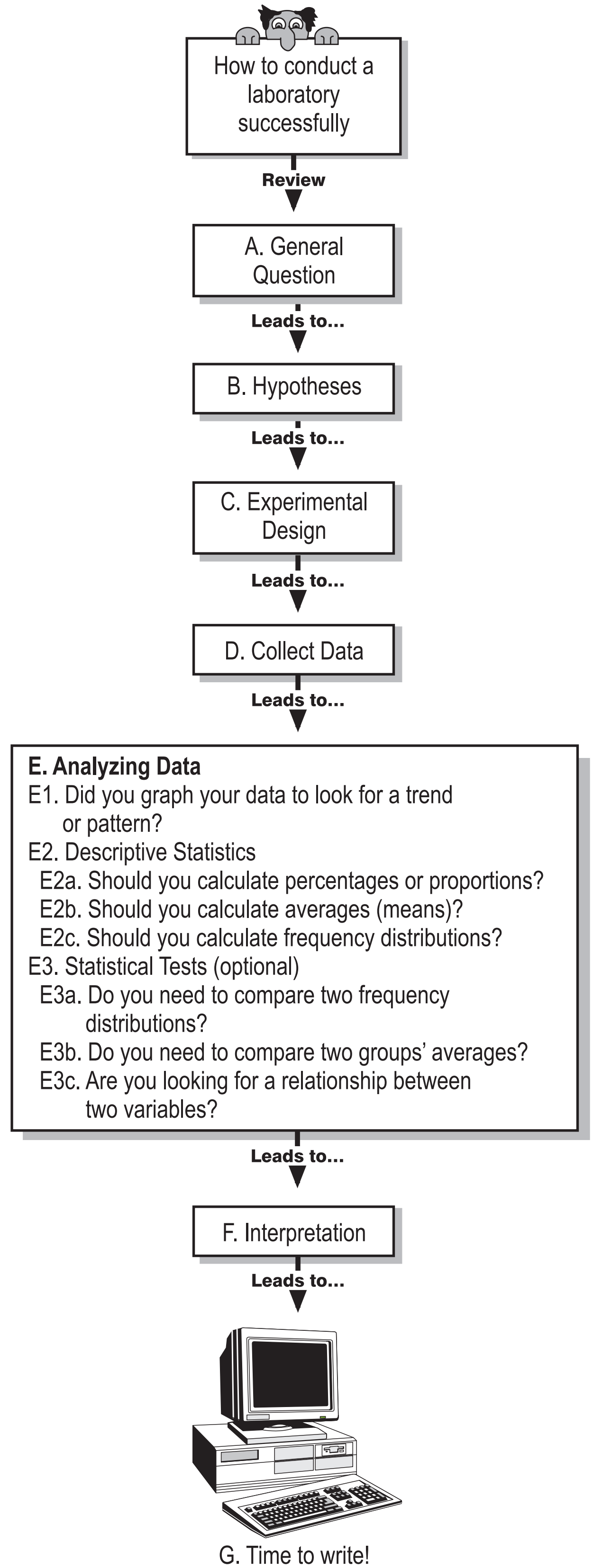
You can't show anyone all your data points and expect them to see what you do, or even want to see it. You need to summarize your data. One way is through the use of descriptive statistics. You are actually familiar with the ones described here, but this may give you a different perspective. You need not limit yourself to these or to the uses presented.

a. Percentage or proportions

These are used to present information as some part of a whole. Saying that 12 students liked something is harder to interpret than $^{12}/_{16}$ or $^{3}/_{4}$ or 75% or .75 of the class enjoyed it. Graphs of percentages are best in terms of a pie chart and stacked bars.

b. Average or mean

This is the classic descriptive statistic. It is a measure that describes the center of a bell-shaped curve distribution. If you had to guess the scores on a test for any person, knowing nothing else about them, you would be the least far off by guessing the mean. More statistical tests are built around the mean than any other statistic.



c. Frequency distribution
This is a tally of the number of items that fall into a range of categories: Red-Green-Blue, Tall-Short, under 10/10-20/over 20, species 1/species 2/species 3, etc.

3. Statistical tests (optional)

These tests are designed to tell you if the results you got were a chance occurrence or the real thing. They are interpreted in terms of means being the same or not the same, distributions being the same or not the same, etc.

You will need to choose a test and make it work. We will dispense with many of the details about when the software can or can't be used based on assumptions of normality and other characteristics. Look up the requirements of each test and what it tests, then decide whether it fits your data and the test of your hypothesis.

a. Determine if the proportion of some group doing something is different from another group
Here we are talking about looking at two frequency distributions and deciding whether they are really different. For example, do the numbers of algae of Species 1, 2, and 3 change over time? Try χ^2.

b. Determine if one group is different from the other
Here we want to ask if the mean of one population is truly bigger than that of another population. Use t-test or ANOVA.

c. Find a relationship between two variables
Does one change like the other or in some proportionate way? If that is what you want to know, then techniques like correlation or regression will work.

F. Interpretation

Now it's time to determine what your results mean, what they "tell" you. If you have designed your experiment well, come up with a good set of relevant alternative hypotheses, and analyzed your data well, this should be easy.

1. Do the data match the predictions that indicate your hypothesis is supported?

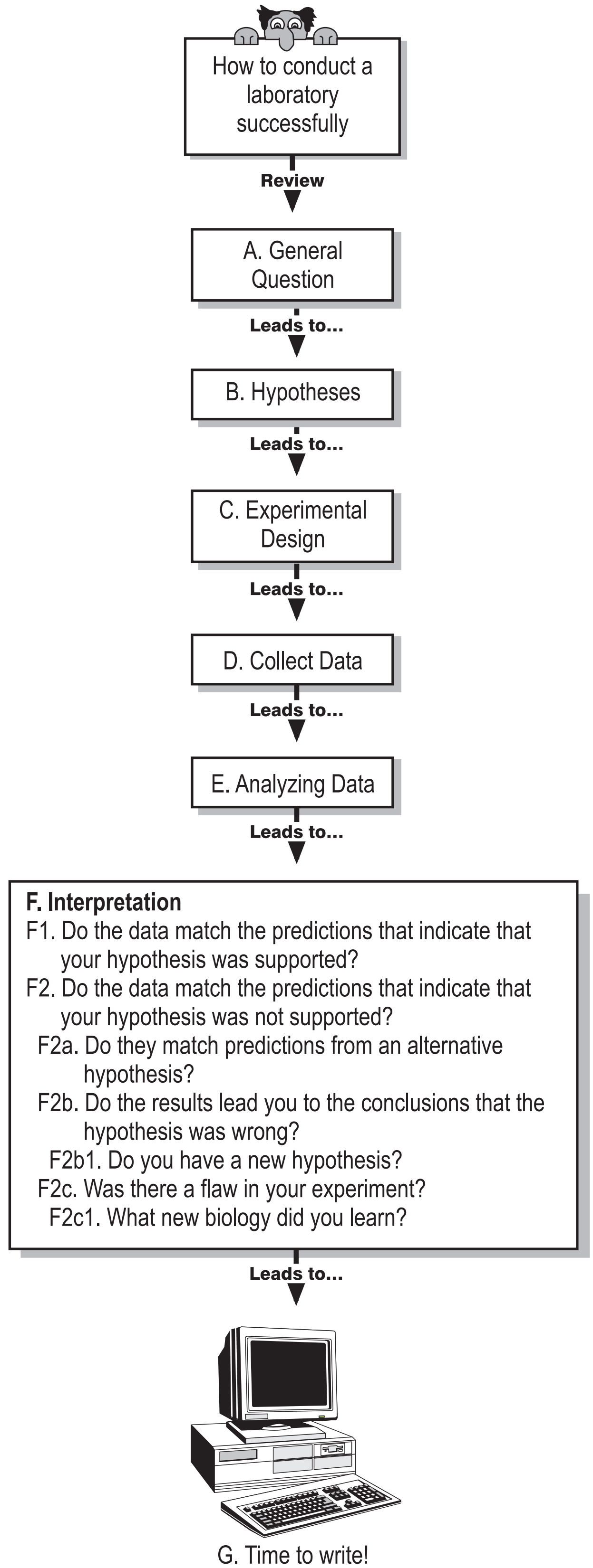
From this you should conclude that your hypothesis was supported (remember it is never "true"; it might be "probably correct"). Discuss this with your teammates because it is possible that you may be falsely interpreting favorably. You should also search again for alternative interpretations and for flaws in your logic. Then go finish your report (you may collect $200).

2. Do the data match the predictions that indicate your hypothesis is refuted?

You will need to sit and think about what your data are "telling" you. What you don't want to do is just explain this away as "We messed up." There are several possible general reasons you got the results you did. Let's look at them.

a. Was it a match to an alternative hypothesis?

If you already thought of an alternative explanation when you designed the experiment—great! That is what a good design will do. Go finish your report (you may collect $200).



b. Was it an incorrect hypothesis?

OK, now, how do you explain this? What makes you think it is wrong? That is, what logic do you now see that makes it obvious that your hypothesis was incorrect? Did you make a logical error before, or did the experiment just disprove a reasonable hypothesis and, hopefully, give you insight into a new one? Go finish your report (you may collect $200).

1) Do you have a new hypothesis? Be prepared to describe and explain the logic behind it.

c. Was it a flaw in your design or procedure?

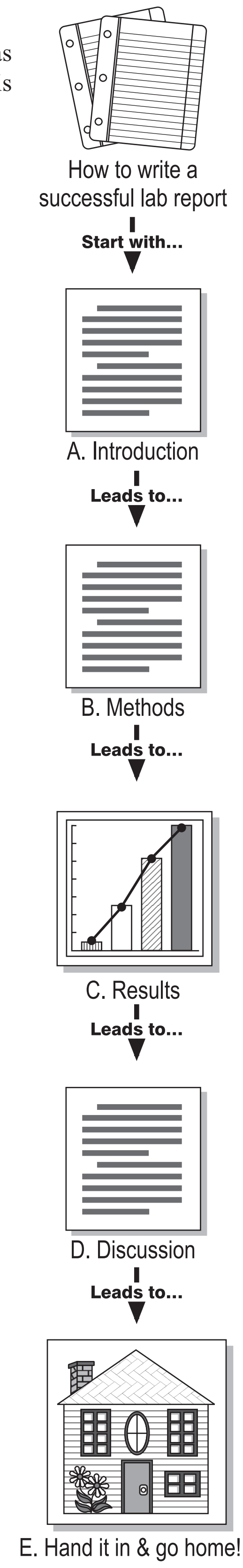
Again, remember, we don't want whining or shallow excuses about how you messed up. How did you find it? When did you find it? How would you correct it?

1) What did you learn? Be prepared to explain the biological, chemical, or physical principles behind the flaw.

When you have figured this out, go finish your report (you may not collect $200).

G. Time to write

You should have been trying to write your report while your experiment was running, so this would be the time to finish up. The rest of this flow chart is explained in the section on “How to write a lab report.”



VI. How to write a lab report

A. Goal

Because the goal of the laboratory is to aid you in learning certain concepts through inquiry and how scientists piece together explanations of the natural world, you need to learn how to report your findings in a way that is both interesting and convincing to your audience. To do this, you will write a short lab report each week in a style similar to that used in professional journals. In these reports, you should make clear what you were investigating and why (Introduction), how you conducted the investigation (Methods), what you found (Results), and what it meant (Discussion). Learning to write a report can be very useful. Everyone needs to learn to write a persuasive argument, but you can practice this by writing a term paper. In contrast, the arguments made in a lab paper are based on data, and you must distinguish observations from interpretation. You learn to weigh evidence of a very different type and distinguish baseless or poorly supported opinion from well supported interpretation. While you learn to do this for yourself, you should also learn to judge the work of others in a similar fashion. Writing a lab report also helps you learn to describe clearly and precisely what you did so that someone else can repeat your procedure. This too is a useful skill.

B. General organization

Your lab report should consist of four sections: introduction, methods, results, and discussion. In addition, if references are used, there should be a references cited section. In the **introduction**, you set the stage for your study. You let your reader know something about what s/he is about to read. Most importantly, you let the reader know what the study is about and why you are studying the question at hand. If you have a hypothesis (a logical tentative explanation of how something works) to test, let the reader know what it is, and what made you think of the hypothesis. For this lab, you may be handed a question or hypothesis, but you should still explain, *in your <u>own</u> words*, where it came from and why it's worth testing.

In the **methods** section, you describe what you did. You should include enough detail so that someone reading your report could repeat your experiment. Since it is what you did, it is written in the past tense and active voice.[1] For our purposes, it is acceptable to refer to the procedure in the lab manual, e.g. "We pipetted 15 ml of methanol following the procedure described in French (2005)", but remember to carefully describe any differences between your method and the method described in the lab manual and to include specifics of choices you made (e.g., in the example above the exact volume pipetted was mentioned specifically). Of course, you should include elements of your own design when appropriate.

In the **results** section, you describe the outcome of the experiment. You should describe any observations you made. You should include summarized data—averages, tables, graphs, not raw data. Be sure to draw your reader's attention to the trends they should see in the data, but don't repeat in your text the data you display in a table or graph. Also, don't interpret your data, just present it. Any statement without data to support it will be suspect. Any figures or tables you include that are not mentioned in the text might as well not be there. For example:

[1]When writing in active voice, the subject of the sentence is "doing" something, whereas in the passive voice the "doing" is the subject of the sentence. For example, "We weighted the rat" is written in active voice; "The rat was weighed by the experimenter" is written in passive voice. Almost always, active voice is shorter and clearer.

"In our survey, there was an increase in performance with an increase in study time (see Figure 1.1). There did, however, appear to be a slower increase in performance, at higher levels of study time, especially between ten and twelve hours of studying per week."

Notice that in the example text, the author did not repeat any specific data values, but clearly brought to the reader's attention the general trend of increasing score with increased studying and that this slowed at the high end of the independent variable.

The results section is also the place to report the results of your statistical analyses, if there were any. Although it is doubtful, a reader might question whether there was truly an increase. To test whether these results could have occurred by chance involves the use of a statistical test. In this case, regression analysis would provide a measure as to whether the data really do fit on a straight line with a slope > 0. In this course, such analyses are optional, but would greatly enhance your reports.

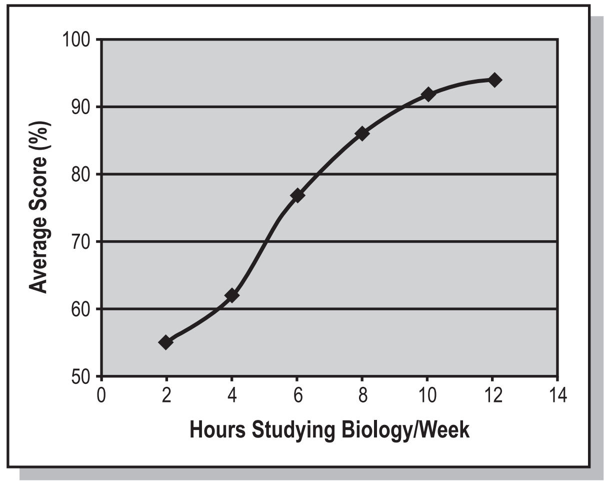


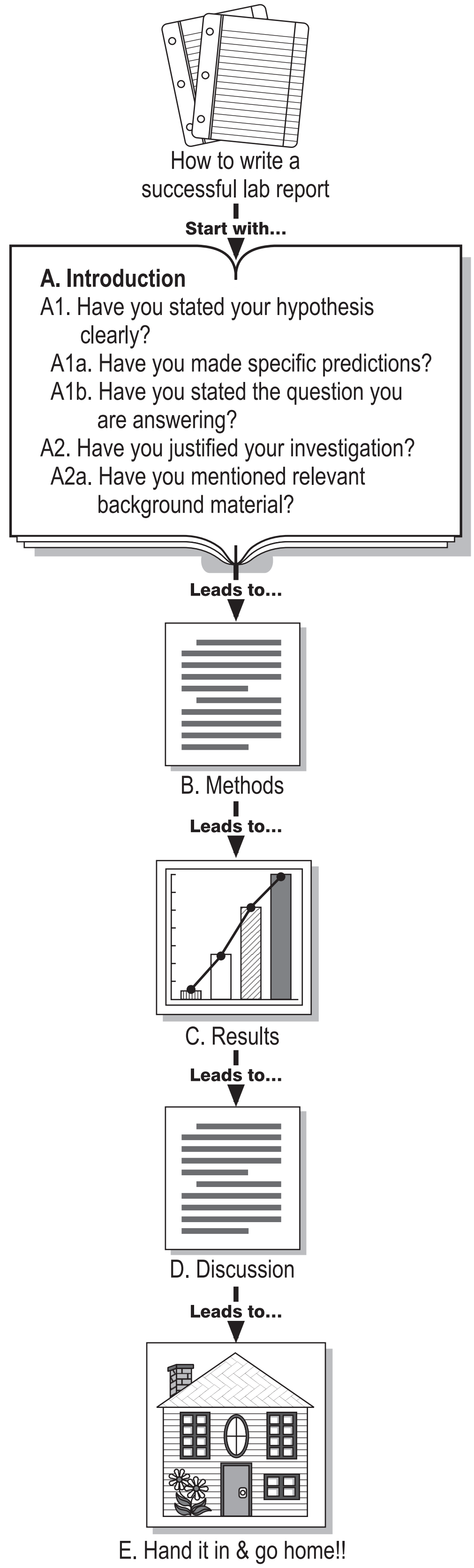
Figure 1.1 | Fictitious comparison of study time, as reported in a non-existent survey, and student success, as measured by average test score (N=146).

In the **discussion** section, you explain what the results mean. Remember a general rule of thumb—you are trying to impress your instructor with the quality of your work. Do the results support your hypothesis or not? What could account for them? Do they fit the prevailing theories or should one be speculating about a new theory? You might answer these questions by comparing your results and interpretation to those of others as found in your textbook or in the literature. You might discuss other articles or tie things back to the hypotheses and predictions you made in your introduction. You might also suggest new hypotheses and experiments.

What if it appears that the experiment(s) failed? Can you explain your results in terms of specific biological phenomena? That is, are there alternative hypotheses that might explain what happened or are there specific things you realize that you had not considered in your design or initial hypothesis? Don't just use the well-worn excuse that you made a mistake or forgot to check something.

C. Specific components

This section is an annotated checklist corresponding to the grading form used to judge your work. Each lab report is worth 20 points. In each investigation, you will find a grading form. This is the sheet your lab instructor will use to grade your report. You can use it as a checklist. Each of the first 20 items is expected to be included in each report, and you earn up to 1 point for each properly done item. There are 5 optional categories. These categories also are worth up to 1 point each (statistics is worth up to 3 points each). Properly completing these elements requires additional effort and indicates exceptional insight or effort. The following section expands on each criterion. Further discussion about and hints for writing a good lab report can be found in Pechenik, J. A. 2004. *A Short Guide to Writing About Biology*. 5th edition. Longman: New York.



INTRODUCTION

1. Statements of question and hypothesis(es) under investigation are clear, specific, and correct

You should describe the general question that frames the work you are doing. Typically, these will be provided to you in terms of the lab question, but you want to show that you can describe it in your own words. You should pose one or more hypotheses based on the general question at hand. You should state your hypothesis(es) in terms of an explanation for a specific set of observations related to the general question (you should be answering one small specific question and your reader should know what it is). You should try to think of competing or alternate hypotheses, i.e. other possible explanations for what you observed. The results from a well designed experiment will help you determine which hypothesis is most likely to be correct.

2. Provides logical argument for why question and hypothesis(es) are being investigated

Why are you investigating what you are investigating? Don't just tell your reader it is because the lab manual or instructor said so. Make it clear why this is interesting or why your hypothesis should make sense. If you did more than one experiment, explain how they fit together. If you can't convince your reader that this is interesting s/he won't want to read further (and you won't earn many points).

METHODS

3. Experimental design is described completely and clearly

Could the person reading your description repeat exactly what you did or would they have to ask a lot of questions?

4. Steps/procedures are proper and justified

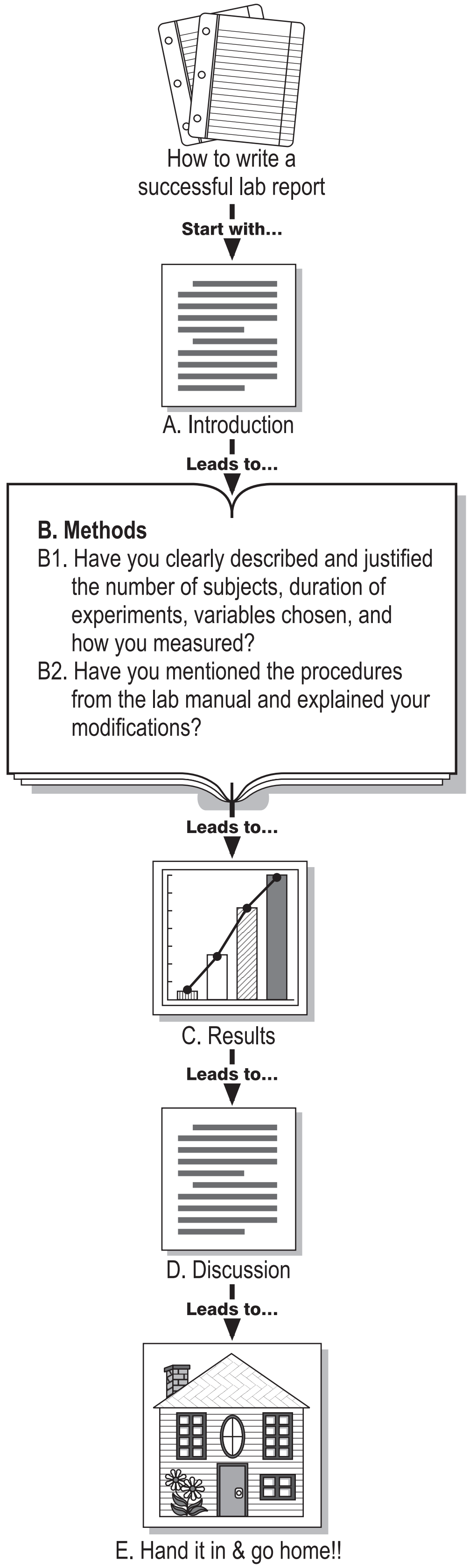
The reader knows what you did, but were the choices you made correct? Do the steps make sense? Did you choose the best way to record or measure something? Did you take your measurements at the right time? Did you omit any procedures that could provide useful data?

5. Experimental and control variables and assumptions are correctly chosen and justified

Did you measure the right thing(s)? Did you control variables so that you could isolate the effect of the experimental variable? What did you assume—the age of the subjects was unimportant? The color of the container had no effect? Were these assumptions reasonable? You don't have to list everything (e.g., "We assumed that the phase of the moon did not affect the rate of diffusion"), but you should think about the most relevant ones and discuss them as needed.

6. Methods provide for appropriate test of selected hypothesis

Did you test what you thought you did? Does the experiment you designed measure what you think it does? As designed, could the experiment lead to ambiguous results or multiple interpretations? Were there obviously better ways of testing what you said you wanted to test?



RESULTS

7. Data are presented without causal interpretation or implications

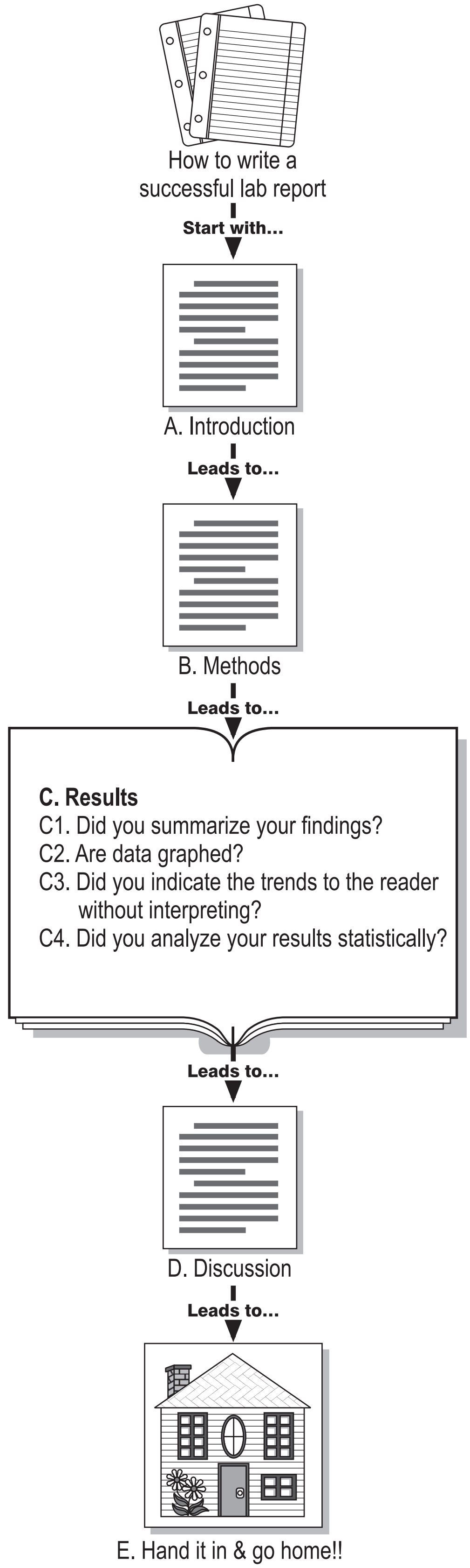
Are the results described so that the reader is aware of what happened independently of interpretation? For example, "Not surprisingly, the plant increased its rate of photosynthesis substantially because more photons of light struck the plant as we moved the light closer" (incorrect), or "CO_2 consumption increased 20% when we changed the distance between the light and the plant from 20 cm to 10 cm" (correct). You interpret your data in the discussion. If properly recorded and described, your data are "correct" no matter how you misinterpret what occurred. Scientists don't disagree with others' data, they disagree with the experimental design, analysis, or interpretation.

8. Data are summarized and displayed appropriately in graphs or tables

Are the data presented in a format that allows the reader to easily see what happened? Are graphs or tables used to organize the data for the reader? Is the appropriate graph, chart or table used? Bar charts are used when the independent variable (experimental) is qualitative, discontinuous, or in a range (type of diet, type of environment, type of weather, presence or absence of light, large or small, 1–5 cm or 8–10 cm or 12–15 cm). Scatter plots (X–Y) or line graphs are used for continuous (or what could be), ordered, numerical data. Whether a graph or a table is presented, the objective is to make it easier for the reader to see the trend (increasing, decreasing, increasing then leveling off, etc.) in the data. You and your reader can't interpret the results if no trend is obvious.

9. Trends in data are made clear in text without repeating the information in tables or graphs

Is the reader left to guess what is going on or what is important (which increases the reader/grader's level of frustration), or do you tell him or her what to expect (this is preferred)? Don't restate the data ("At minute one, the temperature was 4°C, at minute two the temperature was 7°C, and at minute three the temperature was 10°C."), point out the trend ("The temperature increased steadily over time").



10. Figures and tables are properly numbered, captioned, and referred to in text

Does every graph have a figure number? Does every table have a table number? Do they have captions that tell the reader what they are about? Do you refer to the table or figure in the text ("See Figure 6") or have you just tacked them on? If the reader is not told to look at the figure, it doesn't exist and it may appear to the reader that you are drawing conclusions without any data.

11. Figures and tables can be properly interpreted without reference to text

Are the axes of graphs properly labeled including units? Should there be a legend? Did the caption really describe the table? Does the reader know how many subjects you used? Are the values averages or direct counts? Are the axes scaled too large or too small so as to distort the data? If the reader found the table or graph on the floor by itself, would s/he know what the experiment was about?

DISCUSSION

12. Questions and hypotheses stated in introduction are addressed

Do you attempt to answer the question that you asked in the introduction or state whether your data support or fail to support your hypothesis? (Hint: although it is essential that you have a hypothesis clearly in mind before you design an experiment, it sometimes helps to write your introduction after you write your discussion.)

13. Conclusions are supported by the data

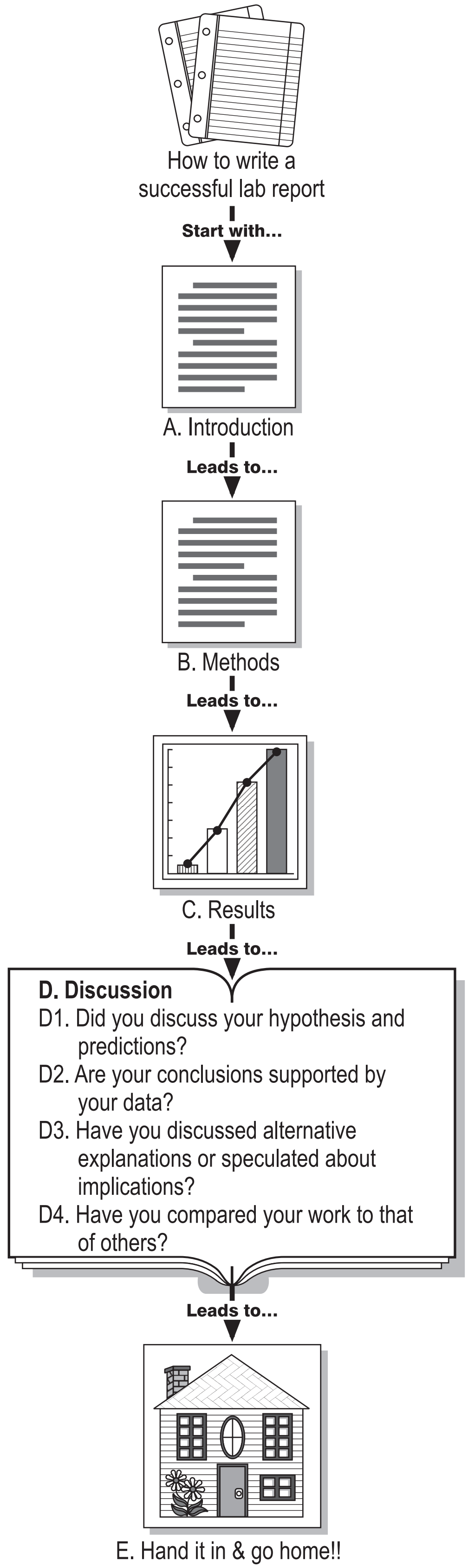
If the reader ever wonders where the data are to support a statement, you are in trouble! Similarly, if you are claiming that your hypothesis is supported because the value of a dependent (measured) variable increased (or decreased, etc.) and the reader sees an increase in the beginning followed by a decrease, you are in trouble. You can't make claims based on what isn't there. You can qualify your answers if justified—"Photosynthesis increased for the first 5 minutes as predicted, supporting the hypothesis that increased light had an effect. However, subsequently, the rate of photosynthesis remained constant, which could have been caused by the plant reaching some maximum rate or the CO_2 sensor failing to read more than 5000 ppm."

14. Alternative explanations are discussed

Did you consider all the possibilities? Are there other valid interpretations? Would the data support other hypotheses? You should address at least the most important alternatives if they exist. Research papers get rejected if the reviewer raises objections that the author ignores.

15. Speculations are clearly stated as such and logically derived from data

Go ahead and discuss possible causes for results that were not testable here. Be sure however that your speculations are reasonable and have some basis for acceptance. ("Species A may be more tolerant of low humidity than species B because of it's waxy coating.")



16. Additional hypotheses are generated

If your experiment is of any interest or generates any data, it should make you think of additional hypotheses and experiments. Tell your reader—show your instructor you are thinking!

17. Unexpected results are interpreted without unnecessary reference to experimenter error

You will very likely produce results at some point that are not what you predicted or expected. Do you fall back on the excuse, the experiment failed, and then search for flaws? No. You think about the biology, look around the room to your colleagues, talk to your instructor, read your text, etc., and discuss your findings in terms of a logical scientific explanation. ("Maybe we overheated our plant and that caused it to stop photosynthesizing" vs. "Perhaps the plant stopped photosynthesizing because the temperature increased and the stomata closed to prevent water loss.")

18. Appropriate comparisons to textbook(s) are made and properly cited

If you are going to complete your experiment successfully in the allotted time, you will need to read and prepare before hand. To interpret your results, you should compare your work to what is known. Show your instructor you have done this by placing your work in the context of what is known about the subject. Your textbook is a convenient reference (you may use others). Rules of plagiarism require that you properly cite the material you use. Scientific journals generally require a specific format for references. We follow a similar guideline for instructional purposes. For the purposes of writing reports for this lab, we follow the guidelines for N-Y citations as found in the Council of Biology Editors (CBE) 1994. *Scientific Style and Format: the CBE Manual for Authors, Editors, and Publishers*. 6th ed. Cambridge University Press, New York, which can be found at the reference desk in the library or in Pechenik, J. A. 2004. *A Short Guide to Writing About Biology*. 5th ed. Longman, New York, which can be purchased at the bookstore or checked out in 2-hour intervals at the reserve desk at the library. These are described in Section GVII.

19. Interpretations and information presented are correct given sources available to student

Obviously you can't earn credit for incorrectly explaining the science. However, you are not held responsible for incorrect explanations that result from your ignorance of detailed knowledge not readily available. In general, your textbook, lab manual, and lectures provide the expected base of knowledge. Be sure to check your text for information that may not have been covered in class.

GENERAL

20. Writing is clear and free of grammar, spelling, and punctuation errors

You are writing as a team and your computer has grammar-checking and spell-checking capabilities. There is no excuse for a badly written paper. Yes, this, and all your college-level classes are English classes!!

EXTRA CREDIT

Option 1. Data are analyzed statistically

You can earn additional credit for attempting to determine the statistical significance of your data. Is that increase really an increase? Are the two treatments really different? You will need to list (and properly apply) the test used, the value of the test statistic, and the level of significance.

Option 2. Appropriate comparisons to literature are made and properly cited

You are highly encouraged to find **journal articles** that provide relevant information with which you can compare your results or which you can use for interpretation. You can access the library from the computers in the lab, LRC or elsewhere (for additional help see the reference Appendix A "The Literature Research Survival Guide" or the science reference librarian will help you perform a search). You must properly cite your reference. Your instructor must be able to find the reference and judge it, and your use of it, to be correct and relevant. **WWW references** may be acceptable. Your instructor may not award additional credit if the material is suspect or just simply tacked on with little relevance. You need to exhibit care when selecting WWW materials because many contain misinformation. The Literature Research Survival Guide will help you judge legitimacy.

Option 3. Methods are illustrated by images or graphics

Using the SwiftCams/USB cameras and video-capture software or *Paint* you can illustrate your methods. You may earn additional credit if the work is appropriate, properly numbered, captioned, and referred to in text.

Option 4. Additional experiments are designed

If you have the time to do so and can come up with an additional experiment based on your results and hypotheses that you have generated, you are encouraged to describe it for additional credit. Note, simply selecting another variable from the list available for the week's experiment does not warrant additional credit.

Option 5. Additional experiments are completed

You are generally expected to try to conduct variations on your first experiment in all labs. If it takes 20 minutes to investigate the effect of light on some biological process and it is obvious that in an additional 10 minutes you also can test the effect of heat, then you should do this as part of your regular effort to answer the question posed for the week's lab. However, teams that perform an unusually high number of experiments in a lab period when compared to other teams or have a particularly complex and interesting experimental design can earn additional credit. The experiment must be written up in the proper format as outlined above.

Option 6. Properly incorporate and cite data from other lab group(s)

Scientists collaborate with colleagues from other labs often and extensively. They share their data and the results of their experiments to build better explanations and support for their hypotheses. You may do the same by discussing experiments and results with other groups, incorporating them in your discussion and clearly citing them, e.g. "Our results clearly showed a linear relationship between size and metabolic rate in the representative endotherms that we tested and led us to predict a similar relationship in ectotherms. Smith, Jones, Johnson and Brown (Lab Group 33-3, Personal Communication) followed a similar protocol using ectotherms and found a relationship like that which we predicted (as indicated in Figure 3). Taken together, we think that our combined results…"

VII. Proper Citation Format

When you include information in your report that you did not get from direct observation, you should tell your reader where the information originated. This practice is called citing a source and the note in your report that informs your reader of the source is called a citation. For instance, if you include information from the lab manual in your introduction, you should cite the lab manual as the source of the information. If you get extra information out of your textbook (and you should be doing this), you should cite the textbook. If you get extra information from a peer-reviewed journal article (which earns you extra points), you should cite the journal article. You get the idea. If you are not the source of the information, you should tell the reader who is.

A. In Text Referencing

When paraphrasing information from a source, proper credit must be given to the author of that source using the Name-Year system. For example, if you read an article by Robert Jones which was written in 2001 titled "Mating calls of flightless birds" and you want to refer to its contents in your paper, you would write (bold lettering for emphasis only):

> Jones (2001) found that female birds are attracted to males producing the loudest calls.

Or

> Males producing the loudest calls attract the most mates **(Jones, 2001).**

Or

> Some birds use loud calls to attract mates **(Jones, 2001)**, while others use color **(Maxwell, 1989)** and mammals sometimes use scent **(Layman, 1990)**.

Use the form of the first sentence if the author is to be the subject of the sentence. Use the form of the second sentence if the citation is to be entirely separate from the grammatical structure of the sentence. Use the form of the third sentence when the sentence refers to different pieces of information gathered from different sources.

Suppose that another author (ex. Bateman (1998) and Judson (1997)) studied mating calls of flightless birds and came to the same conclusion as Jones (2001) did. You would write:

> Loud mating calls from flightless males attract females **(Judson, 1997; Bateman, 1998; Jones, 2001)**.

When using multiple citations as in the above example, order is determined 1) chronologically and 2) alphabetically.

Use the following formats for references with multiple or no authors.

> 1) Use of tanning beds linked to rise in skin cancers (Moller and Smith, 2000). (Two Authors)

2) Global warming - the next wave of natural disasters (Gore et al., 2006). (Three or More Authors)

3) Tooth whitening systems vary in success by users (Anonymous, 2004). (No Author)

B. Literature Cited

Each reference used must be listed on a ***Literature Cited*** page. Each citation used in the report should be included in alphabetic order last name of the **first** author. Do not reorder the authors names alphabetically. In scientific journals, the order of the authors indicates the primary contributors of the information included in the article. The format for journal and book citations is given below with example written above and format elements following.

1. Book

Example:

Salisbury, F., and C. Ross. 1985. Plant Physiology, Third Edition. Wadsworth, Belmont, CA.

Format elements:

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

2. Journal

Boraiko, A.A., and F. Ward. 1980. The pesticide dilemma. National Geographic. 157(2): 145-183.

Author(s). Year of Publication. Article Title. Journal Title. Volume(Issue): Page numbers.

3. Web-based materials

If you know the specific author(s):

Audet, R; Fitzpatrick, C.; and Godin, D. 1996. GIS Pedagogical Issues Group Summary. EDGIS '96. http://www.ncgia.ucsb.edu/education/projects/SEP/EDGIS96/pedagogy.html (accessed 5/06/07).

Author(s) Date. Title. URL (date of access)

If you do not know the specifc author:

United States Department of Labor. 2003. High Growth Job Training Initiative. http://www.doleta.gov/BRG/JobTrainInitiative/ (accessed 5/06/07).

Organization. Date. Title. URL. (date of access)