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RESEARCH WRITING

Where should I begin?

Since a research report is the vehicle through which you will share your research with others, you should have completed most of your research before beginning to work on the report. When your research is completed, and you have gathered all the necessary data and interpreted it, you are ready to begin thinking about the content of your research report. It is a good idea to start by conducting a literature search in your area of research. This will help you to see what has been published on your topic in the past and will give you sources to use in writing your own report.

You can conduct a literature search by browsing through journals important in your field or by conducting a key word search through library databases. After you have finished your research and conducted a literature search, the prewriting exercise below will help you to think through the information you have to present, and the answers that you provide will easily become the basis for your report and will save you time later in the writing process. Of course, depending on the application of your report, some of the questions may be more useful than other in crafting a first draft.

Take out a piece of paper and write down your answers to the following questions, or open up a text editor window and copy and paste the following questions into it so you can answer them on your computer.

1) Describe the purpose of your research. Are you presenting the results of research, outlining a new theory or method, and/or offering a new interpretation of old data?

2) Describe the most important feature of your research.

3) Make a list of anyone who contributed to your research and who could be involved in writing the research report. Describe the contribution they might make to your research report.

4) Compile a list of works by other researchers that you used in your own research or that is related to your research.

5) Describe the ways in which your research proves or disproves other researchers' work.

6) Describe the background of this subject.

7) Describe what you expected to find before you began your research. How did your project change over time? How did your results differ from your expectations?

8) Describe your results. How did you check your results? How can you best represent them: with text, in a table, with a figure, etc?

9) Describe the consequences of your research. What does it mean for the subject? How will it affect future research on this subject?

10) Describe the ideal audience for your report. Who would be most impacted by your research? Who would best understand the consequences of your research?

11) If you are seeking to publish your report, describe the journals in which you would like to see your research appear. What are the specific requirements for these journals? Additionally, what type of language should you use in writing your report? Look carefully at journals to which you are interested in submitting; how do writers describe their experimental data?

12) Consider the specific guidelines under which you are working. If relevant, make a list of the sections you are required to include in your report. If you have freedom in choosing sections to include, make a list of the sections you think will be necessary to include.

After you have finished, move on to the next section to read more about audience analysis, or use your pre-writing exercise to help you get started in drafting the sections of your report.

Audience Analysis

Who is my audience and what will they expect?

It is important to consider your audience before you begin and while you write your research report so that your report will adequately communicate your research and its significance to your readers. For instance, if you don't consider your readers' needs, you might use language that they don't understand or you might explain the background of your work in too much or too little detail. It is best to think of the audience for your research report as peers in your immediate discipline or in a discipline closely related to your subject. This is true even when you write a report for a class that will be graded by an instructor rather than read by other researchers.

If you are writing a research report for a teacher, the greatest challenge you face in writing your report is to write as though the professor is not your only reader. Imagine a broader audience of your peers and colleagues who will not be grading your work. If you visualize an audience of people with a similar background who are interested in your subject, but who do not know as much about it as you do, you will likely make writing your report easier than if you visualize your audience as a group of experts or someone uninterested in your subject. Keep in mind that your goal should be to write in such a way that someone skilled in the art could reproduce your work precisely.

It can help to know why your readers will be motivated to read your research report. Although they might read for a variety of reasons, in general they will read :

- to learn about research related to their particular research interests
- to keep abreast of research in the discipline in general

- to keep current with research related to their teaching interests
- to keep informed about the scientific literature in related disciplines. (Wilkinson 10).

It is also best to assume that your readers will be very busy people and will want information to be presented to them clearly and concisely. This does not mean that you don't need to be accurate or thorough, but it does suggest that you should put information where readers will expect to find it, and it places great emphasis on the abstract of your report. While readers from your own discipline and area of research might read your report closely and all the way through, many other readers will read only the title and abstract. This helps them to keep abreast of research but does not take up a great deal of their time.

Once you have an idea of who your audience is and why they might read your report, you can more easily imagine what their needs as readers are and how you might meet these needs. You should try to think about your research from the perspective of your audience, and ask what you would like to see in your report if you were reading about your particular research for the first time. Thinking about your audience before you write your report can help you to determine the level of detail you need to include in your report and how to organize information.

The following prewriting activity can help you to think about your audience. Take out a piece of paper and write down the answers to these questions, or copy and paste them into a text editor.

- Describe your audience. What is their position? Why will they read your report?
- What does your audience already know about this topic?
- What information will be new to your reader?
- What is the most important thing for your reader to understand from your report?
- List terms and/or procedures that are important to your research but that your audience may not be familiar with. Include terms that you are using in a new or unique way.
- Thoroughly report analytical data supporting your conclusions.

You might return to the issue of your audience after your report is written to determine whether you have met your readers' basic needs. Considering the first draft of your report from your audience's perspective can reveal areas that need revision to you and can lead to your second draft. Some questions you can ask about your report after it is written to determine whether it has met your readers' basic needs are:

- Is my main point easy to identify early in the report?
- Have I carefully described the procedures used?
- Have I defined unfamiliar or technical terms and clearly explained new concepts?
- Have I provided a context for the research or is more background information needed?
- Have I used tables and figures to represent data? Are these easy to read?
- Have I summarized my findings?
- Have I written clearly?
- Have I stayed on topic throughout the report?

These are some of the basic needs and expectations that your readers will have. You may be able to think of others. What else do you expect when you read a report? What things do you hope would not be a part of a report you were reading? You can use these questions as the basis for revision of your research report after you have a first draft. The easiest way to understand what readers will expect is to become a reader yourself if you aren't already one. It will be helpful for you to read a variety of reports to determine the features you particularly like and don't like before writing your own report.

Drafting The Section of Report

Understanding the Sections of Your Report

Reports are generally divided up into sections. Each section has a specific purpose, and often there are specific guidelines for formatting each section. This part of the hypertext offers some general guidelines for working on each section of a report. It's always best to consult a style manual for your discipline, to talk to other people in your discipline who have written reports, and to look at similar reports that have been published in order to more fully understand the expectations for reports in your field.

Generally, a report will include the following sections:

- Title page
- Abstract
- Table of contents
- Introduction
- Body
- Recommedations
- References
- Appendices

This section helps you to understand each of these sections. Just click on any of the links to the left to get started, or click on the next button at the bottom to start navigating through these sections.

Title page

The title page of the research report normally contains four main pieces of information: the report title; the name of the person, company, or organization for whom the report has been prepared; the name of the author and the company or university which originated the report; and the date the report was completed. You might also include other information on the title page such as contract number, a security classification such as CONFIDENTIAL, or a copy number depending on the nature of the report you are writing.

How do I come up with a title?

It is important to take your audience into account when developing a title for your research report. It is a good idea to develop a "working title" for your project as you draft your report initially, but be open to changing your title after you are finished writing to accurately reflect your project. Be sure that your title is accurate; it needs to reflect the major emphasis of your paper and prepare readers for the

information you present. Also, develop a title that will be interesting to readers and that will make them want to read the rest of your report. Try to imagine what you would want to see in the title if you were searching for your paper by keyword; include keywords in the title when possible and when they are relevant.

There are four common approaches that writers often take to writing their titles. Notice how these approaches help to convey the nature of the research and introduce the topic.

1. Include the name of the problem, hypothesis, or theory that was tested or is discussed. Example: Connectionism and Determinism in a Syntactic Parser
2. Include the name of the phenomenon or subject investigated. Example: The Human Brain: Conservation of the Subcortical Auditory System
3. Name the method used to investigate a phenomenon or method developed for application. Example: A Practical EMG-Based Human-Computer Interface for Users with Motor Disabilities
4. Provide a brief description of the results obtained. Example: The Drimolen Skull: The Most Complete Australopithecine Cranium and Mandible to Date

Omit obvious words and phrases such as "A study on . . ." and "An investigation of . . ." whenever you can as well. These make your title unnecessarily wordy.

Here is a sample title page. Note that this format may not be acceptable for your context; always consult your supervisor, instructor, or a style manual for your discipline to see how title pages should be formatted.

Using MRI to Predict Premature Cardiac Failure

submitted to
Dr. David Smith
Research Laboratories
Lafayette, IN 47906
May 7, 2001

by
Ernie English
Purdue University

Abstract

"An abstract is an accurate representation of the contents of a document in an abbreviated form" (Porush 75). An abstract can be the most difficult part of the research report to write because in it you must introduce your subject matter, tell what was done, and present selected results, all in one short (about 150 words) paragraph. As a result, you should usually write the abstract last.

You will need to write an abstract when your dissertation for a higher degree (M.S. or Ph.D.) is accepted, when you submit an article for publication, or when your report will be disseminated to an audience that needs a summary of its contents. You may not have to write an abstract for reports written for a course; check the specific guidelines for your course to see if one is required.

(If you're a graduate student at Purdue, The Purdue Graduate School's Manual for the Preparation of Graduate Theses (available as an Adobe PDF document) will be helpful in showing you how to prepare the abstract for your dissertation.)

An abstract serves an important function in a research report; it communicates the scope of your paper and the topics discussed to your reader, and, in doing so, it facilitates research. Abstracts help scientists to locate materials that are relevant to their research from among published papers, and many times scientists will only read a paper's abstract in order to determine whether the paper will be relevant to them. Considering your audience and their needs will help you to determine what should be included in your abstract.

Ask yourself:

- Why would another researcher be interested in this research?
- What are the most important aspects of the research? What should a reader be sure to know about the research?
- What information will the reader have to have in order to understand the most important aspects?
- What are the main points from each section of your report? Summarize each section in one sentence, if possible.

The most common type of abstract is the informative abstract. An informative abstract summarizes the key information from every major section in the body of the report, and provides the key facts and conclusions from the body of the report. A good way to develop an informative abstract is to devote a sentence or two to each of the major parts of the report. If space permits, you can provide contextual information such as background of the problem and the significance of the research, but you can also omit contextual information because the abstract is not supposed to serve as an introduction to the subject matter of the report—your introduction will serve that role. You can also omit citations for your sources in the abstract. If you summarize information that you borrowed from other writers, you do not have to repeat the citation in the informative abstract. You should, however, include key numerical facts to make the informative abstract brief. Readers will not be surprised to see numerical data in an informative abstract.

Be sure to summarize rather than describe your report in an informative abstract. Phrases such as "This report discusses" or "Several solutions are considered" describe what the content of the report will be rather than actually summarize the report's main points or solutions. Someone reading your informative abstract should have a clear, albeit limited, understanding of the scope and nature of your research, as well as the conclusions you reach.

The following abstract, from an article titled "Are Green Lots Worth More Than Brown Lots? An Economic Incentive For Erosion Control On Residential Developments," was

published in Soil and Water Conservation. In 147 words, this abstract clearly and concisely conveys the main points from the seven- page article that follows it. Notice how the abstract clearly summarizes information from each of the report's major sections:

Introduction	Construction sites are major contributors to nonpoint source (NPS) pollution. However, a lack of personnel to enforce erosion control regulations and limited voluntary compliance means that few developers apply effective erosion control.
Research Problem	New approaches are needed to increase erosion control on construction sites if this source of NPS pollution is to be significantly reduced.
Body	This study tests whether an economic advantage exists for developers who use vegetative cover for erosion control, independent of advantages gained in addressing environmental or regulatory concerns. Improving residential lot appearance from muddy brown to green grass may increase the appeal of the lot to buyers.
Results	A market survey shows that homebuyers and realtors perceive vegetated lots to be worth more than unvegetated lots, and this increased value exceeds the cost of seeding.
Conclusion	Thus, developers can now be encouraged to invest in vegetative cover because of the potentially high return on the investment.

Table of Contents

Most reports will contain a Table of Contents that lists the report's contents and demonstrates how the report has been organized. You should list each major section in your Table of Contents. Sometimes you may want to use additional descriptive headings throughout your report and for your Table of Contents. Using descriptive headings can help readers to see how your report is organized if the section headings are not clear enough. This is likely to be true especially if most of your report is contained in one long section called Body or Discussion that includes everything from the materials and methods you used to the results you found and the conclusions you draw. In this case, it might be best to include additional headings to indicate where readers can look specifically to read about your materials and methods or conclusions.

Consider the two examples below. Which would be more helpful in finding information within the report?

Introduction

a. Contents

The introduction prepares readers for the discussion that follows by introducing the purpose, scope, and background of the research. The audience for your report largely determines the length of the introduction and the amount of detail included in it. You should include enough detail so that someone knowledgeable in your field can understand the subject and your research.

You should begin your introduction at the top of a new page, preceded on the page only by the report's full title. The title is followed by the word Introduction, which can be either a center or side heading. Most introductions contain three parts to provide context for the research: purpose, scope, and background information. These parts often overlap one another, and sometimes one of them may be omitted simply because there is no reason for it to be included.

It is very important to consider the **purpose** of your research and your report in the introduction. If you do not completely understand what the purpose is, there is little chance that the reader will understand your purpose either. The following questions will help you to think about the purpose of your research and your reason for writing a report:

- What did your research discover or prove?
- What kind of problem did you work on?
- Why did you work on this problem? If the problem was assigned, try to imagine why the instructor assigned this particular problem; what were you supposed learn from working on it?
- Why are you writing this report?
- What should the reader know or understand when they are finished reading the report?

Scope refers to the ground covered by the report and will outline the method of investigation used in the project. Considering the scope of your project in the introduction will help readers to understand the parameters of your research and your report. It will also help you to identify limiting factors on your research and acknowledge these early in the report. For example, "if 18 methods for improving packaging are investigated in a project but only 4 are discussed in the report, the scope indicates what factors (such as cost, delivery time, and availability of space) limited the selection" (Blicq and Moretto 165). Scope may also include defining important terms.

These questions will help you to think about the scope of both your research and your report:

- How did you work on the research problem?

- Why did you work on the problem the way you did?
- Were there other obvious approaches you could have taken to this problem? What were the limitations you faced that prevented your trying other approaches?
- What factors contributed to the way you worked on this problem? What factor was most important in deciding how to approach the problem?

Background Information includes facts that the reader must know in order to understand the discussion that follows. These facts may include descriptions of conditions or events that caused the project to be authorized or assigned and details of previous work and reports on the problem or closely related problems. You might also want to review theories that have a bearing on the project and references to other documents although if you need to include a lengthy review of other theories or documents, these should be placed in an appendix.

Ask yourself:

- What facts does the reader need to know in order to understand the discussion that follows?
- Why was the project authorized or assigned?
- Who has done previous work on this problem?
- What theory or model informed your project?
- What facts are already known that support or don't fit the theory?
- What will the reader know about the subject already and what will you need to tell them so they can understand the significance of your work?

b. Beginning an introduction

Introductions serve as a place for you to catch your reader's attention, and they also help to place your project in its context (whether that context is background information or your purpose in writing is up to you). As a result, it is important to consider the approach you will take to begin your introduction. Consider the following examples; they represent two extremes that writers can take in beginning their introductions.

What is the problem with this sentence as an opening to an introduction?

The universe has been expanding from the very moment that it was born.

This sentence is very broad; the writer tries to establish a broad context and relevance for their work but begins with too wide a field of vision, seeming to account for the entire universe since its birth. The introduction should not try to orient the reader with respect to all of human history or the universe, but only the fundamentals of the immediate problem.

One of the ways that the sentence above might be rewritten is:

Recent studies suggest that the universe will continue expanding forever and may pick up speed over time.

The rewritten sentence establishes the report's context within "recent studies" concerning a specific theory related to universe expansion. This context is much more specific than that of the original sentence.

What is the problem with this sentence as an opening sentence to an introduction?

The Fourier series representation of a period time signal creates a corresponding signal in the "frequency domain" which relates information about energy contained at each frequency of the signal.

The second example takes too narrow of an approach because it plunges into the problem immediately without contextualizing the topic for the reader or giving them important background information. This opening statement assumes a reader who is already very familiar with the topic, an assumption that may or may not be correct. It might take additional information to rewrite this sentence so that it provides enough context for readers to familiarize themselves with the topic.

Consider the rewritten introduction, which introduces the idea in four sentences instead of one:

Today's digital-signal-processing applications are pressing the throughput boundaries of the available DSPs. System designs that use multiple processors to complete their tasks as quickly as possible are commonplace, and a major portion of the signal-processing horsepower is required to transform the data from the time domain to the frequency domain and back again. To best use available processors, it is necessary to generate an efficient algorithm to transform data from the time to the frequency domain. The most common method is the fast Fourier transform (FFT).

A good way to begin an introduction is to think of your audience and consider how you might best orient them to your topic. State the problem as specifically as possible and contextualize the project for them. Consider placing either the purpose of your project or the background information first, then moving on to consider scope after your topic has been introduced.

c. Introduction Example

This example of an introduction has been adapted from an article called "Soil Carbon Isotopes Reveal Ancient Grassland Under Forest In Hluhluwe, Kwazulu-Natal," published in the *South African Journal of Science*. The introduction clearly addresses background, purpose, and scope.

Background	The origin and spread of grassland vegetation in South Africa has intrigued biologists. Grasslands have been viewed as being of recent origin, spreading at the expense of forests under the influence of anthropogenic burning, farming, felling and pastoralism.(n1, n2) The age of grasslands elsewhere has recently been revised, however, placing their origin in the late Miocene and spreading to cover large areas by the Pleistocene, long before human impact was of any significance.(n3-n5) Authors in South Africa have supported this concept of ancient grasslands,(n6, n7) challenging the view that Iron Age farmers were responsible for the extent of grasslands in South Africa. Instead, it

	seems that farmers had only localized effects on forest/grassland boundaries and that the extent of grasslands owes more to biophysical processes operating on large temporal and spatial scales.
Purpose	We investigated stable carbon isotope ratios of soil organic matter in the forests of the Hluhluwe-Umfolozi Game Reserve, KwaZulu-Natal. Analysis of soil profiles in the forest indicated a shift from C[sub 3] to C[sub 4] vegetation with depth. These results suggest that the area now covered by mature, tall forest in the region was once grassland. These findings support the hypothesis that the grasslands of KwaZulu-Natal are older than previously thought.
Scope	In this paper we report the results of an analysis of isotopic composition of soil organic matter (SOM) in the Hluhluwe Forest. The forest forms an `island' in an area thought to have been deforested by Iron Age farmers, leading to the surrounding savanna structure of today.(n2) Our results indicate that the Hluhluwe Forest, far from being an ancient relic of a forested landscape, was previously a grassland. Although we have not obtained dates in this study, our preliminary results are consistent with evidence from elsewhere in Africa for a general increase in tree and forest cover since the start of the Holocene.(n8, n9)

The Body of Your Report

The body is usually the longest part of the research report, and it includes all of the evidence that readers need to have in order to understand the subject. This evidence includes details, data, results of tests, facts, and conclusions. Exactly what you include in the body and how it is organized will be determined by the context in which you are writing. Be sure to check the specific guidelines under which you are working to see if your readers are expecting you to organize the body in a particular way.

In general, the body of the research report will include three distinct sections:

- a section on theories, models, and your own hypothesis
- a section in which you discuss the materials and methods you used in your research
- a section in which you present and interpret the results of your research.

You will usually use a heading to identify the beginning of each of these sections.

For more about each section of the body of your report, you can click through the tutorial in order, click on any of the links in the bulleted list, or click on any of the links to the left.

Theories, Models, and Hypotheses

You may or may not need to include a section in which you discuss the theories and models upon which your research project is based. This section can be very important, especially for research articles, formal reports, or scientific papers, but sometimes it will not be required for lab reports and other homework assignments. If you do not have to include a section on theories and models, it will usually be because you are not positing an original hypothesis. This is likely to happen in a course for which you write lab reports. You may be required to conduct research to practice applying the theories and models you are learning about, but you will probably be given your hypothesis and won't need to explain in your lab report where and how the hypothesis was developed since you did not actually develop it yourself. Regardless of whether you include a section on theories and models, your research will be informed by models and theories that other researchers have developed.

If you do need to include a section on theories, models, and your hypothesis, this section does not necessarily need to come before the materials and methods section of the report's body. Placing this discussion early in the paper does help to frame the experiment and the data you will discuss later on, but some writers prefer to save this information until the results section of the report. Other writers prefer to include their discussion of theories and models in the introduction. If you decide to introduce theories and models in an early section of your paper, you can return to them later on in the report.

Theories attempt to explain how nature works; they are accepted if they work and because they help to explain most of the evidence that is available. Theories are not scientific laws; there is no absolute confirmation that they are true. Any project you undertake will certainly be founded upon a theory or set of theories. Models generally grow out of theories. They are "precise, mechanical construction[s] of how phenomena will behave" (Porush 100). Some models evolve even though there is no theory to explain them. In either case, models provide an important guide for future research and can help you set a program of study. However, it is important to understand that models are not necessarily the phenomena that you are interested in researching.

In most cases, you will need to include information about the theories and models that inform your research because these theories and models will directly affect the hypothesis that you propose and on which you base your research. When you develop hypotheses, you predict what you will find after you conduct your research. This prediction is based on existing theories, models, evidence, and logic.

How do I write about theories, models, and hypotheses?

It can seem overwhelming to explain and elaborate on theories and models while also developing your hypothesis. After all, in this section of the paper you will not discuss the

data you found or how you found it; instead, you will introduce the theoretical basis for your project. Such a task can be intimidating, especially if you disagree with earlier theories or models and need to explain their weaknesses. It can help to consider your primary goals for this section. It's always best to talk with your professor, your adviser, or people in your workplace about what the best ways are to write reports in your field, or to consult other reports and use them as models or guides for your writing.

In your section, you may need to:

- define and explain your hypothesis and the theories and models you used to develop it
- define and explain competing hypotheses, theories, and models, including their strengths and weaknesses
- compare and contrast the specific points where they agree or disagree

Prewriting on this section can also help you feel more comfortable including this information in your report and will help you to decide what needs to be included. The following questions are good ones to work through:

- What do I expect this experiment to reveal? Why?
- How does my hypothesis directly answer the question posed by the problem?
- How does the hypothesis fit in with other hypotheses or more general theory? How will my work challenge or support the work of others?
- What is the current theory to which it relates?
- What are alternative views to this theory? What are the strengths and weakness of those views?
- On what literature did I or can I base my explanation?

Notice how the authors of "Cortical Surface-Based Analysis" discuss both the strengths and weaknesses of the previous work that they build on in their research. This discussion of other research comes in their introduction, which is a common place for writers to put it.

Currently, the most widely used method of analyzing functional brain imaging data is to project the functional data from a sequence of slices onto a standardized anatomical 3-D space. The most common of these procedures is based on the Talairach atlas (Talairach et al., 1967; Talairach and Tournoux, 1988; see, e.g., Collins et al., 1994 for an automated prcedure). While this type of approach has certain advantages (ease of use, widespread acceptance, applicability to subcortical structures), it also has significant drawbacks.

These drawbacks derive from the fact that the intrinsic topology of the cerebral cortex is that of 2-D sheet with a highly folded and curved geometry. Estimates of the amount of 'buried' cortex range from 60 to 70% (Zilles et al., 1988; Van Essen and Drury, 1997), implying that distances measured in 3-D space between two points on the cortical surface will substantially underestimate the true distance along the cortical sheet, particularly in cases where the points lie on different banks of a sulcus.

The highly folded nature of the cortical surface also makes it difficult to view functional activity in a meaningful way. The typical means of visualization of this type of data is the project of functional activation onto a set of orthogonal slices. This procedure is problematic as regions of activity which are close together in the volume may be relatively far apart in terms of the distances measured along the cortical surface. In addition, the naturally two-dimensional organization of the cortical maps is largely obscured by the imposition of an external coordinate system in the form of orthogonal slices. These problems have led an increasing number of studies to make use of surface-based techniques for visualization (Tootell et al., 1995; DeYoe et al., Engel et al., 1997; Reppas et al., 1997; Talavage et al., 1997; Van Essen and Drury, 1997; Hadjikhani et al., 1998; Moore et al., 1998).

In order to facilitate the use of surface-based techniques for both display and analysis of structural and functional properties of the cerebral cortex, we have developed a unified procedure which begins with a previously reconstructed cortex (Dale and Sereno, 1993; Dale et al., 1998) and modifies it in order to achieve three separate but related goals.

Materials and Methods

The materials and methods section is similar to an instruction manual. It should describe the apparatus and the procedure that you used in your experiment. Almost all research reports will include a materials and methods section. As always, it is best to ask other experienced writers in your field for advice, or to critically consider other models of writing in your workplace or discipline as possible models.

This section should be clearly and specifically written; another researcher should be able to exactly duplicate the research you performed by following the procedures outlined in this section. However, since some procedures, materials, and methods are standard to your field, you do not necessarily need to describe ones which a researcher in your field would already understand or which are common knowledge for your field. You should decide which actions and features of the research are standard for your field and will be understood easily by readers and which will need in-depth and careful explanation. If your report serves to

introduce any new action or feature, be sure to thoroughly outline the action or feature in the materials and methods section.

All materials and methods sections should address the following questions:

- How was the experiment designed?
- On what subjects or materials was the experiment performed?
- How were the subjects/materials prepared?
- What machinery and equipment was used in the experiment?
- What sequence of events did you follow as you handled the subjects/materials or as you recorded data?

Some other issues that might be relevant to your research and that should be addressed in the materials and methods section are listed below:

- Describe in detail any special or nonstandard equipment used. Consider providing an illustration of the equipment.
- Describe the method you used to record data .
- Include the species, genus, strain, and breeding origins of any animals used.
- Describe the amount and purity of any chemicals used.
- Describe in detail any part of the experimental procedure that is original.
- List any dangers or potential problems that might result from the experimental procedure. It is a good idea to include these in a separate paragraph of the Materials and Methods section labeled "Caution."

The example "Materials and Methods" section below was taken from a student lab report. The subject of the report was "Cardiac Muscle and Cycle."

Materials and Methods

To perform this experiment, the following equipment is needed: the Physiograph VI, myographs A and B, two tension adjusters, two transducer stands, calibration weights, the Grass stimulator and isolation unit, stimulator cable, two pin electrodes, two sleeve electrodes, the ECG pre-amp, a thermometer, saline solution and dish, and the suture board. Begin by collecting the pithed turtle and removing the plastron disk to expose the heart. Throughout the experiment, keep the heart moist with addition of saline to body well. Mount the B myograph above the hole and connect with suture to the frenulum, near the ventricular apex. Remove the pericardium (except for a small amount near suture) so that the ventricular pull is wholly communicated to the myograph. Adjust the tension in the suture until all slack is removed. Obtain a suitable recording of contraction and relaxation; measure heart rate and systolic and diastolic periods. Note heart temperature. Record ventricle activity while increasing myograph tension – verify Starling's Law. Attach a hook electrode to the ventricle apex. Connect the A myograph to the left atrium with the other hook electrode. Connect electrodes through ECG pre-amp to measure EGC. Obtain a three-channel reading of EGC and atrial and ventricular contractions. Insert two pin electrodes into the apex and middle of the ventricle. Connect to Grass stimulator through isolation unit and record the effects of stimulation. Find the refractory period. Connect the stimulator to the right vagus nerve with a sleeve electrode. Record slowing to arrest caused by stimulation. Connect to left vagus nerve and record the inotropic effect on the atrium caused by stimulation. Also record the shortening of the refractory period with stimulation. Finally remove the heart to saline dish and record an EGC of the isolated heartbeat.

Results: Presenting data

In the results section of your report, you will finally get to talk about what you discovered, invented, or confirmed through your research, and you will present your experimental data, observations, and outcome. Because this section focuses on your specific research project, the results section is the most straightforward of the sections to write, and it may be the simplest and most enjoyable section you will write. Regardless of what other sections you need to include, you will always write a section in which you present results, although it might be called discussion rather than "results," All preceding sections of the report (Introduction, Materials and Methods, etc.) lead in to the Results section of the report and all subsequent sections will consider what the results mean (conclusion, recommendations, etc.).

Focus on the facts of your research in the Results section and present them in a straightforward way. Consider how best to organize your results section in the clearest and most logical way. The most common way to organize information in a research report is chronologically. This method of organization allows you to present information in the sequence that events occurred. Organizing information chronologically can be very simple and will not require much preplanning. It does tend to give emphasis to each event regardless of its relative importance, however and, as a result, can be difficult for readers to understand which event or what information is most important, and it can also be difficult for the writer to keep their reader's attention. Blicq and Moretto provide the following exercise to demonstrate this tendency of chronological organization. Can you identify what is most important from the list of events from an astronaut's day?

Astronauts were wakened at 7:15; breakfasted at 7:55, sighted the second stage of the rocket at 9:23, carried out metabolism tests from 9:40 to 10:50, extinguished cabin fire at 11:02, passed directly over Houston at 11:43 . . . (taken from Blicq and Moretto 168).

Another good way to help organize information so that readers will understand what is most important is in a figure or table.

How should I incorporate figures and tables into my report?

Most scientific reports will use some type of figure and/or table to convey information to readers. Figures visually represent data and include graphs, charts, photographs, and illustrations. Tables organize data into groups. You will most likely use figures and tables in your report to represent numerical data from measurements taken during your experiment. Figures and tables should help to simplify information, so you should consider using them when words are not able to convey information as efficiently as a visual

aid would be able to. For instance, if you have to subject numerical data to computer analysis, it will be easier and more concise to represent this visually than it would be through words. Consider using figures and tables when you need to decipher information or the analysis of information, when you need to describe relationships among data that are not apparent otherwise, and when you need to communicate purely visual aspects of a phenomenon or apparatus.

In some cases, you will not have to make a decision about what kind of table or figure you will use. Such is the case when you need to include a photograph in your report, for instance. In other cases, you may have trouble deciding what kind of table or figure would work best in your report. Readers will expect to see certain kinds of information presented in certain kinds of ways, and you can use reader expectations to your advantage. David Porush outlines the purposes that different kinds of tables and figures serve best and most often. It is important to choose the correct way to represent your data; if you understand what your audience expects from each one, you will be prepared to choose the best way to represent data.

- Tables or lists are simple ways to organize the precise data points themselves in one-on-one relationships.
- A graph is best at showing the trend or relationship between two dimensions, or the distribution of data points in a certain dimension (i.e., time, space, across studies, statistically).
- A pie chart is best at showing the relative areas, volumes, or amounts into which a whole (100%) has been divided.
- Flow charts show the organization or relationships between discrete parts of a system. For that reason they are often used in computer programming.
- Photographs are not very good at calling attention to a particular part within a larger structure. They are best at presenting overall shapes, shades, and relative positionings, or when a 'real-life' picture is necessary, as in the picture of a medical condition or an electron micrograph of a particular microscopic structure.
- Illustrations are best when they are simple, unshaded line drawings. Remove all but the essential details in order to keep your line drawing as uncluttered as possible. They suit most purposes for representing real objects or the relationship of parts in a larger object. (Porush 141).

When you include tables and figures in your report it is important that you pay attention to some general guidelines for using them as well. These guidelines can help you decide when to include a table or figure and they will also help you to meet your audience's expectations so that they will understand what is most important from your text and from tables and figures. The most important general rule is that tables and figures should supplement rather than simply repeat information in the report. You should never include a table or figure simply to include them. This is redundant and wastes your reader's time.

Additionally, all tables and figures should:

- be self-contained—they should make complete sense on their own without reference to the text
- be cited in the text—it will be very confusing to your audience to suddenly come upon a table or figure that is not introduced somewhere in the text. They will not have a context for understanding its relevance to your report.
- include a number such as Table 1 or Figure 10—this will help you to distinguish multiple tables and figures from each other.
- include a concise title—it is a good idea to make the most important feature of the data the title of the figure
- include clear and proportionate labels so that readers will understand your table or figure

Sample Results Section

Like the sample "Materials and Method" section, the following "Results" section was taken from a student lab report. Notice that most of the results are presented in a figure and a table.

Table 1 shows the regression equations used to calibrate the myograph data. A two-point calibration was used for the ECG recordings. The values presented in the following graphs all make use of the calibrated data.

Table 1: Linear Regression Equations for Myograph Calibration.

Using known weights, the myograph voltage response was measured over a broad input range. This data was then used to determine first the linear range of the device and second a linear mapping to mass.

Myograph	Linear Equation	R^2
A	V = 0.0113 g	97.1%
B	V = 0.0161 g	95.9%

After setup, the heart rate was determined to be 40 bpm, with a systolic period of 0.735 s and a diastolic period of 0.76 s (see Fig. 1). The ventricular %pull% ranged over 2.91 g on myograph B. The temperature of the body cavity was 26 degrees Celsius.

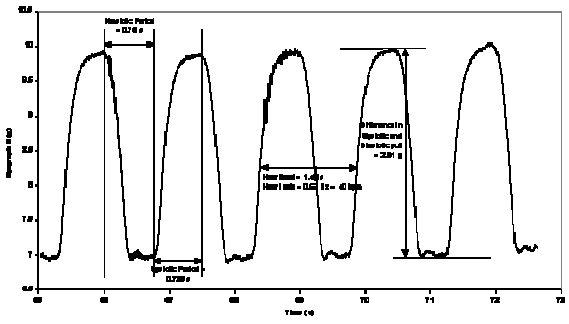

Fig. 1 Ventricular Contractions of the Turtle Heart. The ventricular pull (measured by myograph B) is shown over several cardiac cycles. The diastolic and systolic intervals are labeled, as well as the relative systolic pull and the heart rate.

Results: Interpretation of Data

It is unlikely that you will you title a separate section of your report "Interpretation of Data." Usually, this section,

combined with your presentation of data, will be called "Results" or "Discussion." Sometimes, presentation of data and interpretation of data may be split into separate categories, with presentation called "Results," and interpretation called "Discussion." Regardless of its title, interpretation of data is also crucial to a successful research report.

This section of the report is important because it demonstrates the meaning of your research. Without this section, readers will not necessarily understand what your research proves, or they might not see how it differs from or improves on other research. In this section you will interpret your results and your research as a whole and discuss the relationship of your findings to earlier research. This section of the paper draws upon writing skills that other sections do not because you need to write persuasively in this section as you convince readers that your interpretation of data is logical and correct. As you develop your argument in this section, consider arranging your evidence in the order that best highlights your main point, cite authorities that have come to similar interpretations under similar circumstances, and consider the superiority of your conclusions to opposing viewpoints.

Your interpretation will be most convincing if it proceeds logically. There may be many ways to organize your interpretation of data logically; consider your readers' needs to help you decide how to organize your information:

- What does your reader need to know before anything else in order to understand and be persuaded to believe your argument?
- What does your reader need to know next, or what naturally follows from this first idea?
- What is the most important thing for your reader to understand from your interpretation? Consider placing this first.

One basic way to organize your information logically is to move from what you are most certain about to what you are least certain about. For most research reports, the most certain part of your case will be your data, and many research reports will develop along this outline:

- begin with a discussion of the data
- move on to generalize about or analyze the data
- consider how the data addresses the research problem or hypothesis outlined in the Introduction
- discuss what can be inferred from the data as they relate to other research and scientific concepts

It is also very important for you to identify the nature and extent of any limitations of your research in this section of your report, especially if your results are inadequate, negative, or not consistent with earlier studies or with your own hypothesis. Do not try to defend your research or minimize the seriousness of the limitation in your interpretation; instead, focus on the limitation only as it affects the research and try to account for it.

The authors of "Birth Weight And Cognitive Function In The British 1946 Birth Cohort: Longitudinal Population Based Study," published in the *British Medical Journal,* provide a particularly clear example of a section in which they interpret the results of their study and consider the limitations of their research.

Interpretation

Caution is needed in the interpretation of repeated tests of birth weight with different outcomes, particularly when different numbers are included in each analysis. The problem of assessing cognitive change over time is compounded because there is no single cognitive test that can be used throughout life, as cognitive measures must change with cognitive development. Repeated measures models, unlike the conditional regression models used here, are dependent on the outcome scale used, and standardised scores may not be a realistic scaling in this respect as they assume no cognitive growth with age, and no increased variation in scores with age occurs. [16] Further investigation of these data using such models is in progress. We took a more simple approach here, considering the association between birth weight at the earliest time point then assessing the influence of birth weight on subsequent relative changes in cognitive function. Regression to the mean [17] [18] occurs when fitting such models, as they assume that the score at the earliest age is fixed (that is, measured without error). However, for the measurement error to have a substantial impact on the association between birth weight and change in cognitive score presented here, the cognitive test scores would have to be notably unreliable.

If birth weight is associated with cognitive function in the general population, explanatory factors must be similarly distributed in the normal population. From this perspective, birth weight is strongly related to head circumference at birth [1] which in turn is closely correlated with brain size [19] and so is associated with childhood cognitive function. [20] The most parsimonious explanation for the current results, therefore, is that the relations between these variables, established for comparisons between low and normal birthweight children, also hold across the normal range in the general population. At the neurochemical level, birth weight is associated with insulin-like growth factors, [21] and interest has been growing in the role of glucose metabolism, insulin, and insulin-like growth factors in the development of the central nervous system and cognitive function. [22] [23] How these processes are distributed in the population is not known. However, three key risk factors for low birth weight, nutrition, smoking, and alcohol misuse [15] all influence brain glucose concentrations or the function of insulin-like growth factors, [1] [24] [25] although the pathways are likely to be complex. A reduction in birth weight after maternal starvation in the Dutch famine cohort of the 1940s, for example, was not associated with subsequent cognitive performance. [26]

What is already known on this topic

- Low birth weight is associated with poor cognitive development
- Few studies have examined this association across the full birthweight range in the normal population

What this study adds

- Birth weight is significantly associated with cognitive ability at age 8 years, through adolescence, and into early adulthood, independent of social background
- The associations between birth weight and cognitive function at ages 8, 11, and 15 are evident across the normal birthweight range (>2.5 kg) and

so are not accounted for exclusively by low birth weight
- Birth weight is also associated with educational attainment, suggesting that the association between birth weight and cognition may have functional implications

Recommendations

You may or may not need to include a section titled "Recommendations." This section appears in a report when the results and conclusions indicate that further work needs to be done or when you have considered several ways to resolve a problem or improve a situation and want to determine which one is best. You should not introduce new ideas in the recommendations section, but rely on the evidence presented in the results and conclusions sections. If you find that you need to include a recommendations section you have another opportunity to demonstrate how your research fits within the larger project of science, and the section can serve as a starting point for future dialogue on the subject. It demonstrates that you fully understand the importance and implications of your research, as you suggest ways that it could continue to be developed. Do not include a recommendations section simply for the sake of including one; this will waste your readers' time and take up unnecessary space in your report.

Amy Gatian offers some specific recommendations for future research in the paper "Discussion Of The Effects Of Screen Layout And Feedback Type On Productivity and Satisfaction Of Occasional Users," published in the *Journal of Information Systems*.

Future Research

In the context of this article, an interesting study would be to look at whether visual feedback is actually counter-productive. The implications from findings in this study are that audio feedback from computers is like the audio feedback you get from an alarm clock: it may be annoying, but it is effective. In fact, in this study audio feedback alone was more effective than a combination of audio and visual feedback. One hypothesis potentially worth testing is whether visual feedback, because of the time involved in message translation, i.e., reading, decreases user productivity. Indeed, one of the habits of good data entry personnel is to focus on the data to be entered rather than the visual image of the data on the screen. This procedure speeds up data entry because the operator is not continuously switching back and forth between the screen and the data to be entered.

As previously mentioned, Gibson notes that there is a great deal of diversity in screen layouts and feedback type provided. Given the diversity in screen layouts, it seems appropriate to question which screen layout best promotes user productivity and satisfaction. Clearly, only a few variables can be examined in any given study. While this study addresses lines per entry screen, future research focusing on some of the other variable could provide valuable insights.

References

It is important to include a References section at the end of a report in which you used other sources. Informal or short reports may not have a references section or only a short one while more formal reports will likely have reference sections, sometimes very lengthy ones. If you included a section on the background of your research topic or discussed other theories and models related to your research, you will need a references section.

Reference sections are important because, like the sections on the procedure you used to gather data, they allow other researchers to build on or to duplicate your research. Without references, readers will not be able to tell whether the information that you present is credible, and they will not be able to find it for themselves. Reference sections also allow you to refer to other researchers' work without reviewing that work in detail. You can refer readers to your reference page for more information.

You should include references that you cited directly in the report or that greatly informed your research. You do not need to include secondary materials that are only slightly related to your topic. Do not include references simply to make this section longer.

Reference styles vary greatly from one instructor to another, one journal to another. You should always format your references according to the guidelines provided by the journal or teacher to whom you are submitting your report. One of the most common reference styles used for research reports in the social sciences and some other disciplines is that outlined by the American Psychological Association (APA). Do not assume that this will be the style you should use, however. Talk to your instructor, your supervisor, or look up the appropriate style guide for your discipline.

It is best to compile your own reference list containing a variety of information. This will save you from having to track down pieces of information you may have neglected to make note of if they are specifically requested after you have filed a source, returned it to the library, or misplaced it.

Information to include on your reference list:

- Author's name or authors' names
- Title of the document
- Identification information:
  - Books: city, state, or country of publication, publisher's name, and year of publication. Editor's name, chapter title and author, and page numbers of chapter, if applicable.
  - Journal articles or technical papers: journal's name, volume and issue number, date of issue, page numbers of referenced articles.
  - Reports: report number, name and location of issuing organization, date of issue.
  - Correspondence: name and location of issuing organization; name and location of receiving organization, letter's date.
  - Conversation, conference presentation, or Speech: name and location of speaker's organization; name, identification, and location of listener; date.

The sample reference list below demonstrates the type of information you should include when taking notes on your references.

David Porush.
A Short Guide to Writing About Science.
New York HarperCollins 1995

Anders M. Dale, Bruce Fischl, and Martin I. Sereno.
"Cortical Surface-Based Analysis."
pages 179-194 *NeuroImage* Ed. Arthur W. Toga
Volume 9 Number 2 February 1999.

Appendices

You should place information in an Appendix that is relevant to your subject but needs to be kept separate from the main body of the report to avoid interrupting the line of development of the report. Anything can be placed in an appendix as long as it is relevant and as long as you made reference to it in the body of your report. You should not include an appendix simply for the sake of including one, though.

An appendix should include only one set of data, but additional appendices are acceptable if you need to include several sets of data that do not belong in the same appendix. Label each appendix with a letter, A, B, C, and so on. Do not place the appendices in order of their importance to you, but rather in the order in which you referred to them in your report. You should also paginate each appendix separately so that the first page of each appendix you include begins with 1.

Works Cited

Here are the works cited in the preparation of this report.

Blake, Gary and Bly, Robert W. *The Elements of Technical Writing*. New York: Macmillan, 1993.

Blicq, Ron and Moretto, Lisa. *Technically-Write*. 5th ed. Upper Saddle River, NJ: Prentice, 1999.

Day, Robert A. *How to Write and Publish a Scientific Paper*.3rd ed. Pheonix: Oryx, 1988.

McMurrey, David A. Online Technical Writing—Online Textbook. <http://www.io.com/~hcexres/tcm1603/acchtml/acctoc.html>.

Porush, David. *A Short Guide to Writing About Science*. New York: HarperCollins, 1995.

Wilkinson, Antoinette M. *The Scientist's Handbook for Writing Papers and Dissertations.* Englewood Cliffs, NJ: Prentice, 1991.